5. INTERNATIONAL PARIS CONGRESS ON APPLIED SCIENCES

August 4-8, 2025



EDITORS
Prof. Dr. Cuma AKBAY
Prof. Dr. Gönül GÜROL ÇİFTCİ

ISBN: 979-8-89695-029-5

5. INTERNATIONAL PARIS CONGRESS ON APPLIED SCIENCES

August 4-8, 2025– Paris, France

25.08.2025

Liberty Publishing House

Water Street Corridor New York, NY 10038

www.libertyacademicbooks.com

+1 (314) 597-0372

ALL RIGHTS RESERVED NO PART OF THIS BOOK MAY BE REPRODUCED IN ANY FORM, BY PHOTOCOPYING OR BY ANY ELECTRONIC OR MECHANICAL MEANS, INCLUDING INFORMATION STORAGE OR RETRIEVAL SYSTEMS, WITHOUT PERMISSION IN WRITING FROM BOTH THE COPYRIGHT OWNER AND THE PUBLISHER OF THIS BOOK.

© Liberty Academic Publishers 2025

The digital PDF version of this title is available Open Access and distributed under the terms of the Creative Commons Attribution-Non-Commercial 4.0 license (http://creativecommons.org/licenses/by-nc/4.0/) which permits adaptation, alteration, reproduction and distribution for noncommercial use, without further permission provided the original work is attributed. The derivative works do not need to be licensed on the same terms.

adopted by Mariam Rasulan

PROCEEDINGS BOOK

ISBN: 979-8-89695-156-8

CONGRESS ID

CONGRESS TITLE

5. INTERNATIONAL PARIS CONGRESS ON APPLIED SCIENCES

DATE AND PLACE

August 4-8, 2025– Paris, France

ORGANIZATION

IKSAD INSTITUTE

EDITORS

Prof. Dr. Cuma AKBAY

Prof. Dr. Gönül GÜROL ÇİFTCİ

COORDINATOR

Samet KUŞKIRAN

PARTICIPANTS COUNTRY (21 countries)

TÜRKİYE, MOROCCO, IRAQ, INDIA, BRAZIL, MOLDOVA, GEORGIA, IRAN, PAKISTAN, BOSNIA AND HERZEGOVINA, ETHIOPIA, ALGERIA, SERBIA, UKRAINE, ALBANIA, VIETNAM, SLOVAKIA, ROMANIA, AZERBAIJAN, KOSOVO, ERITREA

Total Accepted Article: 150

Total Rejected Papers: 39

Accepted Article (Türkiye): 67

Accepted Article (Other Countries): 83

ISBN: 979-8-89695-029-5

MEMBERS OF THE ORGANIZING COMMITTEE

Prof. Dr. Anderi JEAN
Gas Petrolium University ROMANIA

Dr. German Prats
Universidad Autonoma Guadalajara MEXICO

Dr. Ethem İlhan ŞAHİN
Adana Alparslan Türkeş Science and Technology University TÜRKİYE

Dr. Elvan CAFEROV
ADPU AZERBAIJAN

Dr. Fouzia BENOUDJIT
M'hamed Bougara university ALGERIA

SCIENTIFIC AND ADVISORY BOARD

Prof. Dr. Anderi JEAN
Gas Petrolium University ROMANIA

Prof. Dr. Betül Apaydın Yıldırım
Atatürk University TÜRKİYE

Prof. Dr. Mevlut ALBAYRAK
Atatürk University TÜRKİYE

Assoc. Prof. Ruslan ABDULLAYEV
Azerbaijan National Academy of Sciences AZERBAIJAN

Dr. Usman Ghani, PhD
Institute of Management Sciences Peshawar PAKISTAN

Dr. Katarzyna Czech, PhD
Warsaw University of Life Sciences, POLAND

Dr. Yuriy Danko, PhD
Sumy National Agrarian University, UKRAINE

Dr. Olena Melnyk, PhD
Sumy National Agrarian University, UKRAINE

Dr. Michal Wojtaszek, PhD
Warsaw University of Life Sciences, POLAND

Dr. Ethem İlhan ŞAHİN
Adana Alparslan Türkeş Science and Technology University
TÜRKİYE

Dr. Maral Jamalova, PhD
Szent İstvan University HUNGARY

Dr. Nicholas Imbeah, PhD
Takoradi Technical University GHANA

Dr. Harshavardhan Reddy Kummitha, PhD
Budapest Business School HUNGARY

Dr. Nihad Habeeb Mutlag Alezerjawi
Al-Kufa University IRAQ

PHOTO GALLERY



PHOTO GALLERY



PHOTO GALLERY





PHOTO GALLERY





PHOTO GALLERY





PHOTO GALLERY



PHOTO GALLERY



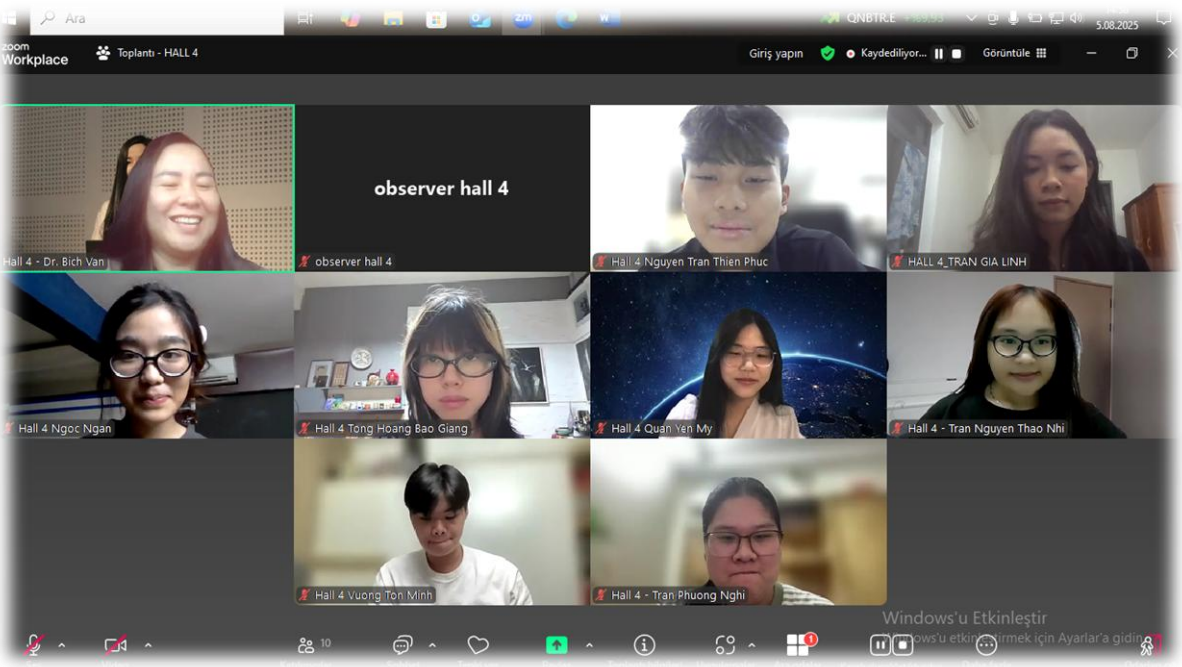


PHOTO GALLERY





PHOTO GALLERY



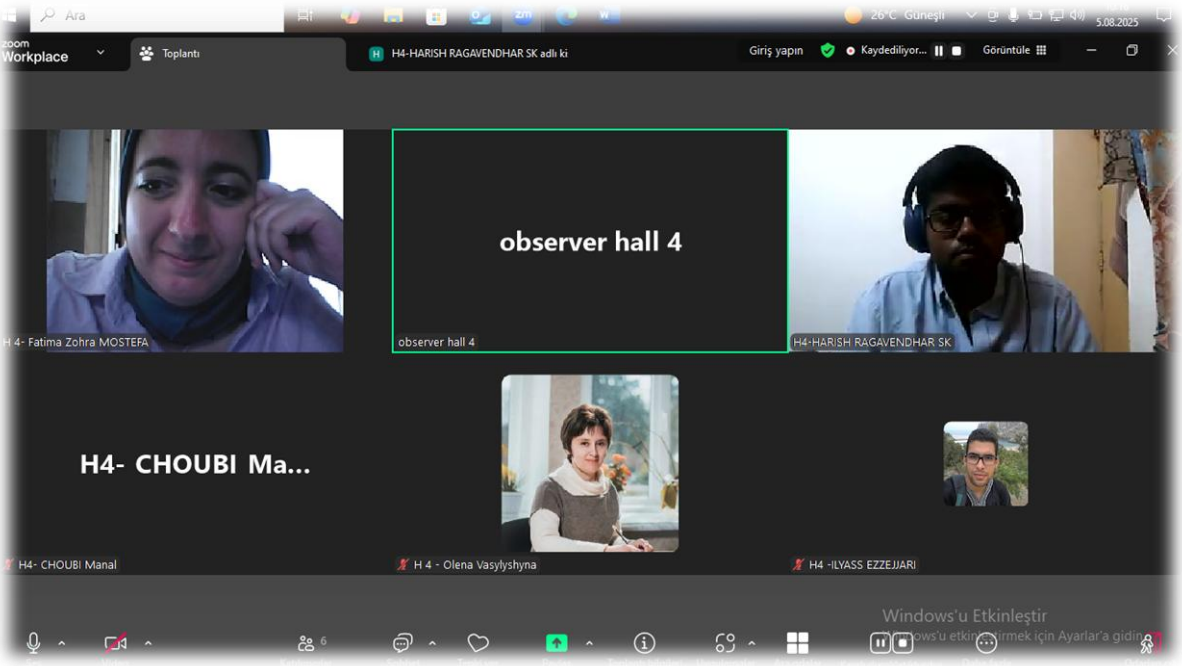
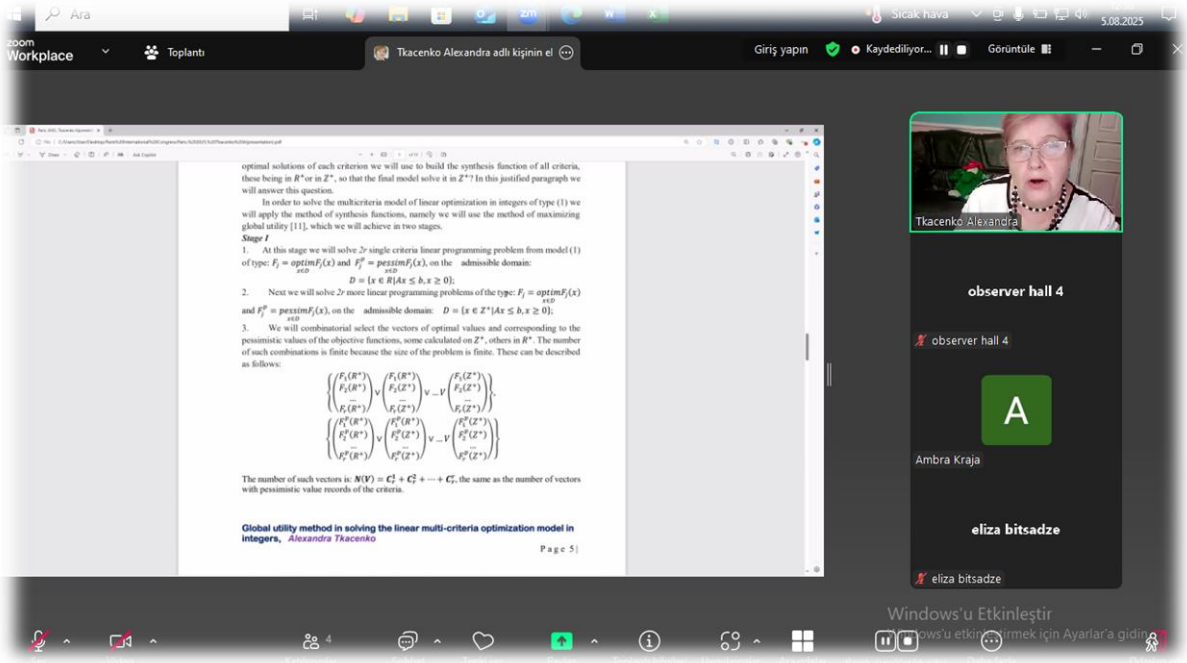


PHOTO GALLERY



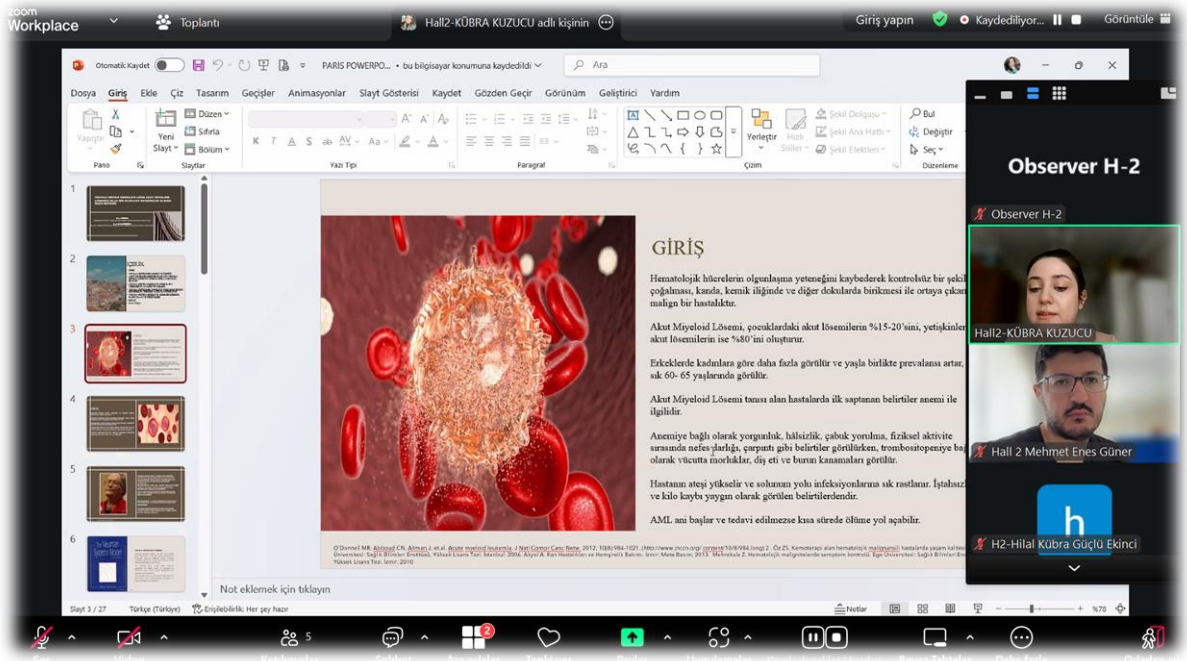


PHOTO GALLERY



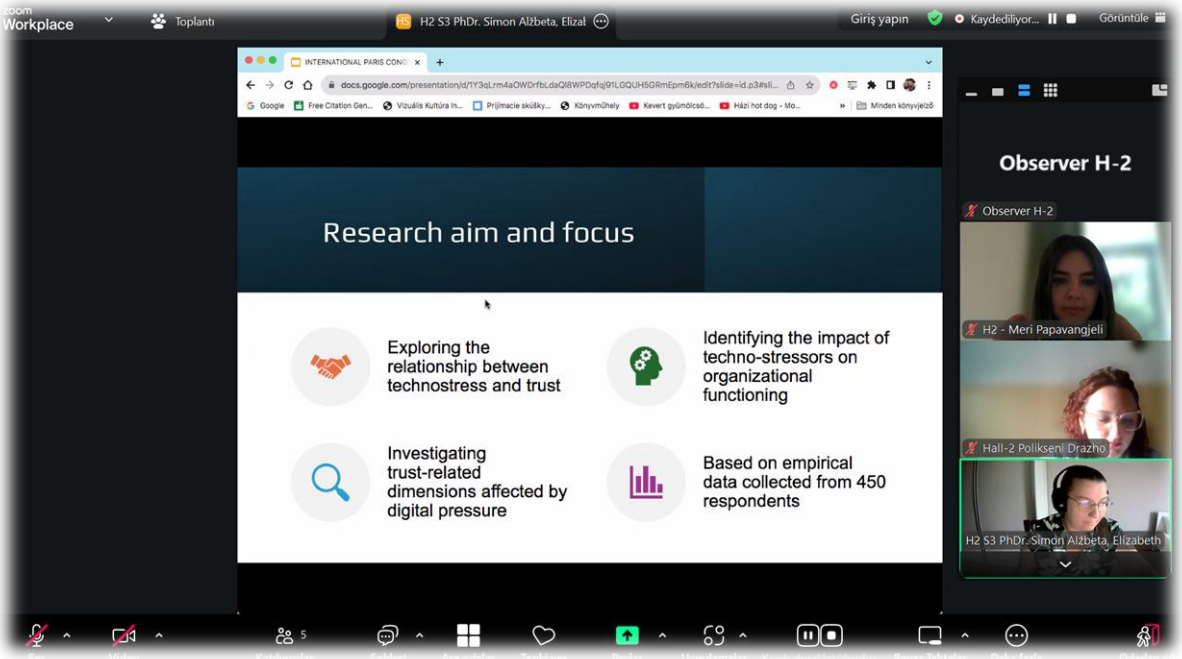


PHOTO GALLERY

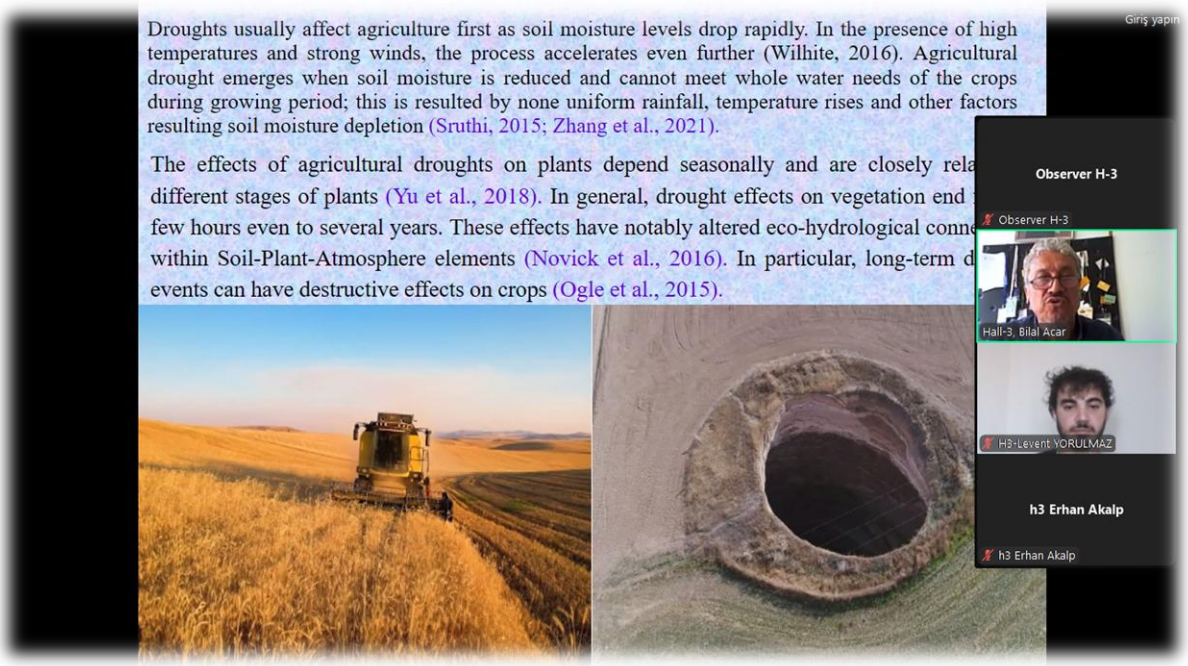
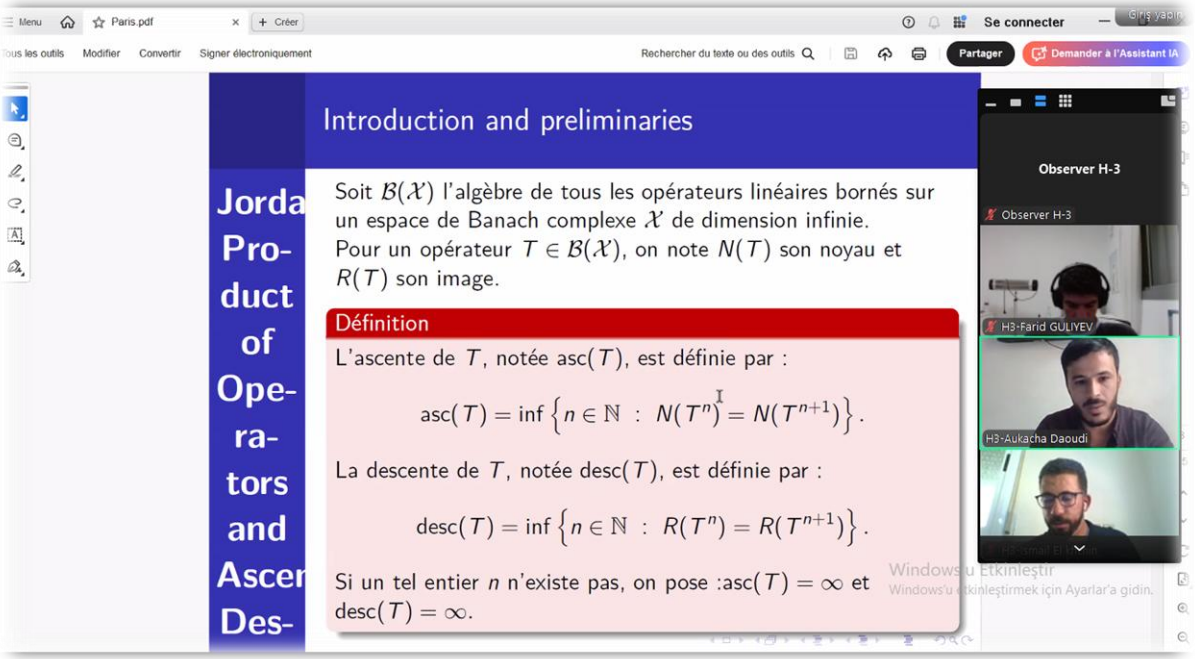




PHOTO GALLERY



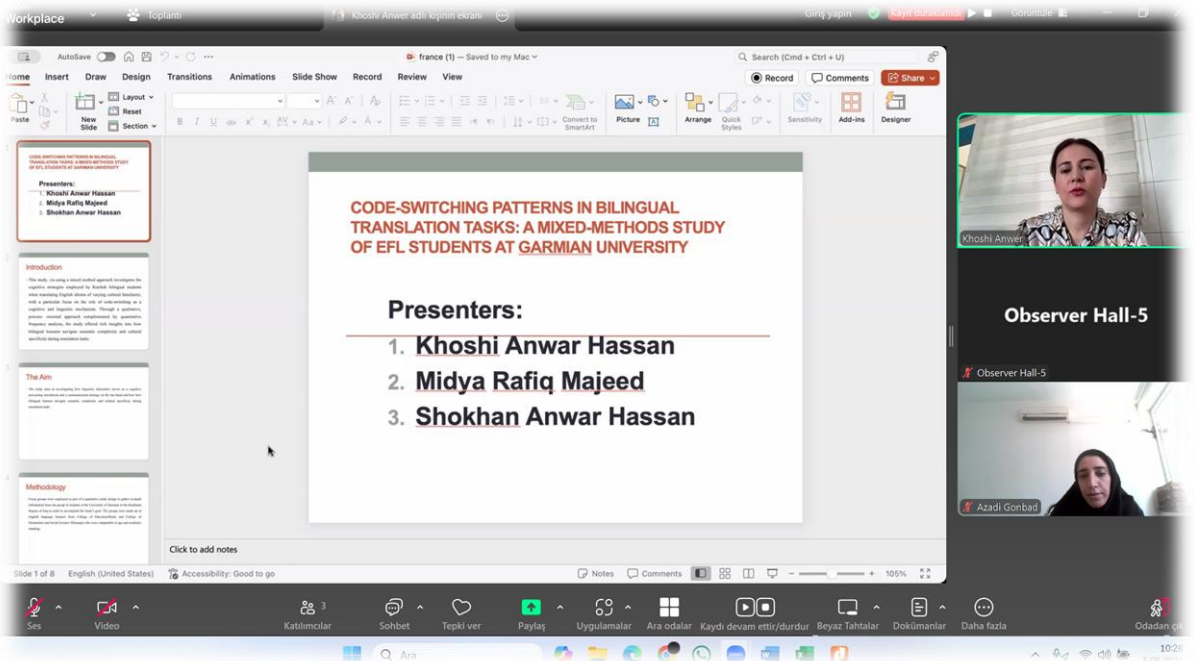
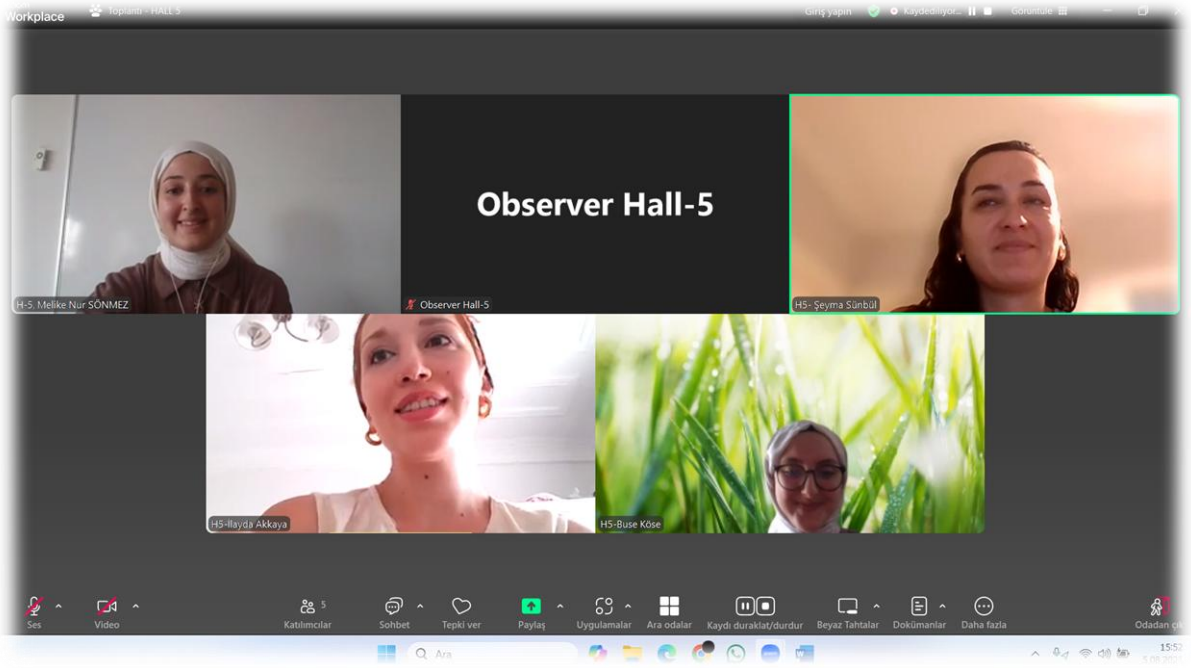


PHOTO GALLERY



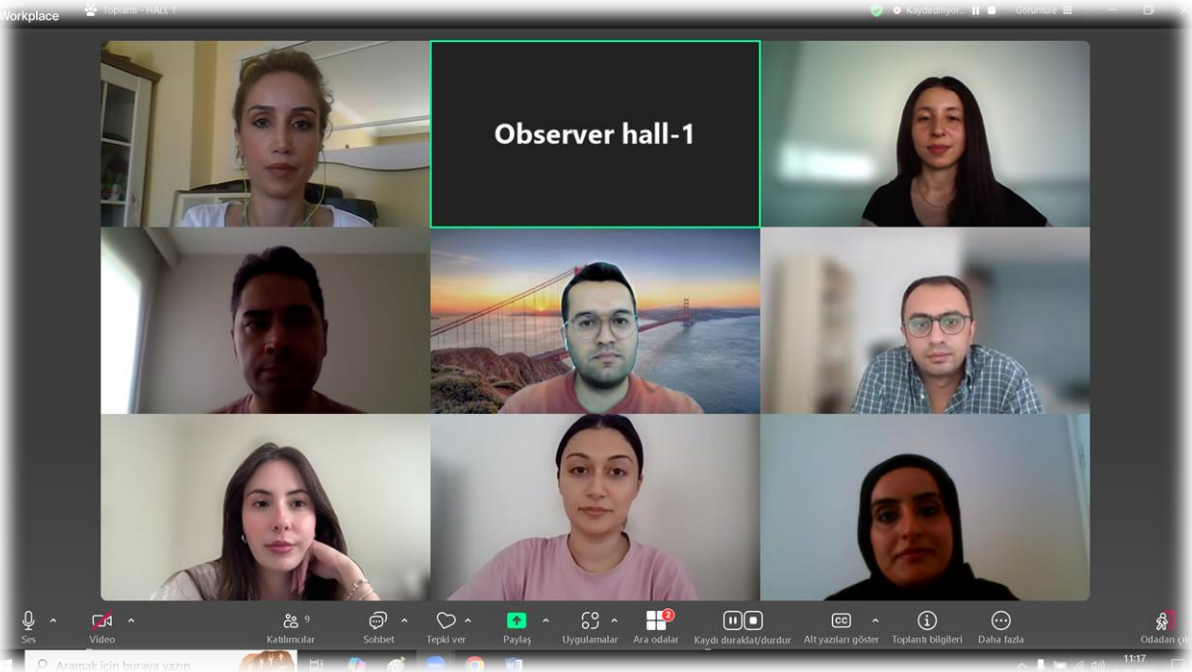
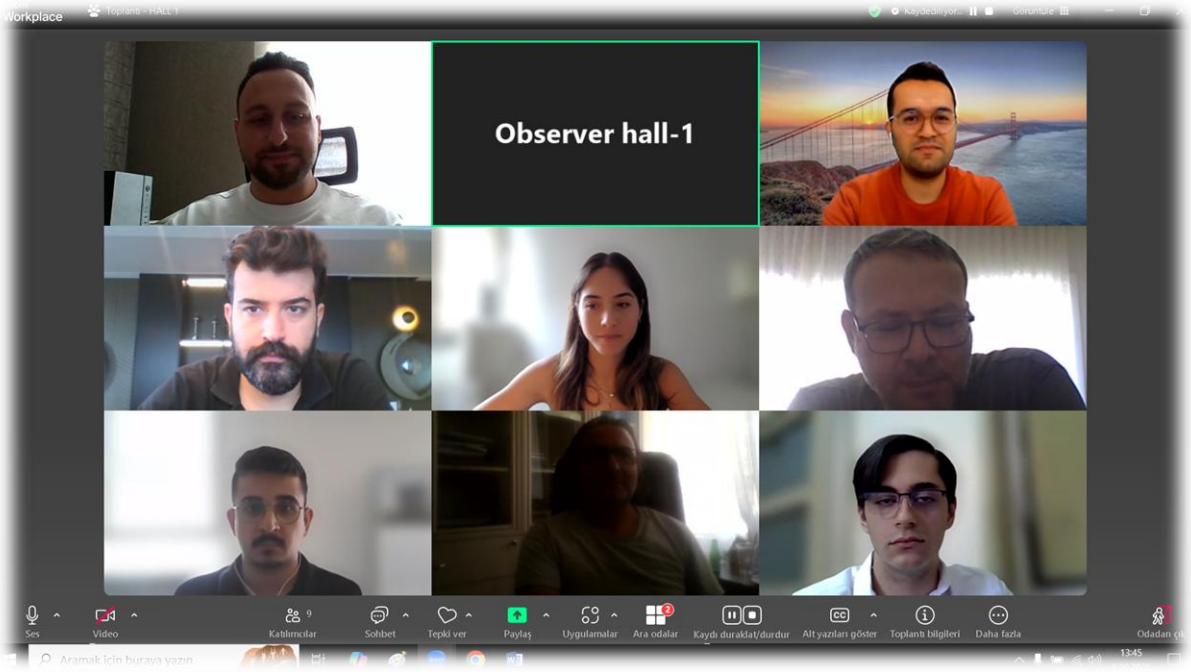
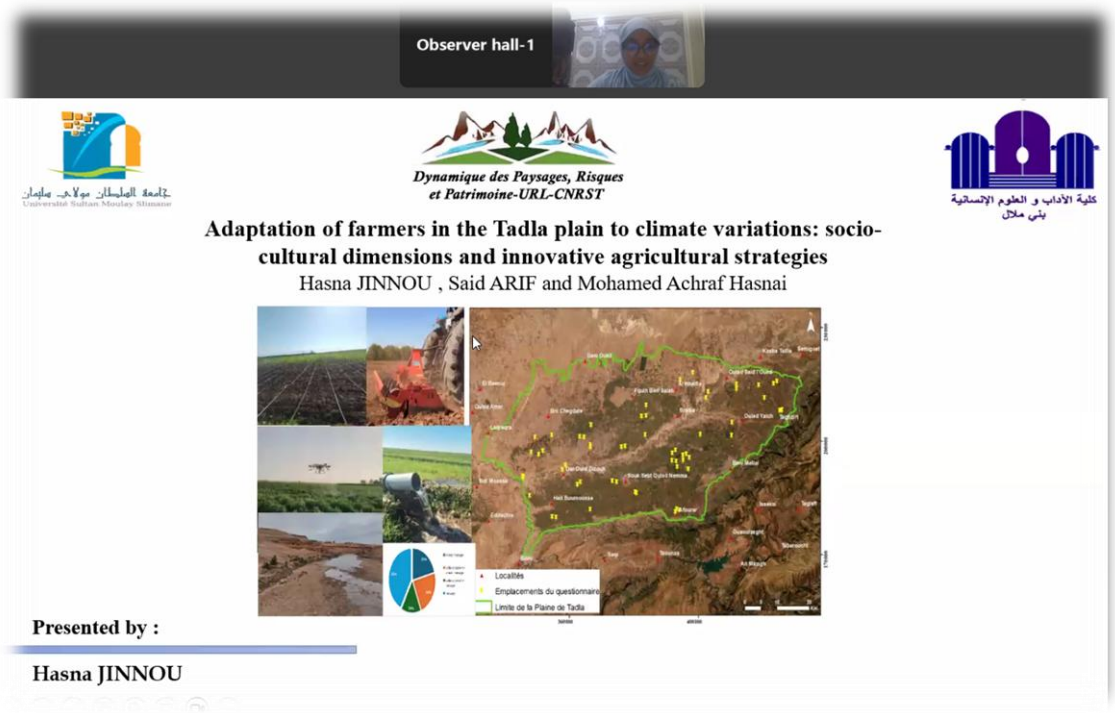


PHOTO GALLERY





5th INTERNATIONAL PARIS CONGRESS ON APPLIED SCIENCES

August 4-8 2025-Paris, FRANCE

CONGRESS PROGRAM

Meeting ID: 829 5595 6031
Zoom Passcode: 050607

https://us02web.zoom.us/j/82955956031?pwd=9cWWBzqmN1aaeg3e5JnacSRMCvNB6c.1

Participant Countries (21)

TÜRKİYE, MOROCCO, IRAQ, INDIA, BRAZIL, MOLDOVA, GEORGIA, IRAN, PAKISTAN, BOSNIA AND HERZEGOVINA, ETHIOPIA, ALGERIA, SERBIA, UKRAINE, ALBANIA, VIETNAM, SLOVAKIA, ROMANIA, AZERBAIJAN, KOSOVO, ERITREA

Önemli, Dikkatle Okuyunuz Lütfen

- Kongremizde Yazım Kurallarına uygun gönderilmiş ve bilim kurulundan geçen bildiriler için online (video konferans sistemi üzerinden) sunum imkanı sağlanmıştır.
- Online sunum yapabilmek için https://zoom.us/join sitesi üzerinden giriş yaparak "Meeting ID or Personal Link Name" yerine ID numarasını girerek oturuma katılabilirsiniz.
- Zoom uygulaması ücretsizdir ve hesap oluşturmaya gerek yoktur.
- Zoom uygulaması kaydolmadan kullanılabilir.
- Uygulama tablet, telefon ve PC'lerde çalışıyor.
- Her oturumdaki sunucular, sunum saatinden 5 dk öncesinde oturuma bağlanmış olmaları gerekmektedir.
- Tüm kongre katılımcıları canlı bağlanarak tüm oturumları dinleyebilir.
- Moderatör – oturumdaki sunum ve bilimsel tartışma (soru-cevap) kısmından sorumludur.

Dikkat Edilmesi Gerekenler - TEKNİK BİLGİLER

- Bilgisayarınızda mikrofon olduğuna ve çalıştığına emin olun.
- Zoom'da ekran paylaşma özelliğini kullanabilmelisiniz.
- Kabul edilen bildiri sahiplerinin mail adreslerine Zoom uygulamasında oluşturduğumuz oturuma ait ID numarası gönderilecektir.
- Katılım belgeleri kongre sonunda tarafınıza pdf olarak gönderilecektir.
- Kongre programında yer ve saat değişikliği gibi talepler dikkate alınmayacaktır.

Important, Please Read Carefully

- To be able to attend a meeting online, login via https://zoom.us/join site, enter ID "Meeting ID or Personal Link Name" and solidify the session.
- The Zoom application is free and no need to create an account.
- The Zoom application can be used without registration.
- The application works on tablets, phones and PCs.
- The participant must be connected to the session 5 minutes before the presentation time.
- All congress participants can connect live and listen to all sessions.
- Moderator is responsible for the presentation and scientific discussion (question-answer) section of the session.

Points to Take into Consideration - TECHNICAL INFORMATION

- Make sure your computer has a microphone and is working.
- You should be able to use screen sharing feature in Zoom.
- Attendance certificates will be sent to you as pdf at the end of the congress.
- Requests such as change of place and time will not be taken into consideration in the congress program.

***

Zoom'a giriş yapmadan önce lütfen örnekteki gibi salon numaranızı, adınızı ve soyadınızı belirtiniz
Before you login to Zoom please indicate your hall number, name and surname

exp. H-5, Radmila Jani

FACE TO FACE PRESENTATIONS

04.08.2025 / SESSION-1

PARIS LOCAL TIME

11 45 : 13 45

HEAD OF SESSION: Prof. Dr. Cuma AKBAY

AUTHORS	AFFILIATION	TOPIC TITLE
Merve HORLU Res. Assist. Cevher Kürşat MACİT Prof. Dr. Bünyamin AKSAKAL Eda ÇULLU FERŞAT Ersoy YILMAZ	*Aisin Automotive Industry Trade Inc. İstanbul TÜRKİYE* *Fırat University TÜRKİYE* *Fırat University TÜRKİYE* *Aisin Automotive Industry Trade Inc. İstanbul TÜRKİYE* *Aisin Automotive Industry Trade Inc. İstanbul TÜRKİYE*	EFFECT OF BORON AND ALUMINA ADDITION TO 316L STAINLESS STEEL ON TRIBOLOGICAL PROPERTIES
Res. Assist. Umut KUMLU Res. Assist. Ömer HÜKÜMDAR Yusuf GÖK Prof. Dr. Mustafa Atakan AKAR Prof. Dr. Ali KESKİN	*Çukurova University TÜRKİYE*	INFLUENCE OF SECTION GEOMETRY AND MATERIAL SELECTION ON ENERGY ABSORPTION IN CRASH BOXES: A FINITE ELEMENT APPROACH
Res. Assist. Umut KUMLU Res. Assist. Ömer HÜKÜMDAR Mikail KERSİN Prof. Dr. Mustafa Atakan AKAR Prof. Dr. Ali KESKİN	*Çukurova University TÜRKİYE*	CRASHWORTHINESS ANALYSIS OF HORIZONTAL AND VERTICAL ELLIPTICAL CROSS-SECTIONAL BEAMS IN VEHICLE DOORS
Assoc. Prof. Dr. Bünyamin AYGÜN Assoc. Prof. Dr. Akın AKINCIOĞLU Prof. Dr. Abdulhalik KARABULUT Prof. Dr. Önder ŞİMŞEK Prof. Dr. Gülşen TOZSİN	*Ağrı İbrahim Çeçen University TÜRKİYE* *Ağrı İbrahim Çeçen University TÜRKİYE* *Atatürk University TÜRKİYE* *Atatürk University TÜRKİYE* *Atatürk University TÜRKİYE*	DEVELOPMENT AND EVALUATION OF HEAT-RESISTANT FLEXIBLE SILICONE-BASED COMPOSITES WITH BORON AND METAL OXIDE ADDITIONS FOR NEUTRON SHIELDING APPLICATIONS
Assoc. Prof. Dr. Bünyamin AYGÜN Assoc. Prof. Dr. Akın AKINCIOĞLU Assoc. Prof. Dr. Nergiz YILDIZ YORGUN Zeynep ITIR NAMLITÜRK	*Ağrı İbrahim Çeçen University TÜRKİYE* *Ağrı İbrahim Çeçen University TÜRKİYE* *Van Yüzüncü Yıl University TÜRKİYE* *AtatürkUniversity TÜRKİYE*	DEVELOPMENT OF FLEXIBLE SILICONE MASTIC-BASED COMPOSITES ENRICHED WITH BORON MINERALS, LIF, AND FEB FOR NEUTRON SHIELDING APPLICATIONS AND EVALUATION OF THEIR ATTENUATION PERFORMANCE
Assoc. Prof. Dr. Selma TOKER KUTAY Prof. Dr. Gülesen ÜSTÜNDAĞ ŞİRAY Assoc. Prof. Dr. Nimet ÖZBAY	*Çukurova University TÜRKİYE*	BIAS REDUCTION OF UTO ESTIMATOR
Prof. Dr. Cuma AKBAY	*Kahramanmaraş Sütçü İmam University TÜRKİYE*	ANALYZING DAIRY PRODUCT DEMAND IN TÜRKİYE: THE ROLE OF SOCIO- DEMOGRAPHIC FACTORS VIA A HECKMAN MODEL
Res. Assist. Ayşe SUNGURLU Assoc. Prof. Dr. Anıl SÜVARİ	*Alanya University TÜRKİYE*	EXAMINATION OF FLEXIBLE INTERIOR SOLUTIONS ON EDUCATIONAL BUILDINGS
Assoc. Prof. Dr. Mehmet ÖZDİN	*Karasu State Hospital TÜRKİYE*	RELATIONSHIP BETWEEN HOMOCYSTEINE LEVELS AND INSULIN RESISTANCE IN OBESE PEOPLE

FACE TO FACE PRESENTATIONS

04.08.2025 / SESSION-2

PARIS LOCAL TIME

16 00 : 18 00

HEAD OF SESSION: Prof. Dr. Gönül GÜROL ÇİFTCİ

AUTHORS	AFFILIATION	TOPIC TITLE
Res. Assist. Osman Mert YAZ Res. Assist. Özlem BAHAR Assoc. Prof. Dr. Melih YILAR Assoc. Prof. Dr. Bahadır DEMİREL	*Erciyes University TÜRKİYE* *Kırşehir Ahi Evran University TÜRKİYE* *Kırşehir Ahi Evran University TÜRKİYE* *Erciyes University TÜRKİYE*	AN OVERVIEW OF THE DEVELOPMENT OF ROBOTIC SYSTEMS IN AGRICULTURE BETWEEN 2015 AND 2025
Res. Assist. Özlem BAHAR Res. Assist. Osman Mert YAZ Assoc. Prof. Dr. Bahadır DEMİREL Assoc. Prof. Dr. Melih YILAR	*Kırşehir Ahi Evran University TÜRKİYE* *Erciyes University TÜRKİYE* *Erciyes University TÜRKİYE* *Kırşehir Ahi Evran University TÜRKİYE*	ARTIFICIAL INTELLIGENCE ASSISTED WEED CONTROL IN THE LAST DECADE: ADVANCES IN CEREAL PRODUCTION AREAS, ADVANTAGES, CHALLENGES AND FUTURE PERSPECTIVES
Prof. Dr. Gönül GÜROL ÇİFTCİ	*Haliç University TÜRKİYE*	EFFECTS OF STIRIPENTOL IN EPILEPSY
Prof. Dr. Gönül GÜROL ÇİFTCİ	*Haliç University TÜRKİYE*	THE IMPORTANCE OF NEURONAL PROGENITOR CELL IN EPILEPSY
Hilal BAL Assoc. Prof. Dr. Esin HAZNECİ	*Ondokuz Mayis University TÜRKİYE*	COST AND PROFITABILITY ANALYSIS OF INDUSTRIAL HEMP PRODUCTION: THE CASE OF AMASYA PROVINCE, TÜRKİYE
Adile SAVSAR Prof. Dr. Filiz ÖĞCE AKTAŞ	*İzmir University of Economics TÜRKİYE*	METAPHORICA L PERCEPTIONS OF NURSING STUDENTS REGARDING THE CONCEPTS OF NURSING, PATIENT AND PATIENT SAFETY: A QUALITATIVE RESEARCH
Elif DAĞTEKİN Prof. Dr. Tülay YAVAN Prof. Dr. Filiz ÖĞCE AKTAŞ	*Dokuz Eylül University TÜRKİYE* *İzmir University of Economics TÜRKİYE* *İzmir University of Economics TÜRKİYE*	DETERMINATION OF FACTORS AFFECTING INITIAL MOBILIZATION OF PATIENTS AFTER CARDIAC SURGERY
Nigar Sadigova	*Azerbaijan University of Architecture and Construction AZERBAIJAN*	CHALLENGES AND PERSPECTIVES OF CREATING A NATIONAL TERMINOLOGICAL SYSTEM FOR THE PEACEFUL USES OF NUCLEAR TECHNOLOGIES

ONLINE PRESENTATIONS

05.08.2025 / HALL-1 / SESSION-1

PARIS LOCAL TIME	ANKARA LOCAL TIME
09 00 : 11 00	10 00 : 12 00

HEAD OF SESSION: Assoc. Prof. Dr. Seçil Gül MEYDAN YILDIZ

AUTHORS	AFFILIATION	TOPIC TITLE
Ahmet Aykut AKTAŞ Ahmad Abu Arra Doç. Dr. Eyüp ŞİŞMAN	*Yıldız Technical University TÜRKİYE*	COMPARISON OF USA (OSHA) AND TÜRKİYE (SGK) IN WORK ACCIDENT REPORTING PROCESSES
Ahmet Aykut AKTAŞ Ahmad Abu Arra Doç. Dr. Eyüp ŞİŞMAN	*Yıldız Technical University TÜRKİYE*	RESEARCH ON THE ESTABLISHMENT OF AN EFFECTIVE OCCUPATIONAL ACCIDENT REPORTING SYSTEM
Dr. Nichirvan Ramadhan TAHER Assoc. Prof. Dr. Hüseyin Suha AKSOY Assoc. Prof. Dr. Mesut GÖR	*Knowledge University IRAQ* *Fırat University TÜRKİYE* *Fırat University TÜRKİYE*	SHEAR STRENGTH PROPERTIES OF SAND REINFORCED WITH RECYCLED PET FLAKES
Env. Eng. Damla DURAL Env. Eng. Ecem YURGA Prof. Dr. Kaan YETILMEZSOY	*Yıldız Technical University TÜRKİYE*	WATER FOOTPRINT ANALYSIS IN BEAUTY SALONS: AN ASSESSMENT IN THE CONTEXT OF SUSTAINABLE WATER MANAGEMENT
Assoc. Prof. Dr. Seçil Gül MEYDAN YILDIZ Hüsne TEMUR Assoc. Prof. Dr. Emine Saka AKIN Prof. Dr. Hazal Ilgın BAHÇECİ BAŞARMAK Vasfiye Hande KAVAK	*Yozgat Bozok University TÜRKİYE* *Antalya Metropolitan Municipality TÜRKİYE* *Karadeniz Technical University TÜRKİYE* *Ankara Hacı Bayram Veli University TÜRKİYE* *Yozgat Bozok University TÜRKİYE*	STRUCTURAL PLAN PROPOSAL IN YOZGAT URBAN SITE
Assoc. Prof. Dr. Seçil Gül MEYDAN YILDIZ Hüsne TEMUR	*Yozgat Bozok University TÜRKİYE* *Antalya Metropolitan Municipality TÜRKİYE*	DISASTER PHENOMENA AND FORMATION OF ASSUMPTIONS IN THE SUSTAINABLE SPATIAL PLANNING PROCESS
Lect. Gamze AYDIN	*İstanbul Esnyurt University TÜRKİYE*	TECHNOLOGICAL PREPAREDNESS FOR DISASTERS: AN INNOVATIVE APPROACH TO THE RISK OF DEW DISASTERS

ONLINE PRESENTATIONS

05.08.2025 / HALL-2 / SESSION-1

PARIS LOCAL TIME	ANKARA LOCAL TIME
09 00 : 11 00	10 00 : 12 00

HEAD OF SESSION: Dr. Hilal Kübra GÜÇLÜ EKİNCİ

AUTHORS	AFFILIATION	TOPIC TITLE
Ebru BARDAŞ ÖZKAN	*Erzincan Binali Yıldırım University TÜRKİYE*	POST-COVID ERA THYROID AUTOIMMUNITY: THE EPIGENETIC LEGACY OF VIRAL EXOSOMES
Ebru BARDAŞ ÖZKAN	*Erzincan Binali Yıldırım University TÜRKİYE*	REVOLUTIONIZING SEPSIS CARE: THE SYNERGISTIC POTENTIAL OF NANOTECHNOLOGY AND HYPERBARIC OXYGEN THERAPY
Exp. Dr. Mehmet Enes GÜNER	*Besni State Hospital Adıyayam TÜRKİYE*	KLIPPEL–TRENAUNAY SYNDROME IN A PEDIATRIC PATIENT: A STRIKING UNILATERAL PRESENTATION
Exp. Dr. Mehmet Enes GÜNER	*Besni State Hospital Adıyayam TÜRKİYE*	ANGIOLYMPHOID HYPERPLASIA WITH EOSINOPHILIA PRESENTING AS AURICULAR NODULES: A RARE CASE REPORT
Dr. Hilal Kübra GÜÇLÜ EKİNCİ	*Erciyes University TÜRKİYE*	MORPHOMETRIC AND TOPOGRAPHIC EVALUATION OF THE FORAMEN MANDIBULAE IN ARCHAEOLOGICAL MANDIBLES FROM THE ROMAN PERIOD
Kübra KUZUCU Prof. Dr. Şerife KARAGÖZOĞLU	*Cumhuriyet University TÜRKİYE*	NURSING CARE OF A PATIENT WITH ACUTE MYELOID LEUKEMIA ACCORDING TO THE NEUMAN SYSTEM MODEL: A CASE REPORT
Kübra KUZUCU Prof. Dr. Şerife KARAGÖZOĞLU	*Cumhuriyet University TÜRKİYE*	PATIENTS WITH ADULT HEMATOLOGICAL MALIGNANCY, REFLECTIONS OF STUDIES CONDUCTED BASED ON NURSING THEORIES AND MODELS ON NURSING CARE

ONLINE PRESENTATIONS

05.08.2025 / HALL-3 / SESSION-1

PARIS LOCAL TIME	ANKARA LOCAL TIME
09 00 : 11 00	10 00 : 12 00

HEAD OF SESSION: Prof. Dr. Bilal ACAR

AUTHORS	AFFILIATION	TOPIC TITLE
Levent YORULMAZ Dr. Sibel IPEKESEN Prof. Dr. Mehmet YILDIRIM	*Dicle University TÜRKİYE*	SPEED BREEDING IN BREAD WHEAT: ESTIMATION OF GENETIC PARAMETERS IN F1 HYBRIDS
Prof. Dr. Bilal ACAR	*Selçuk University TÜRKİYE*	REMEDIES FOR MITIGATING NEGATIVE RESULTS OF DROUGHT ON VEGETATIVE PRODUCTION IN WATER SCANT AREAS
Res. Assist. Erhan AKALP Assist. Prof. Dr. Vedat PİRİNÇ	*Dicle University TÜRKİYE*	THE IMPACTS OF GLOBAL CLIMATE CHANGE ON VEGETABLE PRODUCTION
Res. Assist. Erhan AKALP Assist. Prof. Dr. Vedat PİRİNÇ	*Dicle University TÜRKİYE*	THE ROLE OF TECHNOLOGICAL IMPROVEMENTS IN THE CULTIVATION OF VEGETABLES
Ayfer GÜNEY SARITAŞ Assist. Prof. Dr. Harun ALPTEKİN	*Iğdır University TÜRKİYE*	ALLELOPATHY IN WEED MANAGEMENT: A BIBLIOMETRIC REVIEW
Ayfer GÜNEY SARITAŞ Assist. Prof. Dr. Harun ALPTEKİN	*Iğdır University TÜRKİYE*	GLOBAL RESEARCH TRENDS ON INVASIVE WEEDS: A BIBLIOMETRIC ANALYSIS (1987–2025)

ONLINE PRESENTATIONS

05.08.2025 / HALL-4 / SESSION-1

PARIS LOCAL TIME	ANKARA LOCAL TIME
09 00 : 11 00	10 00 : 12 00

HEAD OF SESSION: Dr. Fatima Zohra MOSTEFA

AUTHORS	AFFILIATION	TOPIC TITLE
Harish Raghvendhar SK Dr. Abhijit Asati	*BITS PILANI, PILANI, INDIA*	10-BIT DIFFERENTIAL SEGMENTED CURRENT STEERING DIGITAL TO ANALOG CONVERTER
Ez-zejjari Ilyass El Ghazi Haddou	*Hassan 2 University MOROCCO*	PRESSURE ENGINEERING OF ELECTRONIC AND MECHANICAL PROPERTIES IN III-NITRIDE SEMICONDUCTORS: A COMPUTATIONAL STUDY
Dr. Fatima Zohra MOSTEFA	*Oran University of Science and Technology USTO-MB ALGERIA*	MEDICAL ASSISTANCE APPLICATION WITH CROSS-BLOCKCHAIN AND THE RAFT CONSENSUS ALGORITHM FOR THE ELDERLY PERSON IN IOT NETWORKS
Aida Makas Dr. Haniza Von	*Sarajevo School of Science and Technology BOSNIA AND HERZEGOVINA*	RETHINKING CREDIT RISK: AI-DRIVEN OUTCOME-BASED CREDIT MODELS FOR SUSTAINABLE FINANCIAL INCLUSION IN EMERGING MARKETS
Warda Waseem Muhammad Yasin Naz Abdul Ghaffar	*Agriculture University PAKISTAN*	COMPARATIVE STUDY OF TITANATE-BASED PEROVSKITE OXIDES FOR ENERGY STORAGE DEVICES
M. Choubi A. Elidrysy S. Harir Z. Elmghabar A. Lahbibi Y. Lghazi	*Hassan II University MOROCCO* *Hassan II University MOROCCO* *Hassan II University MOROCCO* *Mohammed V University MOROCCO* *Hassan II University MOROCCO* *Hassan II University MOROCCO*	CRITICAL BEHAVIORS AND MAGNETOCALORIC EFFECT IN MIXED-SPIN-(1-5/2) HEXAGONAL NANOWIRE WITH MONTE CARLO SIMULATION
Mohamed Lattoui Morsli Sebaa Tyeb Allaoui Noureddine Sarir	*Tiaret University ALGERIA*	ENERGY MANAGEMENT OF A PV–BATTERY–SUPERCAPACITOR HYBRID SYSTEM SUPPLYING VARIABLE LOADS WITH GRID BACKUP
Assoc. Prof. Dr. Olena VASYLYSHYNA	*Uman National University UKRAINE*	THE EFFECT OF TREATMENT WITH ECOLOGICALLY CLEAN COMPOSITIONS ON THE QUALITY OF SOUR CHERRY AND SWEET CHERRY FRUITS DURING STORAGE
Nigar Sadigova	*Azerbaijan University of Architecture and Construction AZERBAIJAN*	CHALLENGES AND PERSPECTIVES OF CREATING A NATIONAL TERMINOLOGICAL SYSTEM FOR THE PEACEFUL USES OF NUCLEAR TECHNOLOGIES

ONLINE PRESENTATIONS

05.08.2025 / HALL-5 / SESSION-1

PARIS LOCAL TIME	ANKARA LOCAL TIME
09 00 : 11 00	10 00 : 12 00

HEAD OF SESSION: Soukaina El Bourachdi

AUTHORS	AFFILIATION	TOPIC TITLE
Badreddine LABAKOUM Dr. Amr FARHAN Lhoucine BEN TALEB Prof. Azeddine MOUHSEN Prof. Aissam LYAZIDI	*Hassan I University MOROCCO*	THE IMPACT OF AUTOCLAVING AND CLEANING ON THE DENTAL SURGICAL GUIDE IMPLANT
Tasawar Iqbal Sidra Altaf	*Agriculture University PAKISTAN*	CORDIA MYXA AS A PHYTOTHERAPEUTIC AGENT IN RHEUMATOID ARTHRITIS: MECHANISMS AND APPLICATIONS
Reza Azadi Gonbad Nasrin Farhadi Omid Lotfifar	*Horticultural Science Research Institute IRAN*	EFFECTS OF GROWTH REGULATORS AND LIGHT INTENSITY ON CALLUS INDUCTION IN FOUR CULTIVARS OF VACCINIUM CORYMBOSUM
Saira Malik Syed Mohsan Raza Shah Uniza Fatima Bukhari Tasawar Fatima Bukhari Iqra	*Education University PAKISTAN*	LEAF STRUCTURAL AND FUNCTIONAL MODIFICATION OF IPOMOEA CARNEA JACQ. AN INVASIVE PLANT SPECIES, UNDER DIVERSE SALINITY GRADIENT
Iram Liaqat	*Government College University PAKISTAN*	ROLE OF FLAGELLAR ASSEMBLY IN SALMONELLA FLHA DELETED STRAIN BIOFILM FORMATION
Iram Liaqat	*Government College University PAKISTAN*	QUORUM SENSING MEDIATED BIOFLM INHIBITION IN MARINE ISOLATES
Soukaina El Bourachdi Yassine Rakcho Amal Lahkimi	*Sidi Mohamed Ben Abdellah University MOROCCO* *Cadi Ayyad University MOROCCO* *Sidi Mohamed Ben Abdellah University MOROCCO*	SUSTAINABLE GREEN SYNTHESIS OF A NOVEL CHITOSAN@EDTA@CELLULOSE COMPOSITE DERIVED FROM SHRIMP SHELL CHITOSAN AND CACTUS-BASED CELLULOSE FOR EFFICIENT METHYL ORANGE DYE REMOVAL: COMPREHENSIVE CHARACTERIZATION, ADSORPTION OPTIMIZATION VIA RESPONSE SURFACE METHODOLOGY, REUSABILITY ASSESSMENT, AND DFT-BASED MECHANISTIC ELUCIDATION
Soukaina El Bourachdi Yassine Rakcho Amal Lahkimi	*Sidi Mohamed Ben Abdellah University MOROCCO* *Cadi Ayyad University MOROCCO* *Sidi Mohamed Ben Abdellah University MOROCCO*	DEVELOPMENT AND COMPREHENSIVE CHARACTERIZATION OF GRAPHENE OXIDE-ENHANCED CHITOSAN COMPOSITE BEADS FOR HIGHLY EFFICIENT, SELECTIVE, AND RAPID CONGO RED DYE ADSORPTION FROM CONTAMINATED WATER: AN INTEGRATIVE, MULTIDISCIPLINARY INVESTIGATON COMBINING MOLECULAR-LEVEL MECHANISTIC INSIGHTS VIA DENSITY FUNCTIONAL THEORY (DFT), EXTENSIVE EXPERIMENTAL VALIDATION, AND ADVANCED STATISTICAL PROCESS OPTIMIZATION USING RESPONSE SURFACE METHODOLOGY (RSM) TOWARDS SUSTAINABLE AND ENVIRONMENTALLY FRIENDLY WASTEWATER REMEDIATION

ONLINE PRESENTATIONS

05.08.2025 / HALL-6 / SESSION-1

PARIS LOCAL TIME	ANKARA LOCAL TIME
09 00 : 11 00	10 00 : 12 00

HEAD OF SESSION: Prof. Dr. Robert Çina

AUTHORS	AFFILIATION	TOPIC TITLE
PhD. Can. Tedi Prifti Prof. Dr. Robert Çina	*Sports University ALBANIA*	INNOVATIVE METHODS FOR THE REHABILITATION OF PELVIS DISBALANCE
Prof. Dr. Robert Çina PhD. Can. Tedi Prifti	*Sports University ALBANIA*	EFFECTIVENESS OF THE GYROTONIC METHOD IN IMPROVING LUMBAR LORDOSIS: 4-WEEK INTERVENTION STUDY USING SURFACE TOPOGRAPHY
Prof. Assoc. Dr. Enkeleida Lleshi Salvator Kurti	*Sports University ALBANIA*	EXPLOSIVE STRENGTH IN ELITE FEMALE BASKETBALL PLAYERS IN TIRANA, ALBANIA
Orkida Kosta Ortensia Kosta	*Sports University ALBANIA*	SKELETAL MUSCLE ENERGY METABOLISM DURING EXERCISE
Danilo Henrique Lattaro Evandro Marianetti Fioco Assoc. Prof. Dr. Selma Siéssere Prof. Dr. Neide Pena Coto Prof. Dr. Simone Cecílio Hallak Regalo	*São Paulo University BRAZIL*	THE IMPACT OF ORAL HEALTH ON SALIVARY AND BLOOD BIOMARKERS IN ELITE SOCCER ATHLETES
Rando KUKELI Victoria KUKELI	*Sports University ALBANIA*	FITNESS PRIORITIES AMONG GYM PARTICIPANTS IN TIRANA: A DEMOGRAPHIC AND GENDER-BASED ANALYSIS
Margarita KUQALI Kostandin DOLLANI Ylli Kaçiu	*Tirana Polytechnic University ALBANIA* *Tirana University ALBANIA* *Kosovo University Clinical Center KOSOVO*	ASSESSMENT OF RADIATION EXPOSURE IN NUCLEAR MEDICINE PROCEDURES IN ALBANIA: DIAGNOSTIC AND THERAPEUTIC IMPLICATIONS



ONLINE PRESENTATIONS

05.08.2025 / HALL-1 / SESSION-2

PARIS LOCAL TIME	ANKARA LOCAL TIME
11 30 : 13 30	12 30 : 14 30

HEAD OF SESSION: Samet KUŞKIRAN

AUTHORS	AFFILIATION	TOPIC TITLE
Gökhan GÜNEŞ Murat ŞEN	*Fırat University TÜRKİYE*	PRODUCTION AND NUMERICAL SIMULATIONS OF A SOFT GRIPPER
Hamit TÜRKMEN Prof. Dr. Hüseyin AKILLI	*Çukurova University TÜRKİYE*	PARAMETRIC DEM-BASED INVESTIGATION OF ADHESIVE FORCES AND THEIR EFFECT ON POWER REQUIREMENTS IN GRANULAR TRANSPORT
Ömer Faruk AVCIOĞLU Durmuş Ali BİRCAN	*Çukurova University TÜRKİYE*	OPTIMAL PARAMETER IDENTIFICATION FOR ACTIVATED TIG WELDING OF TI6AL4V ALLOY USING MULTI-CRITERIA DECISION MAKING (MCDM) METHODS
Erol DOĞAN Durmuş Ali BİRCAN	*Çukurova University TÜRKİYE*	MULTI-CRITERIA OPTIMIZATION OF FLUX COMPOSITION AND WELDING PARAMETERS FOR ACTIVATED TUNGSTEN INERT GAS WELDING OF INCONEL 718
Duygu ARAS Assist. Prof. Dr. Merve TEKE BUDAKLI	*Turkish German University TÜRKİYE*	DESIGN AND EVALUATION OF A REAL-TIME DRIVER MONITORING SYSTEM USING LANDMARK-BASED AND DEEP VISUAL FEATURES
MSc. Eng. Enes AKÇAY Dr. Lect. Arzu KEVEN	*Bayburt University TÜRKİYE* *Kocaeli University TÜRKİYE*	THERMODYNAMIC AND EXERGY ANALYSIS OF R454C AND MIXED REFRIGERANTS IN REFRIGERATED TRUCKS
MSc. Eng. Enes AKÇAY Dr. Lect. Arzu KEVEN	*Bayburt University TÜRKİYE* *Kocaeli University TÜRKİYE*	THERMODYNAMIC COMPARISON OF R452A REFRIGERANT: AN EXERGY BASED ANALYSIS FOR AUTOMOTIVE AIR CONDITIONING SYSTEMS



ONLINE PRESENTATIONS

05.08.2025 / HALL-2 / SESSION-2

PARIS LOCAL TIME	ANKARA LOCAL TIME
11 30 : 13 30	12 30 : 14 30

HEAD OF SESSION: Prof. Dr. Betül APAYDIN YILDIRIM

AUTHORS	AFFILIATION	TOPIC TITLE
Assist. Prof. Dr. Osman ÜNER	*Kırklareli University TÜRKİYE*	ACTIVATED CARBON PRODUCTION FROM DRY ITALIAN THISTLE (CARDUUS PYCNOCEPHALUS L.) AND ITS ADSORPTION APPLICATION FOR METANIL YELLOW
Prof. Dr. Betül APAYDIN YILDIRIM	*Atatürk University TÜRKİYE*	USE OF HEART-TYPE FATTY ACID BINDING PROTEIN (H-FABP) AS A CARDIAC BIOMARKER IN EARLY DIAGNOSIS
Assist. Prof. Dr. CemYALAZA	*Başkent University TÜRKİYE*	IDENTIFICATION OF PLANT-DERIVED ISOFORM-SELECTIVE PI3K INHIBITORS
Prof. Dr. Kadriye URUÇ PARLAK Sinem BİRGÜCÜ	*Ağrı İbrahim Çeçen University TÜRKİYE*	PHYSİOLOGICAL AND BIOCHEMICAL BASES OF PLANT TOLERANCE MECHANISMS UNDER SALT STRESS
Prof. Dr. Ersin GÜNGÖR Yağmur YEŞİLBAŞ	*Bartın University TÜRKİYE*	COMMUNITY-BASED CARBON MANAGEMENT: AN ASSESSMENT FROM THE PERSPECTIVE OF RURAL DEVELOPMENT AND FORESTRY
Yağmur YEŞİLBAŞ Prof. Dr. Ersin GÜNGÖR	*Bartın University TÜRKİYE*	THE IMPACT OF BIOTIC AND ABIOITIC DAMAGE IN FORESTS ON VOLUNTARY CARBON MARKETS
Assist. Prof. Dr. Gamze D. TETİK Assist. Prof. Dr. Gizem CELEP Res. Assist. Dr. Fulya YILMAZ	*Uşak University TÜRKİYE*	THE EFFECT OF RAISING PROCESS ON HANDFEEL PROPERTIES OF BLANKETS



ONLINE PRESENTATIONS

05.08.2025 / HALL-3 / SESSION-2

PARIS LOCAL TIME	ANKARA LOCAL TIME
11 30 : 13 30	12 30 : 14 30

HEAD OF SESSION: Res. Assist. Nurdanur PEHLİVAN

AUTHORS	AFFILIATION	TOPIC TITLE
Lect. Ceren YAMAN	*Cappadocia University TÜRKİYE*	THE IMPACT OF AI-BASED DECISION SUPPORT SYSTEMS ON STRATEGIC DECISION-MAKING IN ORGANIZATIONS: A MANAGEMENT INFORMATION SYSTEMS PERSPECTIVE
Onur METİN Şeref TURHAN	*Kastamonu University TÜRKİYE*	ASSESSMENT OF RADIOLOGICAL HEALTH RISKS CAUSED BY INTERNAL EXPOSURE TO WORKERS IN BENTONITE QUARRIES
Şeref TURHAN Onur METİN	*Kastamonu University TÜRKİYE*	ASSESSMENT OF RADIOLOGICAL HEALTH RISKS ARISING FROM INTERNAL EXPOSURE TO WHICH AGRICULTURAL WORKERS AROUND A COAL-FIRED THERMAL POWER PLANT MAY BE EXPOSED
Prof. Dr. Mitat UYSAL Prof. Dr. S. Aynur UYSAL Res. Assist. Nurdanur PEHLİVAN	*Doğuş University TÜRKİYE*	BUILDING RECOMMENDER SYSTEMS WITH MACHINE LEARNING AND AI
Mustafa Eren GÖKÇEOĞLU Mustafa KURT	*Çanakkale Onsekiz Mart University TÜRKİYE*	ANALYSIS OF METHODS USED IN SOLAR POWER PLANTS IN TURKEY OVER THE YEARS AND CURRENT STATUS
Sinem BOYRAZ Ahmet Can ÜNAL	*Marshall Boya ve Vernik San. A.Ş., Kocaeli TÜRKİYE*	DEVELOPMENT OF DOUBLE CROSS-LINKED ELASTOMERIC EXTERIOR COATINGS WITH BENZOPHENONE DERIVATIVES AND CALCIUM CARBOXYLATE IONS
Gulnabat GOCHOVA Kubilay AYTURAN Fırat HARDALAÇ	*Gazi University TÜRKİYE*	DEEP LEARNING-DRIVEN FAULT DETECTION IN SOLAR PANELS: A YOLOV5M IMPLEMENTATION APPROACH
Assoc. Prof. Dr. Mustafa TUNÇSOY Assoc. Prof. Dr. Benay TUNÇSOY	*Çukurova University TÜRKİYE* *Adana Alparslan Türkeş Science and Technology University TÜRKİYE*	SIZE DEPENDENT EFFECTS OF ALUMINUM OXIDE PARTICLES ON ANTIOXIDANT ENZYMES OF Oreochromis niloticus
Onur Ata ÇETİNKAYA İsmail Can PAYLAN	*Ege University TÜRKİYE*	DETERMINATION OF GENETIC DIVERSITY IN PEPPER SEEDS USING MOLECULAR METHODS

ONLINE PRESENTATIONS

05.08.2025 / HALL-4 / SESSION-2

PARIS LOCAL TIME	ANKARA LOCAL TIME
11 30 : 13 30	12 30 : 14 30

HEAD OF SESSION: Tkacenko ALEXANDRA

AUTHORS	AFFILIATION	TOPIC TITLE
Tkacenko ALEXANDRA	*Moldova State University MOLDOVA*	GLOBAL UTILITY METHOD IN SOLVING THE LINEAR MULTI-CRITERIA OPTIMIZATION MODEL IN INTEGERS
Elza Bitsadze Lia janazde	*Akaki Tsereteli State University GEORGIA*	SCALABLE AND SECURE DATABASE INTEGRATION IN CLOUD INFRASTRUCTURES: CHALLENGES AND TECHNOLOGICAL SOLUTIONS
Elza Bitsadze	*Akaki Tsereteli State University GEORGIA*	INNOVATIONS IN COMPUTATIONAL SCIENCE: ALGORITHMS, DATA, AND MODELING
Željka Nikitović	*Belgrade University SERBIA*	RATE COEFFICIENTS FOR H2+IONS IN Ar/H2 MIXTURES
Noureddine BOUTERAA	*Oran1 University ALGERIA*	ANALYZING FRACTIONAL DIFFERENTIAL EQUATION DEPENDING ON MIXED BOUNDARY CONDITIONS
Msc. Ambra Kraja Msc. Xhentjan Beshiri	*Agricultural University ALBANIA* *European University ALBANIA*	THE IMPACT OF SMART TOURISM ON BUSINESS PERFORMANCE: AN EMPIRICAL ANALYSIS
Khalid Siraj Dr. Karunesh Tiwari Kebron Tesfaldet Lulya Essayas Sidona Sium	*Mai-Nefhi College of Science ERITREA*	ANTIBACTERIAL PROPERTIES OF SILVER NANOPARTICLES PREPARED BY GREEN SYNTHESIS USING ACACIA LAETA
Assist Prof. Dr. Özlem ÖZKAN ÖNÜR Assoc. Dr. Ethem İLHAN ŞAHİN	*İstanbul Nişantaşı TÜRKİYE* *Adana Alparslan Türkeş Science and Technology University TÜRKİYE*	THE ROLE OF MARBLE DUST AND MARBLE CHIPS IN HISTORICAL BUILDING MORTARS: A STUDY ON OTTOMAN AND BYZANTINE PERIODS

ONLINE PRESENTATIONS

05.08.2025 / HALL-5 / SESSION-2

PARIS LOCAL TIME	ANKARA LOCAL TIME
11 30 : 13 30	12 30 : 14 30

HEAD OF SESSION: Dr. Ivan PAVLOVIC

AUTHORS	AFFILIATION	TOPIC TITLE
Etibaria BELGHALIA Farid Elbamtari Abdelouahid SBAI M'barek Choukrad Tahar LAKHLIFI Mohammed BOUACHRINE	*Moulay Ismail University MOROCCO*	COMPUTATIONAL EVALUATION OF PYRAZOLE-BENZIMIDAZOLE DERIVATIVES AS ANTI-PROLIFERATIVE AGENTS AGAINST BREAST CANCER
Bismillah IFTIKHAR	*Hajvery University PAKISTAN*	ICTAL INDUCED CARDIOVASCULAR DISEASES AND ASSOCIATED NEUROLOGICAL COMORBIDITIES : A META ANALYTICAL APPROACH
Dr. Ivan PAVLOVIC Prof. Dr. Slavica ŽİVKOVIC	*Serbia Scientific Institute of Veterinary Medicine SERBIA*	OCCURENCE OF STRONGYLUS EQUINUS OF DOMESTIC MOUNTAIN HORSE IN SERBIA
Taskeen FATIMA	*Hajvery University PAKISTAN*	THE IMPACT OF LIVER CIRRHOSIS ON THE PROGRESSION AND COMPLICATIONS OF DIABETES MELLITUS
Taskeen FATIMA	*Hajvery University PAKISTAN*	THE CLINICAL SIGNIFICANCE OF NORMAL PHYSIOLOGICAL BLOOD PARAMETERS IN HEALTH ASSESSMENT
Soumaya CHAABENE Malek TRABELSI	*Medicine Sfax University TUNISIA* *Honoris United University TUNISIA*	EFFECTS OF A PULMONARY REHABILITATION PROGRAM IN PATIENTS WITH CHRONIC OBSTRUCTIVE PULMONARY DISEASE: A PROSPECTIVE INTERVENTIONAL STUDY
Nora BERISHA Fatmir DRAGIDELLA	*Prishtina University KOSOVO*	PHOTODYNAMIC THERAPY IMPACT ON ORAL HEALTH IN PATIENTS WITH BRACES



ONLINE PRESENTATIONS

05.08.2025 / HALL-6 / SESSION-2

PARIS LOCAL TIME	ANKARA LOCAL TIME
11 30 : 13 30	12 30 : 14 30

HEAD OF SESSION: Amaan ARIF

AUTHORS	AFFILIATION	TOPIC TITLE
Abdelghani Bouchyoua Abdelmajid Khabbach Khalil Hammani Abdelghani Nabloussi	*National Institute of Agricultural Research MOROCCO* *Sidi Mohamed Ben Abdellah University MOROCCO* *Sidi Mohamed Ben Abdellah University MOROCCO* *National Institute of Agricultural Research MOROCCO*	ASSESSING EARLY-STAGE DROUGHT RESPONSE IN MOROCCAN RAPESEED
Amaan ARIF	*Amity University INDIA*	AI-DRIVEN LINGUISTIC MODELLING FOR NEURODEVELOPMENTAL DISORDERS
Iqra Syed Mohsan Raza Shah Muhammad Bedar Bekhat Naseem	*Education University PAKISTAN* *Government College University PAKISTAN*	HABITAT-DRIVEN ECOPHYSIOLOGICAL AND ANATOMICAL VARIABILITY IN AERVA JAVANICA: FROM PLAINS TO DESERTS AND ELEVATION
Bahija MOUNIR Fathallaah BAZI	*Hassan II University MOROCCO*	APATITES: A FAMILY OF HIGH-PERFORMANCE AND ECOLOGICAL CATALYSTS FOR THE SYNTHESIS OF MOLECULES OF BIOLOGICAL INTEREST
M.Sc. Reshma N. Assist. Prof. Dr. Deepthi K.S. Assist. Prof. Dr. Saranya Devi K.	*Calicut University INDIA*	SUSTAINABLE PRODUCTION OF BACTERIAL CELLULOSE BY BACTERIA ISOLATED FROM NATURAL FERMENTED SUBSTRATES FOR ECO-FRIENDLY BIO-LEATHER APPLICATIONS
Arif Gull Hafsa Naeem Ayesha Batool Chashman Ahmed Rimsha Anwar	*Islamia University PAKISTAN* *Agriculture University PAKISTAN* *Agriculture University PAKISTAN* *Quaid e Quaid-e-Azam Medical College PAKISTAN* *Agriculture University PAKISTAN*	NEURAL ACCUMULATION OF MICROPLASTICS: A NEW FRONTIER IN NEUROTOXICOLOGY RESEARCH
Vlad DIACONESCU Bogdan-Catalin SERBAN Matei-Gabriel URSACHESCU Maria Ruxandra SALAGEAN Marius BUMBAC	*Carol Davila University of Medicine and Pharmacy ROMANIA* *National Institute for Research and Development in Microtechnologies– IMT ROMANIA*	IRON COMPLEXES WITH ORGANIC LIGANDS USED AS HEM SUBSTITUTES IN THE TREATMENT OF SEVERE ANEMIA
Vlad DIACONESCU Bogdan-Catalin SERBAN Matei-Gabriel URSACHESCU Maria Ruxandra SALAGEAN Marius BUMBAC	*National College "B. P. Hasdeu", Bulevardul Gării 1 ROMANIA* *National College "Saint Sava", 23 General H. M. Berthelot Street ROMANIA* *Valahia University of Targoviste ROMANIA*	COVALENT SERINE PROTEASE INHIBITORS IN THE TREATMENT OF AUTOIMMUNE DISEASES: A CHEMICO-MEDICAL APPROACH
ALI HAMADA	*Hassan II University MOROCCO*	ELIMINATION OF CRYSTAL VIOLET DYE CONTAINED IN WASTEWATER BY COMBINING ELECTROCOAGULATION TECHNIQUE WITH BIOCOAGULANTS

ONLINE PRESENTATIONS

05.08.2025 / HALL-1 / SESSION-3

PARIS LOCAL TIME	ANKARA LOCAL TIME
14 00 : 16 00	15 00 : 17 00

HEAD OF SESSION: Dr. Berhanu Bekele

AUTHORS	AFFILIATION	TOPIC TITLE
Talha MASHHOOD Shehar BANO	*Government College University PAKISTAN*	PREPARATION AND BIOLOGICAL SCREENING OF HYDRAZONES USING ISOLATED CHOLIC ACID
Shehar BANO Talha MASHHOOD	*Government College University PAKISTAN*	SYNTHESIS AND BIOLOGICAL EVALUATION OF AMIDES USING COUMARIN-3-CARBOXYLIC ACID
Dr. Berhanu Bekele Prof. Aberra Melesse Dr. Wondmeneh Esatu Dr. Tadelle Dessie	*Wachemo University ETHIOPIA* *Hawassa University ETHIOPIA* *International Livestock Research Institute ETHIOPIA* *International Livestock Research Institute ETHIOPIA*	FERTILITY, HATCHABILITY, MORTALITY AND GROWTH PERFORMANCE OF INDIGENOUS, SASSO AND THEIR F1 CROSS CHICKEN GENOTYPES IN ETHIOPIA
Mrs.E.Elavarasi Yuvaraj AR J.Jayadurka Dr.R.Srimivasan	*Bharath Institute of Higher Education and Research INDIA*	MARINE POLLUTION AND ENVIRONMENT: A LOOMING CRISIS
A.Bazit L. Adlani W. Guerrab D. Karra D. Benmessaoud Left M. Zertoubi Y. Ramli H. Zarrok A. Zarrouk M. El Hezzat	*Ibn Tofail University MOROCCO* *Ibn Tofail University MOROCCO* *Mohammed V University MOROCCO* *Ibn Tofail University MOROCCO* *Hassan II University MOROCCO* *Hassan II University MOROCCO* *Mohammed V University MOROCCO* *Ibn Tofail University MOROCCO*	CORROSION INHIBITION BY A IMIDAZOLIDINE DERIVATIVE (IMD 8) FOR CARBON STEEL IN MOLAR HYDROCHLORIC ACID: EXPERIMENTAL, QUANTUM COMPUTATIONAL, AND MOLECULAR DYNAMICS STUDIES
Said Kerraj Mohamed Kadour Atouailaad Ahmed Arifd Abdelkhalk Aboulouard Mustapha Boulghalat Abdessamad Tounsi Mohammed Salah Mohammed El idrissi	*Hassan II University MOROCCO* *Abdelmalek University MOROCCO* *Hassan II University MOROCCO* *Sultan Moulay Slimane University MOROCCO* *Chouaïb Doukkali University MOROCCO* *Sultan Moulay Slimane University MOROCCO*	ENHANCING THE ELECTRONIC AND OPTICAL PERFORMANCE OF DYE-SENSITIED SOLAR CELLS WITH ALIZARIN-BASED DYES: DFT/TDDFT INVESTIGATIONS
Hasna JINNOU Said ARIF Mohamed Achraf HASNAI	*Sultan Moulay Slimane University MOROCCO* *Sultan Moulay Slimane University MOROCCO* *Manager of the agricultural company Farmassist, specializing in agricultural service provision MOROCCO*	ADAPTATION OF FARMERS IN THE TADLA PLAIN TO CLIMATE VARIATIONS: SOCIO-CULTURAL DIMENSIONS AND INNOVATIVE AGRICULTURAL STRATEGIES
Hiba Shahid Prof. Dr. Syed Ali Raza Naqvi	*Government College University PAKISTAN*	ANTIOXIDANT, ENZYME INHBITION AND TOXICOLOGY STUDIES OF METHANOL EXTRACTS OF SELECTED MEDCINIAL PLANTS

ONLINE PRESENTATIONS

05.08.2025 / HALL-2 / SESSION-3

PARIS LOCAL TIME	ANKARA LOCAL TIME
14 00 : 16 00	15 00 : 17 00

HEAD OF SESSION: Dr. Maria Taj

AUTHORS	AFFILIATION	TOPIC TITLE
Dr. Maria Taj	*Jinnah University PAKISTAN*	CLEAN AND GREEN ENVIRONMENT BY USING AGRICULTURAL WASTE WITH BETTER CLEANING PROPERTIES THAN SYNTHETIC ONES
D. I. Tarungwa A. A Mann L.A Fadipe S.I Iyen	*Federal University of Technology NIGERIA* *Federal University NIGERIA*	SUSTAINABLE ALTERNATIVE FOR TEXTILE COLORATION USING PHENOLIC CONTENTS FROM DIFFERENT COMBINATION OF EUCALYPTUS CAMLDULENSIS AND CINNAMOMUM VERUM
Faisal Nazir	*Agriculture University PAKISTAN*	PRODUCTION AND CHARACTERIZATION OF CARBON NANOTUBES FROM BIOCHAR UNDER MICROWAVE IRRADIATION
Ouassila Riouchi Khalid Elkalay Mourad Baghour	*Cadi Ayyad University MOROCCO* *Cadi Ayyad University MOROCCO* *Mohammed 1st University MOROCCO*	BIOTECHNOLOGICAL POTENTIAL OF CHLORELLA VULGARIS: A REVIEW OF CURRENT KNOWLEDGE
Ouassila Riouchi Khalid Elkalay Mourad Baghour	*Cadi Ayyad University MOROCCO* *Cadi Ayyad University MOROCCO* *Mohammed 1st University MOROCCO*	ASSESSMENT OF THE DIVERSITY, ABUNDANCE, AND ECOLOGICAL POTENTIAL OF CHLORELLA VULGARIS IN THE NADOR LAGOON, MOROCCO
Polikseni DRAZHO Luljeta PINGULI Ilirjan MALOLLARİ	*Tirana University ALBANIA*	VALORIZATION OF BREWERY BY PRODUCTS FOR SUSTAINABLE LIVESTOCK FEED: NUTRITIONAL ASSESSMENT OF ORGANIC WASTE IN ALBANIA
Gent SEJKO Dr. Altin TANKU Meri PAPAVANGJELI	*Tirana University ALBANIA*	ANALYSIS OF THE INTERACTION OF MONETARY AND MACROPRUDENTIAL POLICIES: EMPIRICAL EVIDENCE FROM ALBANIA
Alzbeta SIMON CSUHAJOVÁ	*J. Selye University SLOVAKIA*	THE IMPACT OF TECHNOSTRESS ON ORGANISATIONAL FUNCTIONING

ONLINE PRESENTATIONS

05.08.2025 / HALL-3 / SESSION-3

PARIS LOCAL TIME	ANKARA LOCAL TIME
14 00 : 16 00	15 00 : 17 00

HEAD OF SESSION: Dr. Subhashish DEY

AUTHORS	AFFILIATION	TOPIC TITLE
Farid GULIYEV Ismayil ISMAYILOV	*National Aviation Academy AZERBAIJAN*	ANALYZING ATTITUDE KINEMATICS OF SATELLITES IN SEPARATRIX MOTION USING CLASSICAL PARAMETERIZATIONS
Aukacha DAOUDI	*Sidi Mohammed Ben Abdellah University MOROCCO*	JORDAN PRODUCT OF OPERATORS AND ASCENT/ DESCENT PRESERVERS
Konul DADASH GIZI KARIMOVA	*Financial Director and Member of the Executive Committee at Veyseloğlu Group of Companies AZERBAIJAN*	DIGITAL TRANSFORMATION OF RETAIL TRADE IN AZERBAIJAN: TECHNOLOGICAL INTEGRATION STRATEGIES AND TRENDS
Ismail EL KHCHIN Hassane BENBOUZIANE Mustapha ECH-CHÉRIF ELKETTANI	*Sidi Mohammed Ben Abdellah University MOROCCO*	MULTIPLICATIVELY PERIPHERAL SPECTRUM-PRESERVING MAPS
Zohra YAGOUB Hafida BOUZIANE	*University of Science and Technology of Oran Mohamed Boudiaf ALGERIA*	COMPREHENSIVE BENCHMARKS FOR AMYLOID PRONENESS PREDICTION
Assist. Prof. Dr. Kanak LATA	*Srinath University INDIA*	STUDY OF ANOMALY VS. SIGNATURE-BASED DETECTION USING ML
YAKUBU Abubakar LIDANI	*Federal Polytechnic NIGERIA*	A PROPOSED MODEL OF USING WEARABLE DEVICE & MACHINE LEARNING TO PREDICT THE OUTCOME OF SNAKEBITE ENVENOMATION ON PATIENT ATTENDING KALTUNGO SNAKEBITE BAY
Dr. Subhashish DEY	*Gudlavalleru Engineering College INDIA*	FLOOD FREQUENCY ANALYSIS OF PRAKASAM BARRAGE RESERVOIR, VIJAWWADA, KRISHNA DISTRICT, ANDHRA PRADESH, INDIA
Blerina Xhaferaj Anila Kripa Aurel Nuro	*Medicine University ALBANIA* *Agricultural University ALBANA* *Tirana University ALBANIA*	CHEMICAL PROFILE OF ROSMARINUS OFFICINALIS FROM CENTRAL ALBANIA

ONLINE PRESENTATIONS

05.08.2025 / HALL-4 / SESSION-3

PARIS LOCAL TIME	ANKARA LOCAL TIME
14 00 : 16 00	15 00 : 17 00

HEAD OF SESSION: Dr. Nguyen Thi Bich Van

AUTHORS	AFFILIATION	TOPIC TITLE
Dr. Nguyen Thi Bich Van Tong Hoang Bao Giang	*University of Architecture Hochiminh City VIETNAM*	ERGONOMIC ADVANCES IN URBAN FOLDING BIKES: A CASE STUDY OF THE BROMPTON T LINE 4-SPEED AND TERN VERGE X11
Dr. Nguyen Thi Bich Van Nguyen Tran Thien Phuc	*University of Architecture Hochiminh City VIETNAM*	ERGONOMIC SEATING FOR THE MASSES: A STUDY ON HEALTH OUTCOMES AND ECONOMIC FEASIBILITY IN OFFICE FURNITURE DESIGN
Dr. Nguyễn Thị Bích Vân Quan Yến My	*University of Architecture Hochiminh City VIETNAM*	ERGONOMICS UNDERMINED BY AESTHETIC TRENDS: A CRITICAL REVIEW FROM A HEALTH SCIENCE VIEWPOINT
Dr. Nguyen Thi Bich Van Hoang Trong Duc	*University of Architecture Hochiminh City VIETNAM*	ERGONOMIC EFFICACY OF KNEELING CHAIRS: AN ANATOMICAL AND USER- PERCEPTION ANALYSIS FOR HEALTH-CENTRIC DESIGN
Dr. Nguyen Thi Bich Van Tran Nguyen Thao Nhi	*University of Architecture Hochiminh City VIETNAM*	AN APPLICATION OF ERGONOMICS AND ANTHROPOMETRY IN FURNITURE DESIGN: A COMPREHENSIVE CASE STUDY OF THE EAMES LOUNGE CHAIR & OTTOMAN
Dr. Nguyen Thi Bich Van Tran Gia Linh	*University of Architecture Hochiminh City VIETNAM*	ERGONOMIC ICU BEDS: ELEVATING CARE AND PROTECTING HEALTHCARE PROFESSIONALS
Dr. Nguyen Thi Bich Van Trần Phương Nghi	*University of Architecture Hochiminh City VIETNAM*	TOWARDS SMART LIVING: SIMPLE GEOMETRIC MULTI-FUNCTIONAL CHAIR DESIGN FOR URBAN LIFE
Dr. Nguyen Thi Bich Van Pham Thi Ngoc Ngan	*University of Architecture Hochiminh City VIETNAM*	ERGONOMIC EVALUATION OF THE JOIE MULTIPLY HIGH CHAIR: A STUDY ON ANTHROPOMETRIC FIT, SAFETY, AND FUNCTIONAL ADAPTABILITY FOR YOUNG CHILDREN
Dr. Nguyen Thi Bich Van Vương Tôn Minh	*University of Architecture Hochiminh City VIETNAM*	EVALUATE THE ERGONOMIC PERFORMANCE AND USABILITY OF THE BYACRE CARBON ULTRALIGHT ROLLATOR TO ENHANCING USER COMFORT AND SAFETY

ONLINE PRESENTATIONS

05.08.2025 / HALL-5 / SESSION-3

PARIS LOCAL TIME	ANKARA LOCAL TIME
14 00 : 16 00	15 00 : 17 00

HEAD OF SESSION: Res. Assist. Melike Nur SÖNMEZ

AUTHORS	AFFILIATION	TOPIC TITLE
İlayda AKKAYA Dr. Şeyma SÜNBÜL Prof. Dr. Alev KESER	*Ankara University TÜRKİYE*	DIETARY SELF-EFFICACY IN ADULTS: ASSOCIATIONS WITH DEMOGRAPHIC AND LIFESTYLE FACTORS
Dr. Şeyma SÜNBÜL İlayda AKKAYA Prof. Dr. Alev KESER	*Ankara University TÜRKİYE*	ASSOCIATION BETWEEN DIGITAL NUTRITION LITERACY AND NUTRITION KNOWLEDGE LEVELS IN UNIVERSITY STUDENTS
Res. Assist. Melike Nur SÖNMEZ Assist. Prof. Dr. Seda KARAÇAY YIKAR Prof. Dr. Evşen NAZİK	*Tokat Gaziosmanpaşa University TÜRKİYE* *Çukurova University TÜRKİYE*	HOLISTIC APPROACHES FROM PREVENTIVE HEALTH TO PSYCHOSOCIAL SUPPORT IN SEXUALLY TRANSMITTED DISEASES
Res. Assist. Melike Nur SÖNMEZ Assist. Prof. Dr. Seda KARAÇAY YIKAR Prof. Dr. Evşen NAZİK	*Tokat Gaziosmanpaşa University TÜRKİYE* *Çukurova University TÜRKİYE*	FACTORS AFFECTING WOMEN'S HEALTH IN DEVELOPING COUNTRIES AND HE ROLES OF WOMEN'S HEALTH NURSES
Buse KÖSE Şevval BOLAT İsa AVCI	*Karabük University TÜRKİYE*	A DIGITAL EDUCATIONAL GAME FOR TEACHING OCCUPATIONAL HEALTH AND SAFETY TO CHILDREN
Saliha KURT Özlem ERDEM Zuhal ŞEFLEK Assoc. Prof. Dr. Tuğçe DURAN	*Selçuk University TÜRKİYE* *KTO Karatay University TÜRKİYE*	PSYCHOLOGICAL FACTORS AFFECTING COGNITIVE HEARING: THE ROLE OF EMOTIONAL STATE AND MENTAL LOAD

CONTENTS

AUTHOR	TITLE	No
Cuma AKBAY	ANALYZING DAIRY PRODUCT DEMAND IN TÜRKİYE: THE ROLE OF SOCIO-DEMOGRAPHIC FACTORS VIA A HECKMAN MODEL	1
Gonul GUROL CIFTCI	EFFECTS OF STIRIPENTOL IN EPILEPSY	8
Gonul GUROL CIFTCI	THE IMPORTANCE OF NEURONAL PROGENITOR CELLS IN EPILEPSY	14
Merve HORLU Cevher Kürşat MACİT Bünyamin AKSAKAL Eda ÇULLU FERŞAT Ersoy YILMAZ	EFFECT OF BORON AND ALUMINA ADDITION TO 316L STAINLESS STEEL ON TRIBOLOGICAL PROPERTIES	19
Umut KUMLU Ömer HÜKÜMDAR Yusuf GÖK Mustafa Atakan AKAR Ali KESKİN	INFLUENCE OF SECTION GEOMETRY AND MATERIAL SELECTION ON ENERGY ABSORPTION IN CRASH BOXES: A FINITE ELEMENT APPROACH	21
Umut KUMLU Ömer HÜKÜMDAR Mikail KERSİN Mustafa Atakan AKAR Ali KESKİN	CRASHWORTHINESS ANALYSIS OF HORIZONTAL AND VERTICAL ELLIPTICAL CROSS-SECTIONAL BEAMS IN VEHICLE DOORS	38
Bünyamin AYGÜN Akın AKINCIOĞLU Abdulhalik KARABULUT Önder ŞİMŞEK Gülşen TOZSİN	DEVELOPMENT AND EVALUATION OF HEAT-RESISTANT FLEXIBLE SILICONE-BASED COMPOSITES WITH BORON AND METAL OXIDE ADDITIONS FOR NEUTRON SHIELDING APPLICATIONS	50
Bünyamin AYGÜN Akın AKINCIOĞLU Nergiz YILDIZ YORGUN Zeynep ITIR NAMLITÜRK	DEVELOPMENT OF FLEXIBLE SILICONE MASTIC-BASED COMPOSITES ENRICHED WITH BORON MINERALS, LIF, AND FEB FOR NEUTRON SHIELDING APPLICATIONS AND EVALUATION OF THEIR ATTENUATION PERFORMANCE	52
Selma TOKER KUTAY Gülesen ÜSTÜNDAĞ ŞİRAY Nimet ÖZBAY	BIAS REDUCTION OF UTO ESTIMATOR	54
Ayşe SUNGURLU Anıl SÜVARİ	EXAMINATION OF FLEXIBLE INTERIOR SOLUTIONS ON EDUCATIONAL BUILDINGS	55
Mehmet ÖZDİN	RELATIONSHIP BETWEEN HOMOCYSTEINE LEVELS AND INSULIN RESISTANCE IN OBESE PEOPLE	57
Osman Mert YAZ Özlem BAHAR Melih YILAR Bahadır DEMİREL	AN OVERVIEW OF THE DEVELOPMENT OF ROBOTIC SYSTEMS IN AGRICULTURE BETWEEN 2015 AND 2025	59
Özlem BAHAR Osman Mert YAZ Bahadır DEMİREL Melih YILAR	ARTIFICIAL INTELLIGENCE ASSISTED WEED CONTROL IN THE LAST DECADE: ADVANCES IN CEREAL PRODUCTION AREAS, ADVANTAGES, CHALLENGES AND FUTURE PERSPECTIVES	69

Hilal BAL Esin HAZNECİ	COST AND PROFITABILITY ANALYSIS OF INDUSTRIAL HEMP PRODUCTION: THE CASE OF AMASYA PROVINCE, TÜRKİYE	84
Adile SAVSAR Filiz OGCE AKTAS	METAPHORICA L PERCEPTIONS OF NURSING STUDENTS REGARDING THE CONCEPTS OF NURSING, PATIENT AND PATIENT SAFETY: A QUALITATIVE RESEARCH	85
Elif DAĞTEKIN Tülay YAVAN Filiz OGCE AKTAS	DETERMINATION OF FACTORS AFFECTING INITIAL MOBILIZATION OF PATIENTS AFTER CARDIAC SURGERY	86
Nigar Sadigova	CHALLENGES AND PERSPECTIVES OF CREATING A NATIONAL TERMINOLOGICAL SYSTEM FOR THE PEACEFUL USES OF NUCLEAR TECHNOLOGIES	87
ALI Hamada	ELIMINATION OF CRYSTAL VIOLET DYE CONTAINED IN WASTEWATER BY COMBINING ELECTROCOAGULATION TECHNIQUE WITH BIOCOAGULANTS	95
Özlem ÖZKAN ÖNÜR Ethem İLHAN ŞAHİN	THE ROLE OF MARBLE DUST AND MARBLE CHIPS IN HISTORICAL BUILDING MORTARS: A STUDY ON OTTOMAN AND BYZANTINE PERIODS	96
Erol DOĞAN Durmuş Ali BİRCAN	MULTI-CRITERIA OPTIMIZATION OF FLUX COMPOSITION AND WELDING PARAMETERS FOR ACTIVATED TUNGSTEN INERT GAS WELDING OF INCONEL 718	105
Ömer Faruk AVCIOĞLU Durmuş Ali BİRCAN	OPTIMAL PARAMETER IDENTIFICATION FOR ACTIVATED TIG WELDING OF TI6AL4V ALLOY USING MULTI-CRITERIA DECISION MAKING (MCDM) METHODS	106
Aukacha Daoudi	JORDAN PRODUCT OF OPERATORS AND ASCENT/ DESCENT PRESERVERS	107
Ebru BARDAŞ ÖZKAN	REVOLUTIONIZING SEPSIS CARE: THE SYNERGISTIC POTENTIAL OF NANOTECHNOLOGY AND HYPERBARIC OXYGEN THERAPY	108
Ebru BARDAŞ ÖZKAN	POST-COVID ERA THYROID AUTOIMMUNITY: THE EPIGENETIC LEGACY OF VIRAL EXOSOMES	116
YAKUBU Abubakar Lidani	A PROPOSED MODEL OF USING WEARABLE DEVICE & MACHINE LEARNING TO PREDICT THE OUTCOME OF SNAKEBITE ENVENOMATION ON PATIENT ATTENDING KALTUNGO SNAKEBITE BAY	125
Badreddine LABAKOUM Amr FARHAN Lhoucine BEN TALEB Azeddine MOUHSEN Aissam LYAZIDI	THE IMPACT OF AUTOCLAVING AND CLEANING ON THE DENTAL SURGICAL GUIDE IMPLANT	127
Hamit TÜRKMEN Hüseyin Akilli	PARAMETRIC DEM-BASED INVESTIGATION OF ADHESIVE FORCES AND THEIR EFFECT ON POWER REQUIREMENTS IN GRANULAR TRANSPORT	129

Said Kerraj Mohamed Kadour Atouailaad Ahmed Arifd Abdelkhalk Aboulouard Mustapha Boulghalat Abdessamad Tounsi Mohammed Salah Mohammed El idrissi	ENHANCING THE ELECTRONIC AND OPTICAL PERFORMANCE OF DYE-SENSITIED SOLAR CELLS WITH ALIZARIN-BASED DYES: DFT/TDDFT INVESTIGATIONS	130
Etibaria BELGHALIA Farid Elbamtari Abdelouahid SBAI M'barek Choukrad Tahar LAKHLIFI Mohammed BOUACHRINE	COMPUTATIONAL EVALUATION OF PYRAZOLE-BENZIMIDAZOLE DERIVATIVES AS ANTI-PROLIFERATIVE AGENTS AGAINST BREAST CANCER	132
Abdelghani Bouchyoua Abdelmajid Khabbach Khalil Hammani Abdelghani Nabloussi	ASSESSING EARLY-STAGE DROUGHT RESPONSE IN MOROCCAN RAPESEED	133
Iqra Syed Mohsan Raza Shah Muhammad Bedar Bekhat Naseem	HABITAT-DRIVEN ECOPHYSIOLOGICAL AND ANATOMICAL VARIABILITY IN AERVA JAVANICA: FROM PLAINS TO DESERTS AND ELEVATION	134
Elza Bitsadze Lia janadze	SCALABLE AND SECURE DATABASE INTEGRATION IN CLOUD INFRASTRUCTURES: CHALLENGES AND TECHNOLOGICAL SOLUTIONS	135
Enkeleida Lleshi Salvator Kurti	EXPLOSIVE STRENGTH IN ELITE FEMALE BASKETBALL PLAYERS IN TIRANA, ALBANIA	140
Elza Bitsadze	INNOVATIONS IN COMPUTATIONAL SCIENCE: ALGORITHMS, DATA, AND MODELING	146
Enes AKÇAY Arzu KEVEN	THERMODYNAMIC AND EXERGY ANALYSIS OF R454C AND MIXED REFRIGERANTS IN REFRIGERATED TRUCKS	150
Enes AKÇAY Arzu KEVEN	THERMODYNAMIC COMPARISON OF R452A REFRIGERANT: AN EXERGY-BASED ANALYSIS FOR AUTOMOTIVE AIR CONDITIONING SYSTEMS	162
Fatima Zohra MOSTEFA	MEDICAL ASSISTANCE APPLICATION WITH CROSS-BLOCKCHAIN WITH THE RAFT CONSENSUS ALGORITHM FOR THE ELDERLY PERSON IN IOT NETWORKS	170
Harish Raghvendhar SK Abhijit Asati	10-BIT DIFFERENTIAL SEGMENTED CURRENT STEERING DIGITAL TO ANALOG CONVERTER	178
Ambra Kraja Xhentjan Beshiri	THE IMPACT OF SMART TOURISM ON BUSINESS PERFORMANCE: AN EMPIRICAL ANALYSIS	188
Damla DURAL Ecem YURGA Kaan YETILMEZSOY	WATER FOOTPRINT ANALYSIS IN BEAUTY SALONS: AN ASSESSMENT IN THE CONTEXT OF SUSTAINABLE WATER MANAGEMENT	197
Kadriye URUÇ PARLAK Sinem BİRGÜCÜ	PHYSİOLOGICAL AND BIOCHEMICAL BASES OF PLANT TOLERANCE MECHANISMS UNDER SALT STRESS	206
Gökhan GÜNEŞ Murat ŞEN	PRODUCTION AND NUMERICAL SIMULATIONS OF A SOFT GRIPPER	208
Bismillah Iftikhar	ICTAL INDUCED CARDIOVASCULAR DISEASES AND ASSOCIATED NEUROLOGICAL COMORBIDITIES: A META ANALYTICAL APPROACH	209

Ouassila Riouchi Khalid Elkalay Mourad Baghour	BIOTECHNOLOGICAL POTENTIAL OF CHLORELLA VULGARIS: A REVIEW OF CURRENT KNOWLEDGE	210
Ouassila Riouchi Khalid Elkalay Mourad Baghour	ASSESSMENT OF THE DIVERSITY, ABUNDANCE, AND ECOLOGICAL POTENTIAL OF CHLORELLA VULGARIS IN THE NADOR LAGOON, MOROCCO	211
Vlad DIACONESCU Bogdan-Catalin SERBAN Matei-Gabriel URSACHESCU Maria Ruxandra SALAGEAN Marius BUMBAC	COVALENT SERINE PROTEASE INHIBITORS IN THE TREATMENT OF AUTOIMMUNE DISEASES: A CHEMICO-MEDICAL APPROACH	212
Orkida Kosta Ortensia Kosta	SKELETAL MUSCLE ENERGY METABOLISM DURING EXERCISE	214
Kanak Lata	STUDY OF ANOMALY VS. SIGNATURE-BASED DETECTION USING ML	215
Subhashish Dey	FLOOD FREQUENCY ANALYSIS OF PRAKASAM BARRAGE RESERVOIR, VIJAWWADA, KRISHNA DISTRICT, ANDHRA PRADESH, INDIA	216
Kübra KUZUCU Şerife KARAGÖZOĞLU	PATIENTS WITH ADULT HEMATOLOGICAL MALIGNANCY, REFLECTIONS OF STUDIES CONDUCTED BASED ON NURSING THEORIES AND MODELS ON NURSING CARE	217
Kübra KUZUCU Şerife KARAGÖZOĞLU	NURSING CARE OF A PATIENT WITH ACUTE MYELOID LEUKEMIA ACCORDING TO THE NEUMAN SYSTEM MODEL: A CASE REPORT	219
Tedi Prifti Robert Çina	INNOVATIVE METHODS FOR THE REHABILITATION OF PELVIS DISBALANCE	221
Robert Çina Tedi Prifti	EFFECTIVENESS OF THE GYROTONIC METHOD IN IMPROVING LUMBAR LORDOSIS: 4-WEEK INTERVENTION STUDY USING SURFACE TOPOGRAPHY	227
Nguyen Thi Bich Van Tran Nguyen Thao Nhi	AN APPLICATION OF ERGONOMICS AND ANTHROPOMETRY IN FURNITURE DESIGN: A COMPREHENSIVE CASE STUDY OF THE EAMES LOUNGE CHAIR & OTTOMAN	235
Yağmur YEŞİLBAŞ Ersin GÜNGÖR	THE IMPACT OF BIOTIC AND ABIOITIC DAMAGE IN FORESTS ON VOLUNTARY CARBON MARKETS	242
Faisal Nazir	PRODUCTION AND CHARACTERIZATION OF CARBON NANOTUBES FROM BIOCHAR UNDER MICROWAVE IRRADIATION	250
Olena VASYLYSHYNA	THE EFFECT OF TREATMENT WITH ECOLOGICALLY CLEAN COMPOSITIONS ON THE QUALITY OF SOUR CHERRY AND SWEET CHERRY FRUITS DURING STORAGE	251
Nguyen Thi Bich Van Vương Tôn Minh	EVALUATE THE ERGONOMIC PERFORMANCE AND USABILITY OF THE BYACRE CARBON ULTRALIGHT ROLLATOR TO ENHANCING USER COMFORT AND SAFETY	252
Ceren YAMAN	THE IMPACT OF AI-BASED DECISION SUPPORT SYSTEMS ON STRATEGIC DECISION-MAKING IN ORGANIZATIONS: A MANAGEMENT INFORMATION SYSTEMS PERSPECTIVE	259
Nguyen Thi Bich Van Quan Yến My	ERGONOMICS UNDERMINED BY AESTHETIC TRENDS: A CRITICAL REVIEW FROM A HEALTH SCIENCE VIEWPOINT	261

Talha Mashhood Shehar Bano	PREPARATION AND BIOLOGICAL SCREENING OF HYDRAZONES USING ISOLATED CHOLIC ACID	269
Shehar Bano Talha Mashhood	SYNTHESIS AND BIOLOGICAL EVALUATION OF AMIDES USING COUMARIN-3-CARBOXYLIC ACID	270
Hiba Shahid Syed Ali Raza Naqvi	ANTIOXIDANT, ENZYME INHBITION AND TOXICOLOGY STUDIES OF METHANOL EXTRACTS OF SELECTED MEDCINIAL PLANTS	271
Ismail EL KHCHIN Hassane Benbouziane Mustapha Ech-Chérif Elkettani	MULTIPLICATIVELY PERIPHERAL SPECTRUM-PRESERVING MAPS	272
M. Choubi A. Elidrysy S. Harir Z. Elmghabar A. Lahbibi Y. Lghazi	CRITICAL BEHAVIORS AND MAGNETOCALORIC EFFECT IN MIXED-SPIN-(1-5/2) HEXAGONAL NANOWIRE WITH MONTE CARLO SIMULATION	273
Osman ÜNER	ACTIVATED CARBON PRODUCTION FROM DRY ITALIAN THISTLE (CARDUUS PYCNOCEPHALUS L.) AND ITS ADSORPTION APPLICATION FOR METANIL YELLOW	275
Aida Makas Haniza Von	RETHINKING CREDIT RISK: AI-DRIVEN OUTCOME-BASED CREDIT MODELS FOR SUSTAINABLE FINANCIAL INCLUSION IN EMERGING MARKETS	276
Maria Taj	CLEAN AND GREEN ENVIRONMENT BY USING AGRICULTURAL WASTE WITH BETTER CLEANING PROPERTIES THAN SYNTHETIC ONES	277
Warda Waseem Muhammad Yasin Naz Abdul Ghaffar	COMPARATIVE STUDY OF TITANATE-BASED PEROVSKITE OXIDES FOR ENERGY STORAGE DEVICES	278
D. I. Tarungwa A. A Mann L.A Fadipe S.I Iyen	SUSTAINABLE ALTERNATIVE FOR TEXTILE COLORATION USING PHENOLIC CONTENTS FROM DIFFERENT COMBINATION OF EUCALYPTUS CAMLDULENSIS AND CINNAMOMUM VERUM	279
Ez-zejjari Ilyass El Ghazi Haddou	PRESSURE ENGINEERING OF ELECTRONIC AND MECHANICAL PROPERTIES IN III-NITRIDE SEMICONDUCTORS: A COMPUTATIONAL STUDY	280
Cem YALAZA	IDENTIFICATION OF PLANT-DERIVED ISOFORM-SELECTIVE PI3K INHIBITORS	281
Soukaina El Bourachdi Yassine Rakcho Amal Lahkimi	DEVELOPMENT AND COMPREHENSIVE CHARACTERIZATION OF GRAPHENE OXIDE-ENHANCED CHITOSAN COMPOSITE BEADS FOR HIGHLY EFFICIENT, SELECTIVE, AND RAPID CONGO RED DYE ADSORPTION FROM CONTAMINATED WATER: AN INTEGRATIVE, MULTIDISCIPLINARY INVESTIGATON COMBINING MOLECULAR-LEVEL MECHANISTIC INSIGHTS VIA DENSITY FUNCTIONAL THEORY (DFT), EXTENSIVE EXPERIMENTAL VALIDATION, AND ADVANCED STATISTICAL PROCESS OPTIMIZATION USING RESPONSE SURFACE METHODOLOGY (RSM) TOWARDS SUSTAINABLE AND ENVIRONMENTALLY FRIENDLY WASTEWATER REMEDIATION	282

Levent YORULMAZ Sibel IPEKESEN Mehmet YILDIRIM	FAST-TRACKING HYBRIDIZATION IN BREAD WHEAT: A SPEED BREEDING APPROACH TO F_1 GENERATION	283
Reshma N Deepthi K. S. Saranya Devi K	SUSTAINABLE PRODUCTION OF BACTERIAL CELLULOSE BY BACTERIA ISOLATED FROM NATURAL FERMENTED SUBSTRATES FOR ECO-FRIENDLY BIO-LEATHER APPLICATIONS	285
Nichirvan Ramadhan TAHER Hüseyin Suha AKSOY Mesut GÖR	SHEAR STRENGTH PROPERTIES OF SAND REINFORCED WITH RECYCLED PET FLAKES	287
Taskeen Fatıma	THE CLINICAL SIGNIFICANCE OF NORMAL PHYSIOLOGICAL BLOOD PARAMETERS IN HEALTH ASSESSMENT	288
Taskeen Fatıma	THE IMPACT OF LIVER CIRRHOSIS ON THE PROGRESSION AND COMPLICATIONS OF DIABETES MELLITUS	289
Mohamed Lattoui Morsli Sebaa Tyeb Allaoui Noureddine Sarir	ENERGY MANAGEMENT OF A PV–BATTERY–SUPERCAPACITOR HYBRID SYSTEM SUPPLYING VARIABLE LOADS WITH GRID BACKUP	290
Mustafa Eren GÖKÇEOĞLU Mustafa KURT	ANALYSIS OF METHODS USED IN SOLAR POWER PLANTS IN TURKEY OVER THE YEARS AND CURRENT STATUS	291
Bahija MOUNIR Fathallaah BAZI	APATITES: A FAMILY OF HIGH-PERFORMANCE AND ECOLOGICAL CATALYSTS FOR THE SYNTHESIS OF MOLECULES OF BIOLOGICAL INTEREST	292
Iram Liaqat	ROLE OF FLAGELLAR ASSEMBLY IN SALMONELLA FLHA DELETED STRAIN BIOFILM FORMATION	293
Iram Liaqat	QUORUM SENSING MEDIATED BIOFLM INHIBITION IN MARINE ISOLATES	294
Khalid Siraj Kebron Tesfaldet Lulya Essayas Sidona Sium Karunesh Tiwari	ANTIBACTERIAL PROPERTIES OF SILVER NANOPARTICLES PREPARED BY GREEN SYNTHESIS USING ACACIA LAETA	295
Noureddine BOUTERAA	ANALYZING FRACTIONAL DIFFERENTIAL EQUATION DEPENDING ON MIXED BOUNDARY CONDITIONS	296
Reza Azadi Gonbad Nasrin Farhadi Omid Lotfifar	EFFECTS OF GROWTH REGULATORS AND LIGHT INTENSITY ON CALLUS INDUCTION IN FOUR CULTIVARS OF VACCINIUM CORYMBOSUM	297
Berhanu Bekele Aberra Melesse Wondmeneh Esatu Tadelle Dessie	FERTILITY, HATCHABILITY, MORTALITY AND GROWTH PERFORMANCE OF INDIGENOUS, SASSO AND THEIR F1 CROSS CHICKEN GENOTYPES IN ETHIOPIA	298
Mitat UYSAL S. Aynur UYSAL Nurdanur PEHLİVAN	BUILDING RECOMMENDER SYSTEMS WITH MACHINE LEARNING AND AI	299
Bilal ACAR	REMEDIES FOR MITIGATING NEGATIVE RESULTS OF DROUGHT ON VEGETATIVE PRODUCTION IN WATER SCANT AREAS	300
Ayfer GÜNEY SARITAŞ Harun ALPTEKİN	ALLELOPATHY IN WEED MANAGEMENT: A BIBLIOMETRIC REVIEW	308

Alžbeta SIMON CSUHAJOVÁ	THE IMPACT OF TECHNOSTRESS ON ORGANISATIONAL FUNCTIONING	321
Farid Guliyev Ismayil Ismayilov	ANALYZING ATTITUDE KINEMATICS OF SATELLITES IN SEPARATRIX MOTION USING CLASSICAL PARAMETERIZATIONS	334
Mehmet Enes GÜNER	ANGIOLYMPHOID HYPERPLASIA WITH EOSINOPHILIA PRESENTING AS AURICULAR NODULES: A RARE CASE REPORT	335
Blerina Xhaferaj Anila Kripa Aurel Nuro	CHEMICAL PROFILE OF ROSMARINUS OFFICINALIS FROM CENTRAL ALBANIA	337
Nguyen Thi Bich Van Tong Hoang Bao Giang	ERGONOMIC ADVANCES IN URBAN FOLDING BIKES: A CASE STUDY OF THE BROMPTON T LINE 4-SPEED AND TERN VERGE X11	346
A.Bazit L. Adlani W. Guerrab D. Karra D. Benmessaoud Left M. Zertoubi Y. Ramli H. Zarrok A. Zarrouk M. El Hezzat	CORROSION INHIBITION BY A IMIDAZOLIDINE DERIVATIVE (IMD 8) FOR CARBON STEEL IN MOLAR HYDROCHLORIC ACID: EXPERIMENTAL, QUANTUM COMPUTATIONAL, AND MOLECULAR DYNAMICS STUDIES	355
Sinem BOYRAZ Ahmet Can ÜNAL	DEVELOPMENT OF DOUBLE CROSS-LINKED ELASTOMERIC EXTERIOR COATINGS WITH BENZOPHENONE DERIVATIVES AND CALCIUM CARBOXYLATE IONS	357
Ahmet Aykut AKTAŞ Ahmad Abu Arra Eyüp ŞİŞMAN	RESEARCH ON THE ESTABLISHMENT OF AN EFFECTIVE OCCUPATIONAL ACCIDENT REPORTING SYSTEM	359
Ahmet Aykut AKTAŞ Ahmad Abu Arra Eyüp ŞİŞMAN	COMPARISON OF USA (OSHA) AND TÜRKİYE (SGK) IN WORK ACCIDENT REPORTING PROCESSES	361
Gamze D. TETIK Gizem CELEP Fulya YILMAZ	THE EFFECT OF RAISING PROCESS ON HANDFEEL PROPERTIES OF BLANKETS	364
Onur METİN Şeref TURHAN	ASSESSMENT OF RADIOLOGICAL HEALTH RISKS CAUSED BY INTERNAL EXPOSURE TO WORKERS IN BENTONITE QUARRIES	371
Şeref TURHAN Onur METİN	ASSESSMENT OF RADIOLOGICAL HEALTH RISKS ARISING FROM INTERNAL EXPOSURE TO WHICH AGRICULTURAL WORKERS AROUND A COAL-FIRED THERMAL POWER PLANT MAY BE EXPOSED	378
Duygu ARAS Merve TEKE BUDAKLI	DESIGN AND EVALUATION OF A REAL-TIME DRIVER MONITORING SYSTEM USING LANDMARK-BASED AND DEEP VISUAL FEATURES	386
Nguyen Thi Bich Van Pham Thi Ngoc Ngan	ERGONOMIC EVALUATION OF THE JOIE MULTIPLY HIGH CHAIR: A STUDY ON ANTHROPOMETRIC FIT, SAFETY, AND FUNCTIONAL ADAPTABILITY FOR YOUNG CHILDREN	408

Nguyen Thi Bich Van Tran Phuong Nghi	TOWARDS SMART LIVING: SIMPLE GEOMETRIC MULTI-FUNCTIONAL CHAIR DESIGN FOR URBAN LIFE	412
Soumaya CHAABENE Malek TRABELSI	EFFECTS OF A PULMONARY REHABILITATION PROGRAM IN PATIENTS WITH CHRONIC OBSTRUCTIVE PULMONARY DISEASE: A PROSPECTIVE INTERVENTIONAL STUDY	419
Margarita KUQALI Kostandin DOLLANI Ylli KAÇIU	ASSESSMENT OF RADIATION EXPOSURE IN NUCLEAR MEDICINE PROCEDURES IN ALBANIA: DIAGNOSTIC AND THERAPEUTIC IMPLICATIONS	424
Ersin GÜNGÖR Yağmur YEŞİLBAŞ	COMMUNITY-BASED CARBON MANAGEMENT: ASSESSMENT IN TERMS OF RURAL DEVELOPMENT AND FORESTRY	433
Şeyma SÜNBÜL İlayda AKKAYA Alev KESER	ASSOCIATION BETWEEN DIGITAL NUTRITION LITERACY AND NUTRITION KNOWLEDGE LEVELS IN UNIVERSITY STUDENTS	443
Gamze AYDIN	TECHNOLOGICAL PREPAREDNESS FOR DISASTERS: AN INNOVATIVE APPROACH TO THE RISK OF DEW DISASTERS	451
Erhan AKALP Vedat PİRİNÇ	THE IMPACTS OF GLOBAL CLIMATE CHANGE ON VEGETABLE PRODUCTION	455
Erhan AKALP Vedat PİRİNÇ	THE ROLE OF TECHNOLOGICAL IMPROVEMENTS IN THE CULTIVATION OF VEGETABLES	464
İsa AVCI Buse KÖSE Şevval BOLAT	A DIGITAL EDUCATIONAL GAME FOR TEACHING OCCUPATIONAL HEALTH AND SAFETY FOR CHILDREN	470
Gent Sejko Altin Tanku Meri Papavangjeli Tonin Kola	ANALYSIS OF THE INTERACTION OF MONETARY AND MACROPRUDENTIAL POLICIES: EMPIRICAL EVIDENCE FROM ALBANIA	482
Zohra YAGOUB Hafida BOUZIANE	COMPREHENSIVE BENCHMARKS FOR AMYLOID PRONENESS PREDICTION	495
Gulnabat GOCHOVA Kubilay AYTURAN Fırat HARDALAÇ	DEEP LEARNING-DRIVEN FAULT DETECTION IN SOLAR PANELS: A YOLOV5M IMPLEMENTATION APPROACH	503
Hilal Kübra GÜÇLÜ EKİNCİ	MORPHOMETRIC AND TOPOGRAPHIC EVALUATION OF THE FORAMEN MANDIBULAE IN ARCHAEOLOGICAL MANDIBLES FROM THE ROMAN PERIOD	512
Hasna JINNOU Said ARIF Mohamed Achraf HASNAI	ADAPTATION OF FARMERS IN THE TADLA PLAIN TO CLIMATE VARIATIONS: SOCIO-CULTURAL DIMENSIONS AND INNOVATIVE AGRICULTURAL STRATEGIES	519
Nguyen Thi Bich Van Hoang Trong Duc	ERGONOMIC EFFICACY OF KNEELING CHAIRS: AN ANATOMICAL AND USER- PERCEPTION ANALYSIS FOR HEALTH-CENTRIC DESIGN	520
Nguyen Thi Bich Van Tran Gia Linh	ERGONOMIC ICU BEDS: ELEVATING CARE AND PROTECTING HEALTHCARE PROFESSIONALS	526
İlayda AKKAYA Şeyma SÜNBÜL Alev KESER	DIETARY SELF-EFFICACY IN ADULTS: ASSOCIATIONS WITH DEMOGRAPHIC AND LIFESTYLE FACTORS	530
Amaan Arif	AI-DRIVEN LINGUISTIC MODELLING FOR NEURODEVELOPMENTAL DISORDERS	536

Saira Malik Syed Mohsan Raza Shah Uniza Fatima bukhari Tasawar Fatima bukhari Iqra	LEAF STRUCTURAL AND FUNCTIONAL MODIFICATION OF IPOMOEA CARNEA JACQ. AN INVASIVE PLANT SPECIES, UNDER DIVERSE SALINITY GRADIENT	537
Vlad DIACONESCU Bogdan-Catalin SERBAN Matei-Gabriel URSACHESCU Maria Ruxandra SALAGEAN Marius BUMBAC	IRON COMPLEXES WITH ORGANIC LIGANDS USED AS HEM SUBSTITUTES IN THE TREATMENT OF SEVERE ANEMIA	538
Güney SARITAŞ Harun ALPTEKİN	GLOBAL RESEARCH TRENDS ON INVASIVE WEEDS: A BIBLIOMETRIC ANALYSIS (1987–2025)	540
Mehmet Enes GÜNER	KLIPPEL–TRENAUNAY SYNDROME IN A PEDIATRIC PATIENT: A STRIKING UNILATERAL PRESENTATION	553
Mustafa TUNÇSOY Benay TUNÇSOY	SIZE DEPENDENT EFFECTS OF ALUMINUM OXIDE PARTICLES ON ANTIOXIDANT ENZYMES OF Oreochromis niloticus	555
Soukaina El Bourachdi Yassine Rakcho Amal Lahkimi	SUSTAINABLE GREEN SYNTHESIS OF A NOVEL CHITOSAN@EDTA@CELLULOSE COMPOSITE DERIVED FROM SHRIMP SHELL CHITOSAN AND CACTUS-BASED CELLULOSE FOR EFFICIENT METHYL ORANGE DYE REMOVAL: COMPREHENSIVE CHARACTERIZATION, ADSORPTION OPTIMIZATION VIA RESPONSE SURFACE METHODOLOGY, REUSABILITY ASSESSMENT, AND DFT-BASED MECHANISTIC ELUCIDATION	556
E.Elavarasi Yuvaraj AR J.Jayadurka R.Srimivasan	MARINE POLLUTION AND ENVIRONMENT: A LOOMING CRISIS	557
Danilo Henrique Lattaro Evandro Marianetti Fioco Selma Siéssere Neide Pena Coto Simone Cecílio Hallak Regalo	THE IMPACT OF ORAL HEALTH ON SALIVARY AND BLOOD BIOMARKERS IN ELITE SOCCER ATHLETES	565
Arif Gull Hafsa Naeem Ayesha Batool Chashman Ahmed Rimsha Anwar	NEURAL ACCUMULATION OF MICROPLASTICS: A NEW FRONTIER IN NEUROTOXICOLOGY RESEARCH	567
Nguyen Thi Bich Van Nguyen Tran Thien Phuc	ERGONOMIC SEATING FOR THE MASSES: A STUDY ON HEALTH OUTCOMES AND ECONOMIC FEASIBILITY IN OFFICE FURNITURE DESIGN	568
Željka Nikitović	RATE COEFFICIENTS FOR H2+ IONS IN Ar/H2 MIXTURES	573
Ivan PAVLOVIC Slavica ŽİVKOVIC	OCCURENCE OF STRONGYLUS EQUINUS OF DOMESTIC MOUNTAIN HORSE IN SERBIA	574
Onur Ata ÇETİNKAYA İsmail Can PAYLAN	DETERMINATION OF GENETIC DIVERSITY IN PEPPER SEEDS USING MOLECULAR METHODS	575
Saliha KURT Özlem ERDEM Zuhal ŞEFLEK Tuğçe DURAN	PSYCHOLOGICAL FACTORS AFFECTING COGNITIVE HEARING: THE ROLE OF EMOTIONAL STATE AND MENTAL LOAD	577

Tkacenko Alexandra	GLOBAL UTILITY METHOD IN SOLVING THE LINEAR MULTI-CRITERIA OPTIMIZATION MODEL IN INTEGERS	579
Rando KUKELI Victoria KUKELI	FITNESS PRIORITIES AMONG GYM PARTICIPANTS IN TIRANA: A DEMOGRAPHIC AND GENDER-BASED ANALYSIS	580
Betul APAYDIN YILDIRIM	USE OF HEART-TYPE FATTY ACID BINDING PROTEIN (H-FABP) AS A CARDIAC BIOMARKER IN EARLY DIAGNOSIS	587
Polikseni DRAZHO Luljeta PINGULI Ilirjan MALOLLARI	VALORIZATION OF BREWERY BY PRODUCTS FOR SUSTAINABLE LIVESTOCK FEED: NUTRITIONAL ASSESSMENT OF ORGANIC WASTE IN ALBANIA	594

ANALYZING DAIRY PRODUCT DEMAND IN TÜRKİYE: THE ROLE OF SOCIO-DEMOGRAPHIC FACTORS VIA A HECKMAN MODEL

Prof. Dr. Cuma AKBAY

Kahramanmaraş Sütcü Imam University, Agricultural Faculty, Department of Agricultural Economics, Kahramanmaraş, Türkiye

ABSTRACT

Dairy products hold a significant place in human nutrition due to their high nutritional value and health benefits. This study analyzes dairy consumption patterns among households in Türkiye, emphasizing the share of dairy in household expenditures and the socio-demographic factors influencing demand. Using data from the national Household Food Consumption Survey, which includes information from 11521 households, the study provides a comprehensive overview of dairy consumption behavior across the country. To account for potential selection bias caused by households that do not consume any dairy products, the Heckman two-step model was employed. In the first stage, factors affecting the likelihood of dairy consumption were examined; in the second, the determinants of expenditure levels among consumers were analyzed. Results show that 98% of households consume at least one type of dairy product, with cheese, whole milk, and yogurt being the most frequently consumed items. A positive relationship was found between income and dairy expenditures. The model also indicates that married individuals, and larger households are more likely to consume dairy products. Moreover, older age groups, especially individuals aged 35 and above, show higher levels of dairy demand. Dairy consumption in Türkiye is widespread but varies significantly across demographic groups. These findings provide valuable insights for producers and policymakers aiming to develop targeted strategies in marketing and nutrition programs.

Key Words: Dairy consumption, demand, household, Heckman model, Türkiye

INTRODUCTION

Among animal-based food products, dairy products hold an important place due to their valuable nutritional content. Being one of the best sources of nutrition, dairy has supported human health (Garcia et al., 2019) and has been a vital part of human diets for approximately 8,000 years (Rozenberg et al., 2016). Dairy products contain high-quality proteins (Van Meijl et al., 2008) and essential amino acids, and they are important dietary sources of calcium, phosphorus, potassium, and vitamins A and D (McGrane et al., 2011).

Globally, around 150 million households are engaged in milk production (FAO, 2021). According to FAO's milk production data, global milk production in 2019 was 883.3 million tons. Of this, 81.04% was cow milk, 15.14% buffalo milk, 2.25% goat milk, 1.20% sheep milk, and 0.35% camel milk. The countries with the highest milk production, accounting for 62.36% of global output, are India, the USA, Pakistan, China, Brazil, Germany, Russia, France, Türkiye, and New Zealand (FAO, 2019). Türkiye, ranking among the top ten countries in global milk production, produced 14.2 million tons of dairy products in 2020 (TUIK, 2020). These

products include cow milk, drinking milk, yogurt, ayran, cow cheese, cheeses made from sheep, goat, buffalo or mixed milk, butter, cream, full-fat and semi-skimmed milk powders, and non-fat milk powder.

Milk is an important sector that offers countries various investment opportunities and a broad market potential by being marketed both in its raw form and as processed products such as cheese, yogurt, butter, clotted cream, cream, and milk powder, thereby creating added value. At the same time, it is known as a significant food for consumers due to its nutritional value and its role in preventing various diseases. Therefore, the level of consumption is of great importance, and various studies have been conducted on this subject. Mishra et al. (2021) describe dairy products as having evolved from luxury goods into widely consumed staples for millions, owing to their high nutritional value, affordability, and accessibility (Rozenberg et al., 2016). In Western countries, dairy accounts for 9–12% of total energy intake (Bonjour, 2011). A study in Poland also reported cheese and milk as the top contributors of energy and nutrients within the dairy group (Górska-Warsewicz et al., 2019).

Several studies (Chen et al., 2007; Shimazaki et al., 2008; Van Meijl et al., 2008; Aune et al., 2013; He et al., 2016; Farvid et al., 2017; Lee and Kim, 2019) have reported the positive impacts of dairy consumption on health and the prevention of various diseases. For example, Chen et al. (2007) confirmed a moderate positive association between dairy consumption and the risk of Parkinson's disease. He et al. (2016) argued that increased dairy intake is necessary to improve calcium levels and prevent conditions such as osteoporosis. Van Meijl et al. (2008) provided evidence of dairy's role in preventing and treating metabolic syndrome, although they called for more experimental research. The objective of this study is to investigate the influence of socio-demographic factors of households and consumers on dairy product demand in Türkiye.

This paper is organized as follows: The first part provides an introduction to the significance of dairy products and a review of related literature. The second part describes the materials and methods employed in the study, including the data source and the econometric model used for analysis. The third part presents the empirical results obtained from the Heckman selection model, highlighting the socio-demographic factors influencing dairy product demand in Türkiye. Finally, the last section offers conclusions drawn from the findings and proposes recommendations for policymakers, marketers, and future research.

MATERIAL AND METHOD

The data used in this study comes from the 2019 Household Budget Survey conducted by the Turkish Statistical Institute (TURKSTAT). The dataset comprises 11521 household surveys. It includes information about the socio-demographic characteristics of the households as well as their dairy expenditures within a one-month period. The dairy products listed in the dataset include whole milk, low-fat milk, yogurt, cheese, and butter. All other dairy products are grouped under the category of "other dairy products."

Descriptive statistics were employed to determine the socio-demographic characteristics of consumers. Additionally, the Heckman Selection Model was used to estimate the effect of households' socio-demographic characteristics on dairy consumption demand.

The Heckman Model, developed by James Heckman, is designed to correct sample selection bias and estimate an unbiased causal effect when applied to observational data (Briggs, 2004). The selection model is frequently used in fields such as economics, biostatistics, finance, sociology, and political science (Marchenko and Genton, 2012). In this model, the same explanatory variables may appear in both the selection and outcome equations. However, at

least one variable included in the selection equation should not appear in the outcome equation (Miran, 2018).

FINDINGS AND DISCUSSION

As a result of the household surveys conducted, the following characteristics of participants were determined: the average age was 51.73 years; 76.7% were male; 78.8% were married; 39.6% were primary school graduates; the average household size was 3.36 individuals; and 39.2% had children. Individuals who were unemployed or not currently working but had previous work experience were grouped together, comprising 39.7% of the sample, while 60.3% were employed.

An analysis of dairy product consumption status revealed that 98% of households consume at least one type of dairy product (Table 1). Cheese (85.1%), whole milk (79.0%), and yogurt (71.0%) are the most commonly consumed dairy products. In a study conducted in Vietnam, the household consumption rate of dairy products was reported at 48.65% (Phuong et al., 2014). Fuller et al. (2007) stated that in China, 90.4% of households purchase milk and 58.9% purchase yogurt. However, another study indicated that per capita milk consumption in China remains low compared to developed countries, averaging 68.56 kg per year (Cheng et al., 2015). In Slovakia, recent trends showed a decline in fluid milk consumption (except for cheese, cottage cheese, sour milk products, and butter), with an annual per capita decrease of 0.998 kg (Kubicová et al., 2014). In Türkiye, a study conducted in Ankara, Istanbul, and Izmir reported that 89% of consumers consumed dairy products (Onurlubaş and Çakırlar, 2016). Kibar et al. (2020) found that all participants in their study consumed dairy products.

Table 1. Consumers' dairy product consumption decision

	Consume		**Not consume**	
	Frequencies	**(%)**	**Frequencies**	**(%)**
Whole milk	9.101	78,99	2.420	21,01
Low-fat milk	2.165	18,79	9.356	81,21
Yogurt	8.177	70,97	3.344	29,03
Cheese	9.808	85,13	1.713	14,87
Butter	3.705	32,16	7.816	67,84
Other dairy products	2.306	20,02	9.215	79,98
Total	11.288	97,98	233	2,02

It is well known that the socio-demographic characteristics of households significantly influence dairy consumption (Phuong et al., 2014; Terin et al., 2015). In this study, the Heckman Selection Model was applied to estimate the effects of factors such as age, gender, marital status, education, income, and household size on household demand for dairy products.

Variables in the model were classified as continuous (expenditure), and categorical variables (gender, and marital status, age, education, income group, and household size). Table 2 provides explanations for each variable used in the model.

Table 2. Description of Variables Used in the Model

Independent variables	Description	Mean	Std. dev.
DGender	Female = 1, Male = 0	0.770	0.423
DMarital	Married = 1, Single = 0	0.788	0.409
DAge_1*	1 if age ≤ 35, otherwise 0	0.156	0.363
DAge_2	1 if age 36–45, otherwise 0	0.225	0.418
DAge_3	1 if age 46–55, otherwise 0	0.223	0.417
DAge_4	1 if age 56–65, otherwise 0	0.195	0.396
DAge_5	1 if age ≥ 66, otherwise 0	0.201	0.401
DEducation_1*	1 if no education, otherwise 0	0.132	0.339
DEducation_2	1 if primary school, otherwise 0	0.396	0.489
DEducation_3	1 if middle school, otherwise 0	0.134	0.341
DEducation_4	1 if high school, otherwise 0	0.163	0.369
DEducation_5	1 if university and above, otherwise 0	0.175	0.380
DIncome_1*	1 if income < 3,000 TL, otherwise 0	0.349	0.477
DIncome_2	1 if income 3,000–5,000 TL, otherwise 0	0.411	0.492
DIncome_3	1 if income > 5,000 TL, otherwise 0	0.240	0.427
DHHSIZE_1*	1 if household size ≤ 3, otherwise 0	0.582	0.493
DHHSIZE_2	1 if household size = 4, otherwise 0	0.212	0.409
DHHSIZE_3	1 if household size > 4, otherwise 0	0.206	0.405
LNExpenditure	Natural logarithm of household expenditure (TL/Month)	8.225	0.664

*Reference categories are indicated for dummy variables.

Fuller et al. (2007) stated that demographic characteristics have a significant impact on milk consumption behavior. The results of the Heckman selection model show that marital status, age, and income significantly influence the likelihood of consuming dairy products in Türkiye (Table 3). The significant and positive lambda value confirms the absence of sample selection bias, demonstrating the suitability of the Two-Stage Heckman Selection Model for this analysis.

According to the model results, married individuals are more likely to consume dairy products and spend more than singles ($p<0,05$). Women are less likely to consume dairy products and spend less compared to men. But results are not statistically significant ($p>0,05$). In addition, the analysis indicates a clear positive association between age and dairy product demand, suggesting that older individuals tend to consume greater quantities of dairy products compared to younger age groups ($p<0,05$). Moreover, households with more than four members are more likely to demand dairy products ($p<0,05$). High-income households have a greater likelihood of consumption compared to low- and middle-income households ($p<0,05$). Individuals with higher education are were also more likely to consume and spend than those with no formal education, but results were not statistically significant ($p>0,05$).

In their study, Terin et al. (2015) found that having a household head who is married positively affects dairy consumption. Aidoo et al. (2009) identified the main determinants of total dairy expenditure as the income level of the household head, the urbanization level of the area where the consumer resides, and the distance from the household to the point of dairy product purchase.

Table 3. Dairy product demand by socio-demographic characteristics

	Selection equation		Outcome equation	
	B	**Std. error**	**B**	**Std. error**
Constant	0.774	0.102***	-394.705	16.050***
DGender	-0.010	0.045	-0.946	3.223
DMarital	0.300	0.043***	26.878	3.357***
DAge_2	0.241	0.056***	23.511	3.725***
DAge_3	0.336	0.057***	41.454	3.787***
DAge_4	0.517	0.062***	65.952	3.975***
DAge_5	0.571	0.061***	72.575	4.137***
DEducation_2	-0.082	0.049*	-3.215	3.756
DEducation_3	-0.092	0.065	-1.758	4.689
DEducation_4	-0.102	0.064	-2.294	4.593
DEducation_5	-0.015	0.077	5.489	4.781
DIncome_2	-0.289	0.033***		
DIncome_3	0.882	0.107***		
DHHSIZE_2			5.438	2.619**
DHHSIZE_3			16.996	2.716***
LNExpenditure			56.232	1.879***
Lambda			115.880	0.801***
Sigma: 116.091; Rho: 0.998; Log-likelihood: -69960.45; Akaike criterion: 139950.90				

***, **, * indicate significance at the 0.01, 0.05, and 0.10 levels respectively.

CONCLUSIONS AND RECOMMENDATIONS

In this study, the effects of socio-demographic factors on the overall demand for milk and dairy products in Türkiye were analyzed. The results indicate that almost all households consume at least one product from the milk and dairy group. Among the products with the highest average expenditures, cheese, whole milk, and yogurt rank at the top.

The findings of the Heckman selection model, applied to determine the impact of socio-demographic characteristics on milk and dairy product consumption, indicate that women are more likely than men, married individuals more likely than singles, and higher education graduates more likely than those without formal education to consume milk and dairy products, and that their consumption expenditures are also higher.

The results of this study identify marital status, age, education, household size and income as key factors influencing household dairy preferences in Türkiye. These findings provide valuable insights for producers and policymakers aiming to develop targeted strategies in marketing and nutrition programs. These insights underscore the importance for businesses to tailor their marketing and product strategies according to these socio-demographic characteristics to effectively target different consumer segments.

For future research, it would be valuable to extend the analysis beyond socio-demographic variables by exploring the influence of social, cultural, and behavioral factors on consumption demand. Such investigations would enrich the literature and provide a more comprehensive understanding of dairy product consumption dynamics in Türkiye.

REFERENCES

Aidoo, R., Nurah, G.K., Fialor, S.C. & Ohene-Yankyera, K. (2009). Determinants of Dairy Consumption Expenditure in Urban Communities of Southern Ghana. Journal of Science and Technology (Ghana), 29(1).

Aune, D., Norat, T., Romundstad, P. & Vatten, L.J. (2013). Dairy Products and the Risk of Type 2 Diabetes: A Systematic Review and Dose-Response Meta-Analysis of Cohort Studies. The American journal of clinical nutrition, 98(4), 1066-1083.

Bonjour, J.P. (2011). Calcium and Phosphate: A Duet of Ions Playing for Bone Health. Journal of the American College of Nutrition, 30(sup5), 438S-448S.

Briggs, D.C. (2004). Causal Inference and the Heckman Model. Journal of Educational and Behavioral Statistics, 29(4), 397-420.

Chen, H., O'Reilly, E., McCullough, M. L., Rodriguez, C., Schwarzschild, M. A., Calle, E. E., & Ascherio, A. (2007). Consumption of Dairy Products and Risk of Parkinson's Disease. American Journal of Epidemiology, 165(9), 998-1006.

Cheng, L., Yin, C. & Chien, H. (2015). Demand for Milk Quantity and Safety in Urban China: Evidence from Beijing and Harbin. Australian Journal of Agricultural and Resource Economics, 59(2), 275-287.

FAO (2019). Food and Agriculture Organization of the United Nations http://www.fao.org/faostat/en/#data (Erişim Tarihi: 12.09.2021)

FAO (2021). Food and Agriculture Organization of the United Nations. http://www.fao.org/faostat/en/#data/QCL (Erişim Tarihi: 12.09.2021)

Farvid, M.S., Malekshah, A. F., Pourshams, A., Poustchi, H., Sepanlou, S. G., Sharafkhah, M., ... & Malekzadeh, R. (2017). Dairy Food Intake and All-Cause, Cardiovascular Disease, and Cancer Mortality: The Golestan Cohort Study. American Journal of Epidemiology, 185(8), 697-711.

Fuller, F., Beghin, J. & Rozelle, S. (2007). Consumption of Dairy Products in Urban China: Results from Beijing, Shangai and Guangzhou. Australian Journal of Agricultural and Resource Economics, 51(4), 459-474.

Garcia, S.N., Osburn, B.I. & Cullor, J.S. (2019). A One Health Perspective on Dairy Production and Dairy Food Safety. One Health, 7, 100086.

Górska-Warsewicz, H., Rejman, K., Laskowski, W. & Czeczotko, M. (2019). Milk and Dairy Products and Their Nutritional Contribution to the Average Polish Diet. Nutrients, 11(8), 1771.

He, Y., Yang, X., Xia, J., Zhao, L. & Yang, Y. (2016). Consumption of Meat and Dairy Products in China: A Review. Proceedings of the Nutrition Society, 75(3), 385-391.

Kibar, M., Mikail, N. & Yılmaz, A. (2020). Siirt İli Merkez İlçede Süt ve Süt Ürünleri Tüketim Alışkanlıkları ve Etkileyen Faktörler. Batman Üniversitesi Yaşam Bilimleri Dergisi, 10(1), 99-113.

Kubicová, L., Kadekova, K. & Dobák, D. (2014). Trends in Consumption of Milk and Dairy Products in Slovakia after EU Accession. Zeszyty Naukowe Szkoły Głównej Gospodarstwa Wiejskiego w Warszawie. Polityki Europejskie, Finanse i Marketing, (12 [61]).

Lee, K. & Kim, J. (2019). Dairy Food Consumption is Inversely Associated with the Prevalence of Periodontal Disease in Korean Adults. Nutrients, 11(5), 1035.

Marchenko, Y.V. & Genton, M.G. (2012). A Heckman Selection-t Model. Journal of the American Statistical Association, 107(497), 304-317.

McGrane, M.M., Essery, E., Obbagy, J., Lyon, J., MacNeil, P., Spahn, J. & Van Horn, L. (2011). Dairy Consumption, Blood Pressure, and Risk of Hypertension: An Evidence-Based Review of Recent Literature. Current Cardiovascular Risk Reports, 5(4), 287.

Miran, B. 2018. Ekonometri. Lambert Academic Publishing, İzmir.

Mishra, P., Matuka, A., Abotaleb, M.S.A., Weerasinghe, W.P.M.C.N., Karakaya, K. & Das, S. S. (2021). Modeling and Forecasting of Milk Production in the SAARC Countries and China. Modeling Earth Systems and Environment, 1-13.

Onurlubaş, E. & Çakırlar, H. (2016). Tüketicilerin Süt ve Süt Ürünleri Tüketimini Etkileyen Faktörlerin Belirlenmesi Üzerine Bir Araştırma. Çankırı Karatekin Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 7(1), 217-242.

Phuong, N.V., Cuong, T.H. & Mergenthaler, M. (2014). Dairy Products Expenditure Pattern in Vietnam: Effects of Household Characteristics on Expenditure for Dairy Products (No. 871-2016-60794).

Rozenberg, S., Body, J. J., Bruyere, O., Bergmann, P., Brandi, M.L., Cooper, C., ... & Reginster, J.Y. (2016). Effects of Dairy Products Consumption on Health: Benefits and Beliefs—a Commentary from the Belgian Bone Club and the European Society for Clinical and Economic Aspects of Osteoporosis, Osteoarthritis and Musculoskeletal Diseases. Calcified tissue international, 98(1), 1-17.

Shimazaki, Y., Shirota, T., Uchida, K., Yonemoto, K., Kiyohara, Y., Iida, M., ... & Yamashita, Y. (2008). Intake of Dairy Products and Periodontal Disease: The Hisayama Study. Journal of periodontology, 79(1), 131-137.

Terin, M., Bilgiç, A., Güler, İ. & Yavuz, F. (2015). Türkiye'de Süt Ürünleri Tüketim Harcamalarına Etki Eden Faktörlerin Analizi: Çoklu Heckman Örneklem Seçicilik Sistem Yaklaşımı. Journal Of Agricultural Sciences, 21(4), 500-515.

TÜİK (2020). Süt ve Süt Üretimleri Bülteni. https://data.tuik.gov.tr/Bulten/Index?p=Sut-ve-Sut-Urunleri-Uretimi-Haziran-2021-37237&dil=1 (Erişim Tarihi: 08.09.2021)

Van Meijl, L., Vrolix, R. & Mensink, R. (2008). Dairy Product Consumption and the Metabolic Syndrome. Nutrition Research Reviews, 21(2), 148-157.

EFFECTS OF STIRIPENTOL IN EPILEPSY

Prof. Dr. Gonul GUROL CIFTCI

Halic University, Faculty of Medicine, Department of Physiology, Istanbul, Turkey

ORCID ID: https://orcid.org/0000-0001-5343-9189

ABSTRACT

The fact that seizures, which occur as a result of abnormal neuronal discharges in the brain tissue, happen in a wide range from childhood to old age, causes serious disadvantages in the maintenance of the welfare of epilepsy patients and even society. The observation of resistance mechanisms that develop over time to epileptic treatments started at early or late ages also causes seizures not to be controlled. It directs patients to seek alternative treatment methods such as epilepsy surgery, neuromodulation, and various dietary applications. This also paves the way for the formation of a low quality of life for epilepsy patients in society. Despite the variety of multiple antiepileptic drugs, epilepsy patients who still develop drug resistance today are waiting for an undeniable rate of recovery. There are many studies in the literature on the suitability of using stiripentol, an antiepileptic drug with multiple mechanisms of action, in both pediatric and adult individuals, and its effectiveness in Dravet syndrome, a severe form of childhood epilepsy. In addition to its antiepileptic activity, recent studies have shown that it is also effective in glucose metabolism, and it is hoped that dietary practices, which have been studied in many studies in the treatment of epilepsy, may also provide benefits through common pathways. This suggests that stiripentol may also be effective in metabolic disorders seen as comorbidities in patients with epilepsy. In newly designed studies, it is suggested that in addition to glucose metabolism in patients with epilepsy, the combination of activities such as exercise and nutrition that can accompany this metabolism and stiripentol treatment may be more beneficial. In this context, in order to further elucidate the role of stiripentol in epilepsy, metabolic and transcriptomic analyses and methodologies enriched by the latest generation techniques in different age groups in different types of epilepsy will pave the way for the elucidation of etiopathogenesis.

Keywords: Epilepsy, Antiepileptic drug, Stiripentol, Seizure

It is estimated that more than 70 million people suffer from epilepsy in the world. It is emphasized that the underlying reason why not all patients with epilepsy can be treated completely may be the resistance mechanisms that develop in patients against antiepileptic drug (AED) treatment (Perucca et al., 2023, Klein et al., 2024, Waris et al., 2024, Abilkhayyr & Orazova, 2025). The multifaceted and complex nature of the disease's pathophysiological mechanisms, which are not yet fully understood, impacts the treatment process (Hu et al., 2023). Because epilepsy affects individuals of all ages and social classes and is a chronic neurological disorder, patients' quality of life is also affected (Tsigebrhan et al., 2023, Aliyev et al., 2025). However, patients' quality of life can vary depending on the variety of AEDs used in treatment. Various AEDs, such as phenytoin, carbamazepine, sodium valproate, everolimus, fenfluramine, and cannabidiol, are initiated depending on the course of the disease and the primary diagnostic tool for diagnosing epilepsy, including electroencephalography (EEG) monitoring, along with clinical and neurological examinations (Schmidt and Schachter, 2014, Perucca E, 2021, Riva et al., 2021, Malekmohammad et al., 2024, Taherahmadi et al., 2025). Side effects, withdrawal

symptoms, and even drug interactions that can occur with long-term use are common issues during treatment. This significantly increases the economic burden of epilepsy on society (Hu et al., 2023).

The main changes that are prominent concerning epileptogenesis include abnormal neuronal cycles, abnormal ion channel functions, imbalances in neurotransmitter release, genetic predispositions, structural brain abnormalities, neuroinflammation, metabolic/endocrine disorders, and oxidative stress (Abed M., 2023, Hu et al., 2023, Waris et al., 2024, Dahalia et al., 2025, Lu et al., 2025). Disability, functional impairment, cognitive and neurodevelopmental disorders in patients due to uncontrolled seizures in epilepsy, and more importantly, the high risk of sudden unexpected death in epilepsy (SUDEP), the presence of side effects, toxicity, and unsatisfactory results of AEDs in terms of clinical efficacy and tolerance force researchers to discover new treatment strategies as soon as possible (Landmark and Johannessen, 2008, Jyonouchi and Geng, 2016, Riva et al., 2021). Findings from a study investigating the quality of life of epilepsy patients using neuropsychological tests indicate a higher quality of life with levetiracetam and oxcarbazepine, while a lower quality of life was observed in the carbamazepine and valproate group (Aliyev et al., 2025). The clinical use of AEDs in neurological and psychiatric disorders other than epilepsy highlights the existence of mutually beneficial/interactive mechanisms (Landmark and Johannessen, 2008). This situation highlights the crucial importance of the treatment approach in managing comorbid conditions commonly seen with epilepsy, in addition to therapeutic expectations, in ensuring both individual and societal well-being, and the importance of personalized treatment approaches. The low quality of life found in patients with epilepsy in many studies further highlights this need (Tombini et al., 2021, Dwivedi et al., 2022, Rozensztrauch et al., 2022, Tsigebrhan et al., 2023, Strzelczyk et al., 2023).

The high prevalence of epilepsy, particularly in the pediatric population, leads to several cognitive and behavioral disorders (Helmstaedter et al., 2014, Holmes G.L., 2015, Paramonova et al., 2024, Duzova et al., 2025). In Dravet syndrome, or severe myoclonic epilepsy, early developmental stages of infancy are normal, but progressive cognitive delay is detected between the ages of 1 and 4 (Scheffer et al., 2009; Kim and Ko, 2016). The first symptom of Dravet syndrome is a convulsive seizure, which can appear between 1 and 18 months. It can be distinguished from focal epilepsies by the presence of a long-lasting generalized seizure type caused by fever. Seizure frequency increases over time, while seizure duration decreases (Gao et al., 2023).

Dravet syndrome is a form of monogenic epilepsy and a developmental epileptic encephalopathy. It has been suggested that early diagnosis and appropriate medication prescription can significantly improve cognitive deficits in the long term (Feng et al., 2024). The high rate of SUDEP in life-threatening and long-term epileptic encephalopathies like Dravet syndrome creates a significant caregiver burden (Mercier et al., 2025). Genetic testing for mutations in the voltage-gated sodium channel 1a gene (SCN1A) is also recommended to confirm the diagnosis of Dravet syndrome (Wheless, J., & Weatherspoon, 2025). However, it is also known that approximately 15% of individuals with Dravet syndrome may not have the SCN1A mutation (Wirrell and Nabbout, 2019). Benzodiazepine compounds are the first-line treatment for acute Dravet syndrome, while agents such as phenytoin and phenobarbital, although controversial, may be beneficial in the second-line setting (Vaitkevicius et al., 2022, Gao et al., 2023). In chronic treatment approaches, personalized treatment options are preferred. These options include cannabidiol, fenfluramine, and stiripentol (Gao et al., 2023). Unfortunately, the long-term drug-resistant seizures and SUDEP seen in Dravet syndrome pose a serious risk to patients. Stiripentol is the only medication approved for use in children as young as six months of age with Dravet syndrome (Wheless, J., & Weatherspoon, 2025).

Stiripentol is used clinically as a drug with a multifaceted mechanism of action. These mechanisms include being a positive allosteric modulator of GABAA receptors, targeting both

synaptic and extrasynaptic receptors, inhibiting ion channels such as postsynaptic T-type calcium channels Cav3.1, 3.2 and 3.3, altering brain energy metabolism in neurons and astrocytes by inhibiting lactate dehydrogenase (LDH1, LDH5) which plays a role in lactate (Lac)-pyruvate (Pyr) shuttles, interacting pharmacokinetically with concomitant antiepileptic drugs such as clobazam by inhibiting various cytochrome P450, and having a general neuroprotective effect in neurotoxic conditions such as prolonged seizures (Riban et al., 2022, Bacq et al., 2024, Bononi et al., 2024, Howlid C., 2024, Masubuchi et al., 2024, Wheless, J., & Weatherspoon, 2025). One of the most important findings from research is that stiripentol acts on GABA transaminase, inhibiting GABA reuptake and thus increasing cerebral GABA levels (Bacq et al., 2024). This is because the vast majority of SCN1A mutations underlie seizures and progressive neurodevelopmental disorders, primarily due to a defect in voltage-gating of Nav1.1 in GABAergic neurons, leading to an imbalance of excitatory and inhibitory neurotransmitters. The weakening of inhibitory input further reinforces abnormal network synchronization, leading to these deficits (Chilcott et al., 2020, Li et al., 2023, Wang et al., 2025). Some antiseizure medications, such as lamotrigine, carbamazepine, and phenytoin, have been found to worsen seizures in Dravet syndrome, and avoiding these medications in individuals with Dravet syndrome is recommended. However, cognitive problems have also been observed with long-term use of some medications (Saito et al., 2001, Thanh et al., 2002, Wilmshurst et al., 2015, de Lange et al., 2018, Wirrell and Nabbout, 2019). Non-pharmacological interventions used in Dravet syndrome include ketogenic diets, vagus nerve stimulation, and, although very limited, surgical options (Wirrell and Nabbout, 2019).

In conclusion, early diagnosis remains crucial for individuals with Dravet syndrome, and early initiation of effective antiepileptic medication remains crucial for controlling both seizure severity and seizure frequency. Effective treatment strategies need to be developed to improve the quality of life of patients with comorbid disabilities/disorders.

REFERENCES

Abed, M. (2023). A Comprehensive Examination of Human Brain Disorders. Journal of Biomedical and Sustainable Healthcare Applications, 3(2), 141-152.

Abilkhayyr, A., & Orazova, G. (2025). Features of the organization of medical care for people suffering from epilepsy. kjcns, 38-45.

Aliyev, D., & Ro'zimatov, K. M. (2025). The Impact Of Modern Antiepileptic Drugs On The Quality Of Life Of Patients With Epilepsy. Modern Science and Research, 4(1), 27-33.

Bacq, A., Depaulis, A., Castagné, V., Le Guern, M. E., Wirrell, E. C., & Verleye, M. (2024). An update on stiripentol mechanisms of action: a narrative review. Advances in therapy, 41(4), 1351-1371.

Bononi, G., Di Bussolo, V., Tuccinardi, T., Minutolo, F., & Granchi, C. (2024). A patent review of lactate dehydrogenase inhibitors (2014–present). Expert Opinion on Therapeutic Patents, 34(11), 1121-1135.

Chilcott, E., Díaz, J. A., Bertram, C., Berti, M., & Karda, R. (2022). Genetic therapeutic advancements for Dravet Syndrome. Epilepsy & Behavior, 132, 108741.

Dahalia, M., Gupta, S., Majid, H., Vohora, D., & Nidhi. (2025). Pirfenidone regulates seizures through the HMGB1/TLR4 axis to improve cognitive functions and modulate oxidative stress and neurotransmitters in PTZ-induced kindling in mice. Frontiers in Pharmacology, 15, 1528032.

de Lange, I. M., Gunning, B., Sonsma, A. C., van Gemert, L., van Kempen, M., Verbeek, N. E., ... & Brilstra, E. H. (2018). Influence of contraindicated medication use on cognitive

outcome in Dravet syndrome and age at first afebrile seizure as a clinical predictor in SCN 1A-related seizure phenotypes. Epilepsia, 59(6), 1154-1165.

Duzova, U. S., Seflek, Z., Eren, F., Ozturk, S., & Tutar, M. F. (2025). A computer-assisted rehabilitation program improves self-management, cognition, and quality of life in epilepsy: A randomized controlled trial. Epilepsy & Behavior, 164, 110277.

Dwivedi, R., Tiwari, P., Pahuja, M., Dada, R., & Tripathi, M. (2022). Anti-seizure medications and quality of life in person with epilepsy. Heliyon, 8(10).

Feng, T., Makiello, P., Dunwoody, B., Steckler, F., Symonds, J. D., Zuberi, S. M., ... & Brunklaus, A. (2024). Long-term predictors of developmental outcome and disease burden in SCN1A-positive Dravet syndrome. Brain Communications, 6(1), fcae004.

Gao, C., Pielas, M., Jiao, F., Mei, D., Wang, X., Kotulska, K., & Jozwiak, S. (2023). Epilepsy in Dravet syndrome—current and future therapeutic opportunities. Journal of Clinical Medicine, 12(7), 2532.

Helmstaedter, C., Aldenkamp, A. P., Baker, G. A., Mazarati, A., Ryvlin, P., & Sankar, R. (2014). Disentangling the relationship between epilepsy and its behavioral comorbidities—the need for prospective studies in new-onset epilepsies. Epilepsy & Behavior, 31, 43-47.

Holmes, G. L. (2015). Cognitive impairment in epilepsy: the role of network abnormalities. Epileptic Disorders, 17(2), 101-116.

Howlid, C. (2024). Stiripentol as Treatment for Epileptic Seizures (Bachelor's thesis, NTNU).

Hu, T., Zhang, J., Wang, J., Sha, L., Xia, Y., Ortyl, T. C., ... & Chen, L. (2023). Advances in epilepsy: mechanisms, clinical trials, and drug therapies. Journal of medicinal chemistry, 66(7), 4434-4467.

Jyonouchi, H., & Geng, L. (2016). Intractable epilepsy (IE) and responses to anakinra, a human recombinant IL-1 receptor agonist. J Clin Cell Immunol, 7(5), 1000456.

Kim, E. H., & Ko, T. S. (2016). Cognitive impairment in childhood onset epilepsy: up-to-date information about its causes. Korean journal of pediatrics, 59(4), 155.

Klein, P., Kaminski, R. M., Koepp, M., & Löscher, W. (2024). New epilepsy therapies in development. Nature Reviews Drug Discovery, 23(9), 682-708.

Landmark, C. J., & Johannessen, S. I. (2008). Modifications of antiepileptic drugs for improved tolerability and efficacy. Perspectives in medicinal chemistry, 2, 1177391X0800200001.

Li, M., Yang, L., Qian, W., Ray, S., Lu, Z., Liu, T., ... & Wang, H. (2023). A novel rat model of Dravet syndrome recapitulates clinical hallmarks. Neurobiology of Disease, 184, 106193.

Lu, Y., Li, Y., Su, W., Lv, Y., Zheng, Z., Zhao, A., & Wang, Z. (2025). Vagus Nerve Stimulation Ameliorates Learning-Memory Deficits and Suppresses Neuronal Apoptosis via the ERK/CREB/BDNF Signaling Pathway in Epileptic Rats. International Journal of Neuroscience, (just-accepted), 1-12.

Malekmohammad, K., Riva, A., & Rafieian-Kopaei, M. (2024). Recent advances in the treatment of epilepsy. *Frontiers in Pharmacology*, *15*, 1444138.

Masubuchi, Y., Takahashi, C., & Gendo, R. (2024). Time-dependent inhibition of CYP1A2 by stiripentol and structurally related methylenedioxyphenyl compounds via metabolic intermediate complex formation. Drug Metabolism and Disposition, 52(1), 63-68.

Mercier, A., Dorris, L., Brunklaus, A., Symonds, J. D., Zuberi, S. M., Finch, T., ... & Eldred, C. (2025). Trauma, coping, and adjustment when parenting a child with Dravet syndrome. European Journal of Paediatric Neurology, 54, 96-106.

Paramonova, A. I., Lysova, K. D., Timechko, E. E., Senchenko, G. V., Sapronova, M. R., & Dmitrenko, D. V. (2024). Cognitive impairment in childhood-onset epilepsy. Epilepsy and paroxysmal conditions, 16(1), 54-68.

Perucca, E. (2021). The pharmacological treatment of epilepsy: recent advances and future perspectives. Acta Epileptologica, 3(1), 22.

Perucca, E., Perucca, P., White, H. S., & Wirrell, E. C. (2023). Drug resistance in epilepsy. The Lancet Neurology, 22(8), 723-734.

Riban, V., Heulard, I., Reversat, L., Si Hocine, H., & Verleye, M. (2022). Stiripentol inhibits spike-and-wave discharges in animal models of absence seizures: a new mechanism of action involving T-type calcium channels. Epilepsia, 63(5), 1200-1210.

Riva, A., Golda, A., Balagura, G., Amadori, E., Vari, M. S., Piccolo, G., ... & Striano, P. (2021). New trends and most promising therapeutic strategies for epilepsy treatment. Frontiers in neurology, 12, 753753.

Rozensztrauch, A., & Kołtuniuk, A. (2022). The quality of life of children with epilepsy and the impact of the disease on the family functioning. International journal of environmental research and public health, 19(4), 2277.

Saito, Y., Oguni, H., Awaya, Y., Hayashi, K., & Osawa, M. (2001). Phenytoin-induced choreoathetosis in patients with severe myoclonic epilepsy in infancy. Neuropediatrics, 32(05), 231-235.

Scheffer, I. E., Zhang, Y. H., Jansen, F. E., & Dibbens, L. (2009). Dravet syndrome or genetic (generalized) epilepsy with febrile seizures plus?. Brain and Development, 31(5), 394-400.

Schmidt, D., & Schachter, S. C. (2014). Drug treatment of epilepsy in adults. Bmj, 348.

Strzelczyk, A., Aledo-Serrano, A., Coppola, A., Didelot, A., Bates, E., Sainz-Fuertes, R. ve Lawthom, C. (2023). Epilepsinin yaşam kalitesi üzerindeki etkisi: Avrupa anketinden elde edilen bulgular. Epilepsi ve Davranış , 142 , 109179.

Taherahmadi, H., Shariatmadari, F., & Satarzadeh, M. The Thinning Brain In Pediatric Epilepsy: A Systematic Review on Cortical and Sub-Cortical Thickness Alterations. J Cell Sci Regenerative Med 2025, 1(1), 27-32.

Thanh, T. N., Chiron, C., Dellatolas, G., Rey, E., Pons, G., Vincent, J., & Dulac, O. (2002). Long-term efficacy and tolerance of stiripentaol in severe myoclonic epilepsy of infancy (Dravet's syndrome). Archives de pédiatrie: organe officiel de la Sociéte française de pédiatrie, 9(11), 1120-1127.

Tombini, M., Assenza, G., Quintiliani, L., Ricci, L., Lanzone, J., & Di Lazzaro, V. (2021). Epilepsy and quality of life: what does really matter?. Neurological Sciences, 42(9), 3757-3765.

Tsigebrhan, R., Derese, A., Kariuki, S. M., Fekadu, A., Medhin, G., Newton, C. R., ... & Hanlon, C. (2023). Co-morbid mental health conditions in people with epilepsy and association with quality of life in low-and middle-income countries: a systematic review and meta-analysis. Health and Quality of Life Outcomes, 21(1), 5.

Vaitkevicius, H., Ramsay, R. E., Swisher, C. B., Husain, A. M., Aimetti, A., & Gasior, M. (2022). Intravenous ganaxolone for the treatment of refractory status epilepticus: Results from an open-label, dose-finding, phase 2 trial. Epilepsia, 63(9), 2381-2391.

Wang, J., Zhang, G., Huang, S., Wei, M., Wu, Y., & Xie, Z. (2025). Dravet syndrome: novel insights into SCN1A-mediated epileptic neurodevelopmental disorders within the molecular diagnostic-therapeutic framework. Frontiers in Neuroscience, 19, 1634718.

Waris, A., Siraj, M., Khan, A., Lin, J., Asim, M., & Alhumaydh, F. A. (2024). A comprehensive overview of the current status and advancements in various treatment strategies against epilepsy. ACS Pharmacology & Translational Science, 7(12), 3729-3757.

Wheless, J., & Weatherspoon, S. (2025). Use of stiripentol in Dravet syndrome: a guide for clinicians. Pediatric Neurology, 162, 76-86.

Wirrell, E. C., & Nabbout, R. (2019). Recent advances in the drug treatment of Dravet syndrome. CNS drugs, 33(9), 867-881.

Wilmshurst, J. M., Gaillard, W. D., Vinayan, K. P., Tsuchida, T. N., Plouin, P., Van Bogaert, P., ... & Cross, J. H. (2015). Summary of recommendations for the management of infantile seizures: Task f orce r eport for the ilae c ommission of p ediatrics. Epilepsia, 56(8), 1185-1197.

Wirrell, E. C., & Nabbout, R. (2019). Recent advances in the drug treatment of Dravet syndrome. CNS drugs, 33(9), 867-881.

THE IMPORTANCE OF NEURONAL PROGENITOR CELLS IN EPILEPSY

Prof. Dr. Gonul GUROL CIFTCI

Halic University, Faculty of Medicine, Department of Physiology, Istanbul, Turkey

ORCID ID: https://orcid.org/0000-0001-5343-9189

ABSTRACT

In addition to having worldwide effects, the fact that the mortality rate of epilepsy, which is characterized by chronic recurrent seizures, is reaching undeniable levels day by day, reveals the importance of designing new strategic plans for the diagnosis and treatment of this disease. Although it is known that abnormal discharges of neurons are responsible for the formation of recurrent seizures, the underlying processes have not yet been fully elucidated. It is suggested that neurogenesis, which has many potential roles in brain functions, interacts with dynamic processes. In the diagnosis and treatment of epilepsy, the effects of epigenetic and metabolic signalling pathways on neurogenesis have recently become prominent research topics. As a result of research on the discovery of drugs that affect neurogenesis, the effects of glial cells, chemokines, neurotrophic factors, neurotransmitters, hormones, and exercise on this process have also been evaluated. However, it has been reported that early use of antiepileptic drugs in the classical treatment of epilepsy may affect the characteristics of neural stem cells. However, it has also been shown that these characterizations vary depending on the variety of antiepileptic treatments used. Therefore, it is recommended that these studies, which demonstrate that neurogenesis varies according to the type of epilepsy and the treatment applied, be investigated in more detail through more comprehensive experimental and clinical studies that include different types of epilepsy, as well as acute and chronic drug applications.

Key Words: Epilepsy; Neurogenesis; Neuronal Progenitor Cell; Seizure

Considering the cellular and regional diversity of the human brain, the complexity of stem cell morphology and stem cell polarity, which constitute the cells of the cortex, is thought to reflect this. Therefore, it is suggested that protein complexes mediate progenitor responses through cell membranes. Therefore, a detailed examination of the stages of cortical cell polarity formation is crucial for understanding the workings of the human brain, as it can shed light on the mechanisms of neurological diseases (Andrews et al., 2022). Brain development, which begins with neurulation, continues with the coordination of multiple complex processes. Neuroepithelial cells and radial glial cells, the versatile stem cells of the nervous system, play an active role in this process. Numerous intermediate cells are formed as a result of symmetric and asymmetric divisions (Rakic P., 2009, Stiles and Jernigan, 2010, Andrews et al., 2022, Eichmüller and Knoblich, 2022). For proper functioning, both the number and location of cells in brain tissue require accurate positioning. However, differences in the developmental origins of neurons and the existence of neuronal/glial subclassifications further complicate this structure. These differences are mediated by cell migration during neural development, which is spatially and temporally regulated (Zhao and Bhattacharyya, 2018). The developmental processes of the human brain, which emerge as a result of this complex yet systematic organization, are difficult to explain solely through experimental modeling. Three-dimensional

cell culture models derived from pluripotent stem cells, called organoids, allow for the study of brain development in vitro. Furthermore, these stem cells can be used to investigate not only normal developmental processes but also the contribution/relationship of specific mutations to neurodevelopmental and neurodegenerative processes (Zhao and Bhattacharyya, 2018, Eichmüller and Knoblich, 2022). Moreover, beyond the complexity of human brain developmental mechanisms, data on their precise spatial and temporal genetic controls can be obtained, providing insights into the genetic architecture of diseases (Zhou et al., 2024). However, through experimental modeling, the contribution of social, cognitive, and sensory functions that influence human brain development to our abilities can be investigated in detail. It is also important to note that neural and glial cells in the human brain are more diverse than in rodents. Epilepsy, characterized by seizures, is the most common neurological disease, has multifaceted pathophysiological mechanisms, and represents a serious public health problem in low- and middle-income countries (Nepal et al., 2025).

The primary causes of epilepsy, a multifaceted, heterogeneous disease, include genetic factors, metabolic disorders, neuroinflammation, neurotransmitter imbalance, trauma, congenital anomalies, infectious diseases, and oxidative stress (Alberto and Liliana, 2016, Almanni et al., 2021, Ravizza et al., 2024, Kamieniak et al., 2024, Sidhu et al., 2025). In addition, epigenetic regulations, which have numerous effects on neuronal functions from embryogenesis to the end of life, are among the recent research topics (Chen et al., 2017). Recent studies utilize neurogenetic biomarkers to investigate underlying information about seizures, such as the mechanisms of epileptic seizure formation, seizure susceptibility, seizure progression, therapeutic responses, and the genetic basis of seizures. These markers suggest the existence of a multilayered genetic architecture underlying epileptogenesis. This evidence-based database is enabling long-term research on seizure onset prediction, diagnostic improvement, drug selection, and surgical intervention. Efforts are underway to integrate these data with neuroimaging and electrophysiological responses (Sidhu et al., 2025, Aklamanu B. W., 2025).

The need for detailed investigation of the steps in epileptogenesis increases day by day due to reasons such as the increased likelihood of seizures in society, the decreased quality of life of epilepsy patients, the social burden, and the negative effects on the cognitive, behavioral, and emotional states of patients due to this disease (Brown et al., 2024). When we examine the cell types selected in stem cell therapies for epilepsy, the most frequently encountered are mesenchymal stem cells, neural stem cells, embryonic stem cells, and induced pluripotent stem cells. It has been suggested that mesenchymal stem cells may reduce seizure frequency due to their ability to produce extracellular vesicles and growth factors, while neural stem cells, by secreting neurotrophic factors, are effective in epilepsy through their immunomodulatory effects. Embryonic stem cells, on the other hand, hold promise for intractable epilepsies (Ma et al., 2026). However, a very recent study in the literature describes the "TERA2.cl.SP12" stem cell line as a stem cell line that exhibits epileptiform activity and responds to antiepileptic drug effects to derive both neurons and glial cells (Salmanzadeh et al., 2023). Given that prolonged seizures in epilepsy impair hippocampal neurogenesis, it has been suggested that neural stem cell transplantation may be effective in reducing seizure frequency (Toda et al., 2019, Geribaldi-Doldan et al., 2023). Variations in the speed and extent of neural cell migration have been demonstrated in different forms of epilepsy.

Examining the hippocampus of young patients with temporal lobe epilepsy has reported increased cell proliferation and neural progenitors. Similar results are supported by animal studies (Crespel et al., 2005, Shrestha et al., 2020, Blümcke et al., 2021, Moreno-Jiménez et al., 2021, Arshad et al., 2022, Elliott et al., 2025). A study in which human embryonic stem cell-derived human interneuron progenitors were transplanted into the mouse hippocampus demonstrated maturation of dendritic branches after transplantation (Shrestha et al., 2020). In

another similar study, the same type of stem cells was transplanted into the hippocampi of rats in the kainic acid model of status epilepticus, and it was determined that the transplanted cells established inhibitory synapses with host neurons, thus reducing epileptic seizures in animals (Waloschková et al., 2021). The common conclusion from these studies is that stem cell-based treatment strategies have been proposed in the literature as an approach to correcting the imbalance in the electrical activity of the epileptiform network in the brain (Chang and Chang, 2022). In a recent study using neuroglial cell cultures derived from human stem cells for epilepsy, fenamates were shown to have antiepileptic activity. The same study also highlighted the anti-inflammatory effects of fenamates using neuroglial circuits derived from functionally mature human stem cells (Salmanzadeh and Halliwell, 2024). Using a mouse model of chronic mesial temporoparietal epilepsy, interneurons were administered intrahippocampally in a single dose, and almost all animals were seizure-free (Bershteyn et al., 2023). A phase I clinical trial found that seizures in epilepsy patients decreased after autologous mesenchymal stem cell therapy (Hlebokazov et al., 2017, Chang and Chang, 2022).

Consequently, it is crucial to diagnose and diagnose epilepsy earlier, examine individual responses, and manage it to reduce societal costs. Therefore, the steps of epileptogenesis should be examined in detail in larger cohort studies, drawing on findings from advances in neurogenetics, neuroimaging, and artificial intelligence. In this regard, organoids not only enable disease modeling but also offer powerful approaches to advanced neurological/neuropsychiatric drug discovery and development. Furthermore, thanks to stem cell technologies, stem cell transplantation treatment strategies offer new applications for patients with epilepsy. However, due to the lack of sufficient knowledge in this area, further research is needed.

REFERENCES

Aklamanu, B. W. (2025). A Review of Neuroimaging in Epilepsy: Diagnostic Strategies and Clinical Decision Framework. Brain Disorders, 100261.

Alberto, L., & Liliana, C. (2016). Role of ABC-Transporters in Epileptogenesis and Pharmacoresistant Epilepsy. In Epileptology-The Modern State of Science. IntechOpen.

Almannai, M., Al Mahmoud, R. A., Mekki, M., & El-Hattab, A. W. (2021). Metabolic seizures. Frontiers in neurology, 12, 640371.

Andrews, M. G., Subramanian, L., Salma, J., & Kriegstein, A. R. (2022). How mechanisms of stem cell polarity shape the human cerebral cortex. Nature Reviews Neuroscience, 23(12), 711-724.

Arshad, M. N., Oppenheimer, S., Jeong, J., Buyukdemirtas, B., & Naegele, J. R. (2022). Hippocampal transplants of fetal GABAergic progenitors regulate adult neurogenesis in mice with temporal lobe epilepsy. Neurobiology of disease, 174, 105879.

Bershteyn, M., Bröer, S., Parekh, M., Maury, Y., Havlicek, S., Kriks, S., ... & Nicholas, C. R. (2023). Human pallial MGE-type GABAergic interneuron cell therapy for chronic focal epilepsy. Cell Stem Cell, 30(10), 1331-1350.

Blümcke, I., Schewe, J. C., Normann, S., Brüstle, O., Schramm, J., Elger, C. E., & Wiestler, O. D. (2001). Increase of nestin-immunoreactive neural precursor cells in the dentate gyrus of pediatric patients with early-onset temporal lobe epilepsy. Hippocampus, 11(3), 311-321.

Brown, R., Rabeling, A., & Goolam, M. (2024). Progress and potential of brain organoids in epilepsy research. Stem Cell Research & Therapy, 15(1), 361.

Chang, B. L., & Chang, K. H. (2022). Stem cell therapy in treating epilepsy. Frontiers in neuroscience, 16, 934507.

Crespel, A., Rigau, V., Coubes, P., Rousset, M. C., De Bock, F., Okano, H., ... & Lerner-Natoli, M. (2005). Increased number of neural progenitors in human temporal lobe epilepsy. Neurobiology of disease, 19(3), 436-450.

Eichmüller, O. L., & Knoblich, J. A. (2022). Human cerebral organoids—a new tool for clinical neurology research. Nature Reviews Neurology, 18(11), 661-680.

Elliott, T., Liu, K. Y., Hazan, J., Wilson, J., Vallipuram, H., Jones, K., ... & Howard, R. (2025). Hippocampal neurogenesis in adult primates: a systematic review. Molecular Psychiatry, 30(3), 1195-1206.

Geribaldi-Doldan, N., Carrascal, L., Perez-Garcia, P., Oliva-Montero, J. M., Pardillo-Diaz, R., Dominguez-Garcia, S., ... & Castro, C. (2023). Migratory response of cells in neurogenic niches to neuronal death: the onset of harmonic repair?. International journal of molecular sciences, 24(7), 6587.

Kamieniak, M., Kośmider, K., Miziak, B., & Czuczwar, S. J. (2024). The Oxidative Stress in Epilepsy—Focus on Melatonin. International journal of molecular sciences, 25(23), 12943.

Ma, X., Wang, Z., Niu, Y., Zhao, J., Wang, X., Wang, X., ... & Jiang, W. (2026). Stem cell repair strategies for epilepsy. Neural Regeneration Research, 21(4), 1428-1446.

Moreno-Jiménez, E. P., Terreros-Roncal, J., Flor-García, M., Rábano, A., & Llorens-Martín, M. (2021). Evidences for adult hippocampal neurogenesis in humans. Journal of Neuroscience, 41(12), 2541-2553.

Nepal, G., Yadav, J. K., Lamsal, S., & Ojha, R. (2025). Pragmatic strategies for improving prevention, diagnosis, and treatment of epilepsy in low-and middle-income countries. Epilepsy Research, 107586.

Rakic, P. (2009). Evolution of the neocortex: a perspective from developmental biology. Nature Reviews Neuroscience, 10(10), 724-735.

Ravizza, T., Scheper, M., Di Sapia, R., Gorter, J., Aronica, E., & Vezzani, A. (2024). mTOR and neuroinflammation in epilepsy: implications for disease progression and treatment. Nature Reviews Neuroscience, 25(5), 334-350.

Salmanzadeh, H., Poojari, A., Rabiee, A., Zeitlin, B. D., & Halliwell, R. F. (2023). Neuropharmacology of human TERA2. cl. SP12 stem cell-derived neurons in ultra-long-term culture for antiseizure drug discovery. Frontiers in Neuroscience, 17, 1182720.

Salmanzadeh, H., & Halliwell, R. F. (2024). Antiseizure properties of fenamate NSAIDs determined in mature human stem-cell derived neuroglial circuits. Frontiers in Pharmacology, 15, 1385523.

Shrestha, S., Anderson, N. C., Grabel, L. B., Naegele, J. R., & Aaron, G. B. (2020). Development of electrophysiological and morphological properties of human embryonic stem cell-derived GABAergic interneurons at different times after transplantation into the mouse hippocampus. PLoS One, 15(8), e0237426.

Sidhu, R. K., Maparu, K., & Aran, K. R. (2025). Neurogenetic biomarkers in epilepsy: A comprehensive narrative review of progression and therapeutic approaches. Mutation Research-Reviews in Mutation Research, 796, 108556.

Stiles, J., & Jernigan, T. L. (2010). The basics of brain development. Neuropsychology review, 20(4), 327-348.

Toda, T., Parylak, S. L., Linker, S. B., & Gage, F. H. (2019). The role of adult hippocampal neurogenesis in brain health and disease. Molecular psychiatry, 24(1), 67-87.

Waloschková, E., Gonzalez-Ramos, A., Mikroulis, A., Kudláček, J., Andersson, M., Ledri, M., & Kokaia, M. (2021). Human stem cell-derived GABAergic interneurons establish efferent synapses onto host neurons in rat epileptic hippocampus and inhibit spontaneous recurrent seizures. International journal of molecular sciences, 22(24), 13243.

Zhao, X., & Bhattacharyya, A. (2018). Human models are needed for studying human neurodevelopmental disorders. The American Journal of Human Genetics, 103(6), 829-857.

Zhou, Y., Song, H., & Ming, G. L. (2024). Genetics of human brain development. Nature Reviews Genetics, 25(1), 26-45.

EFFECT OF BORON AND ALUMINA ADDITION TO 316L STAINLESS STEEL ON TRIBOLOGICAL PROPERTIES

Merve HORLU
Aisin Automotive Industry Trade Inc. Istanbul, Turkey
ORCID ID: https://orcid.org/0000-0003-0775-2849

Cevher Kürşat MACİT
Firat University, School of Aviation, Aircraft Airframe-Engine Maintenance. Elazığ, Turkey
ORCID ID: https://orcid.org/0000-0003-0466-7788

Bünyamin AKSAKAL
Firat University, School of Aviation, Aircraft Airframe-Engine Maintenance. Elazığ, Turkey
ORCID ID: https://orcid.org/0000-0003-4844-9387

Eda ÇULLU FERŞAT
Aisin Automotive Industry Trade Inc. Istanbul, Turkey
ORCID ID: https://orcid.org/0009-0005-3786-9871

Ersoy YILMAZ
Aisin Automotive Industry Trade Inc. Istanbul, Turkey
ORCID ID: https://orcid.org/0009-0005-4623-6267

ABSTRACT

Introduction and Purpose: This study explores the influence of boron (B) and alumina (Al_2O_3) reinforcements on the microstructural, mechanical, and tribological properties of 316L stainless steel matrix composites.

Materials and Methods: Hybrid composites were synthesized through a combination of mechanical alloying and powder metallurgy techniques. Different proportions of boron and alumina were incorporated into the stainless steel matrix. The resulting samples underwent characterization via X-ray diffraction (XRD), scanning electron microscopy with energy-dispersive spectroscopy (SEM-EDX), density measurements, hardness testing, and room-temperature wear testing.

Results: XRD analysis confirmed the retention of the crystalline structure of alumina and the formation of iron boride phases due to boron incorporation. The hybrid-reinforced composites demonstrated a substantial increase in hardness when compared to the unreinforced matrix. Tribological tests also showed a marked reduction in wear rates and a significant decrease in

the coefficient of friction, highlighting the improved wear resistance of the hybrid composites under ambient conditions.

Discussion and Conclusion: The findings reveal that the combined use of boron and alumina provides a synergistic enhancement in both mechanical strength and wear resistance of the 316L stainless steel matrix. These hybrid composites exhibit promising potential for applications in demanding industrial environments such as the automotive sector, where resistance to severe wear is critical.

Key Words: Stainless steel, Boron, Alumina, Wear resistance, Hybrid composites.

INFLUENCE OF SECTION GEOMETRY AND MATERIAL SELECTION ON ENERGY ABSORPTION IN CRASH BOXES: A FINITE ELEMENT APPROACH

Umut KUMLU

Çukurova University, Faculty of Engineering, Department of Automotive Engineering, Adana, Turkey

ORCID ID: https://orcid.org/0000-0001-7624-6240

Ömer HÜKÜMDAR

Çukurova University, Faculty of Engineering, Department of Automotive Engineering, Adana, Turkey

ORCID ID: https://orcid.org/0000-0002-0806-3562

Yusuf GÖK

Çukurova University, Faculty of Engineering, Department of Automotive Engineering, Adana, Turkey

ORCID ID: https://orcid.org/0009-0002-8124-2820

Mustafa Atakan AKAR

Çukurova University, Faculty of Engineering, Department of Automotive Engineering, Adana, Turkey

ORCID ID: https://orcid.org/0000-0002-0192-0605

Ali KESKİN

Çukurova University, Faculty of Engineering, Department of Automotive Engineering, Adana, Turkey

ORCID ID: https://orcid.org/0000-0002-1089-3952

ABSTRACT

Nowadays, in order to increase structural safety in the automotive industry, studies to improve the impact energy absorption capacity of thin-walled structures have gained great momentum. In parallel with this, studies in this field aim to improve the energy absorption performance by optimizing the geometrical properties of structural elements used in crash boxes. In this study, the crushing behaviour and energy absorption capabilities of thin-walled structures with various cross-section geometries under axial impact loading are investigated numerically. Three different configurations are modelled to determine the contribution of cross-section and material types in the impact absorption of thin-walled structures. Simulations were carried out

using the finite element method (FEM) dynamic collision scenario. The crash scenarios for each configuration were analyzed under identical conditions using two different materials (DP-600 and AL6061-T6) and constant thickness (1 mm). Dynamic crash simulations were compared with respect to Specific Energy Absorption (SEA), Total Energy (EA), Peak Crushing Force (PCF), and Mean Crushing Force (MCF) values to investigate the effects of material types and the crushing behaviour of crash boxes on geometric cross-sections. According to the data obtained in the study, the highest SEA value was found to be 33.89 kJ/kg in the AL-S2 combination, while the highest CLE value of 0.428 was found in the AL-S2 combination. When compared in square models, the AL-S2 combination had 2.61 times higher result than the AL-S combination in terms of SEA value. When evaluated in terms of CLE value, the AL-S2 combination had 2.39 times higher results compared to the AL-S combination. When the research results were evaluated, flower-section combinations stood out compared to square-section combinations in terms of both SEA and CLE values. The results of the analyses showed that cross-section configurations and material types play a positive role in the crashworthiness characteristics of thin-walled structures.

Keywords: Crash boxes, Axial collision, Flower section, Finite element method, Deformation

INTRODUCTION

Today, increasing fuel prices, production costs and environmental problems on a global scale significantly affect both automobile manufacturers and consumers. Various technological solutions have been developed in order to reduce carbon dioxide (CO_2) emissions and to utilize the diminishing fossil fuel reserves efficiently. With the increasing world population, there is a significant increase in the number of traffic accidents (World Health Organization, 2018). These accidents cause various social and economic problems as well as loss of life and property. Against such problems, automobile manufacturers try to develop solutions by following certain engineering procedures and processes. Various safety systems are used to ensure driver and passenger safety in vehicle accidents. These systems are generally divided into two categories as active and passive safety systems (Lopes et al., 2023). The safety of vehicles in frontal collision situations depends on the frontal collision geometry and the impact resistance properties of this structure. Such structures are usually designed using pipes, special section profiles and specific geometric shapes and are placed between the front bumper of the vehicle and the main chassis frame. Design changes on the front bumper and body frame are evaluated by automobile manufacturers within the scope of research and development (R&D) and product development activities; as a result of these studies, it is aimed to develop crash boxes that can absorb the kinetic energy generated during a collision. The main purpose of crash boxes is to absorb the energy generated during a collision and distribute it in a way to minimize the impact on driver and passenger safety. The impact resistance of these structures has been the subject of research for a long time. Furthermore, the acceleration effect caused by the collapse of the energy absorber may be closely related to injury to passengers or damage to property. Therefore, structural crashworthiness is critical to vehicle safety, which has been revitalized over the last decade with lightweight design to address growing concerns in environmental and energy consumption. These solutions include lightweight vehicle body and chassis designs, the proliferation of electric vehicles, the use of crash boxes and the preference for composite materials. The main factors affecting durability are the type of material used, cross-sectional dimensions, geometric design and mounting location on the vehicle. Due to the high cost and time-consuming nature of real-life experimental studies, researchers have developed numerical simulations using the finite element method (FEM) to analyse the impact resistance of crash boxes (Deulgaonkar et al., 2020). Within the scope of these simulations, performance criteria such as reaction forces, MCF, SEA and PCF are analyzed. Marzbanrad et al. (2009), Conducted

a study in which they applied elastic and plastic boundary conditions to the bottom of a crash box to improve the stability of the force generated during a collision. According to their findings, the inclusion of weakened boundaries created a favorable environment for the crash box to undergo further bending and deformation during the collision. Consequently, this favored the formation of a more stable distribution of the impact load and facilitated higher energy absorption capacity. Later, Abramowicz and Jones, (1986) developed theoretical equations to predict the average collapse load of square and circular tubes under axial deformation behaviour. They also developed a theoretical expression based on the deformation pattern of the pipes to predict the half-fold length of the pipe. The crash performance of energy absorbing boxes with new types of cross-sections designed in the study was investigated and their crashworthiness was supported by data (Abramowicz & Jones, 1997; Abramowicz & Jones, 1984; Nia et al. 2010), conducted a study to investigate the energy absorption capacity of crash boxes with different cross-sectional geometries using both experimental and finite element methods. The results revealed that the circular design exhibited the highest energy absorption capacity. Moreover, for polygonal structures, energy absorption rates decreased as the number of corners decreased. Interestingly, increasing the sheet thickness from 1 mm to 1.5 mm did not cause any significant difference in energy absorption, maximum forces or average forces Ali et al. (2015), conducted theoretical, numerical and experimental studies on dynamic axial crushing of pentagonal and cross-shaped tubes and observed that aluminium and steel pentagonal and cross tubes absorbed 31-60% and 48-92% more energy than rectangular tubes of the same mass, respectively. In the current study, first of all, based on the literature, the data of the thin-walled structure with square cross-section were taken as reference and the verification study was carried out. During the validation period, AL6061-T6 was used as the material. In the ongoing process of the study, DP600 steel parameters were included in the simulations and the effects of different designs and alloys on collision performances were examined. In the simulations created using ANSYS Workbench/Explicit Dynamics module, explicit analysis type was preferred for collisions. In this study, the crash performances of thin-walled structures with three different cross-sectional geometries were investigated. The cross sections used are square, plus and flower shaped. The Johnson-Cook material model was used in the simulations and the relevant material data were included in the analyses. The aim of this study was to investigate the effect of an energy absorption structure on the crashworthiness characteristics of thin-walled structures under the effect of frictional force.

MATERIAL AND METHOD

Crash resistance indicators

The absorbed energy is a function of the crushing distance of the impact. The relationship between EA and impact displacement is expressed as in Equation 1;

$$EA = \int_0^{\delta} F(x)\, d\delta \tag{1}$$

The most important crash performance criterion is SEA. This value is the ratio of the total energy absorbed to the mass of the structure absorbing the impact energy. In almost all studies in the literature, the collision process is discussed over this value. SEA is defined as shown in Equation 2;

$$SEA = \frac{EA}{m} \tag{2}$$

Another important crash performance indicator is MCF, which indicates the average crush strength during the crash process. The MCF value is obtained as in Equation 3;

$$MCF = \frac{EA}{\delta} \tag{3}$$

Finally, CLE, the crash performance indicator analyzed in this study, represents the energy absorption efficiency, which indicates the degree of load stability during impact. CLE is formulated as in Equation 4;

$$CLE = \frac{MCF}{PCF} \tag{4}$$

Material properties

In the study, simulation models created using FEM based on the literature were carried out. The properties of the preferred materials were entered into the simulation models designed using the Johnson-Cook plasticity model. In this material model, the deformation property also includes the effect of temperature. Therefore, it is often used in collisions where high-speed collisions are analysed. The Johnson-cook model is as described in Equation 5 and Equation 6 (Johnson & Cook, 1983);

$$\sigma = \left(A + B{\varepsilon_p}^n\right).\left(1 + C.ln\frac{\dot{\varepsilon}}{\dot{\varepsilon_0}}\right)(1 - (T^*)^m) \tag{5}$$

$$T^* = \left[\frac{T - T_0}{T_m - T_0}\right] \tag{6}$$

The terms represent the following;

- A is the initial yield stress,
- B is the hardening constant,
- ε_p plastic strain
- n is the strain hardening exponent,
- C is the strain rate constant,
- m is the thermal softening exponent,
- ε is the strain rate
- ε_0 is the strain rate reference,
- T* is a coefficient that depends on ambient temperature, local temperature and melting temperature.
- T_m is the melting temperature
- T_0 ambient temperature

The model described by Johnson and Cook in 1980 is relatively simple and includes three different parts. The first part explains the connection between stress and strain. In the second part, the relationship between strain rate and stress is described. In the third part, the material temperature is related to the stress value during plastic deformation. The Johnson-Cook material model provides an accurate description of the plastic stress associated with high strain rates, even without accounting for changes in elastic properties (Ascenção et al., 2021). In the research, AA6061-T6 and DP600 steel steel were preferred as thin-walled structural materials. DP (Dual Phase) high strength steels (HSS) are widely used in automotive applications . These steels high to improve crashworthiness and reduce damage in accidentsoffer superior properties, including a combination of and good ductility, making them well suited for thin-walled structures in vehicles Aluminium 6061-T6 alloy has high strength and maintains its durability under various loading conditions. After hardening, the alloy exhibits high tensile strength, elasticity and fracture toughness. AL6061-T6 alloy is used in many applications in the automotive industry such as body parts, chassis components and wheels. Thanks to its light weight, high strength and

durability, it increases fuel efficiency and improves vehicle performance. Advanced high-strength sheets, called dual-phase (DP), reduce vehicle weights, lower fuel consumption and therefore contribute to the reduction of exhaust gas emissions. In addition, it is preferred by the automotive industry because it provides high strength and increases passenger safety. Dual-phase steels are easy to shape due to their higher strength, toughening rate, ability to absorb energy and lower yield strength compared to high-strength low-alloy steels. of DP steels strength The high strength allows for enhanced energy absorption during a collision, while their ductility allows them to undergo significant deformation without fracture (Adanur & Varol, 2023). The combination of these properties makes DP steels an excellent choice for improving the crashworthiness of automotive structures because they can effectively absorb and dissipate impact energy, reduce the probability of serious damage and improve occupant safety. In this study, DP 600 and AL6061-T6 material properties were used because they are effective in the dynamic impact performance of automotive parts. These materials are currently used by automotive manufacturers due to their advantages such as high impact energy absorption ability, high strength, easy welding and easier forming than other alloys. Also, the reason for choosing these materials in this study is to make a comparison between aluminium alloys and different steels in terms of their ability to absorb impact energy. The strength properties and Johnson-Cook parameters of the materials defined in the simulation are given in Table 1.

Table 1. Properties of materials and Johnson-Cook parameters

Parameters	**Materials**	
	AA-6061-T6 (Kaya & Özyurt, 2022; Lesuer et al., 2001)	**DP600(**Alipour et al., 2015)
A (MPa)	324	350
B (MPa)	114	902
n	0.42	0.189
C	0.002	0.0144
m	1.34	1.23
$T_{(m)}$ (K)	925	1673.2
Yield Strength (MPa)	276	417
Tensile Strength (MPa)	562	818
Density (kg/m^3)	2700	8000
Elastic Modulus (GPa)	70	207
Poisson Ratio	0.33	0.284

Simulation Model

It is based on the international study of Xu et al. (2022). In the simulation, the speed of the impactor was set to 50 km/h and the mass to 500 kg. The simulations were carried out in ANSYS Workbench/Explicit Dynamics module and an explicit type of analysis was used due to the high impact velocity. The thin-walled crash box structure was designed to be 160 mm long and 1 mm thick. This value is set depending on the amount of displacement of the allowable deformation. The crush box geometry models in the study were created from shell structures. The schematic view of the simulation model is shown in Figure 1.

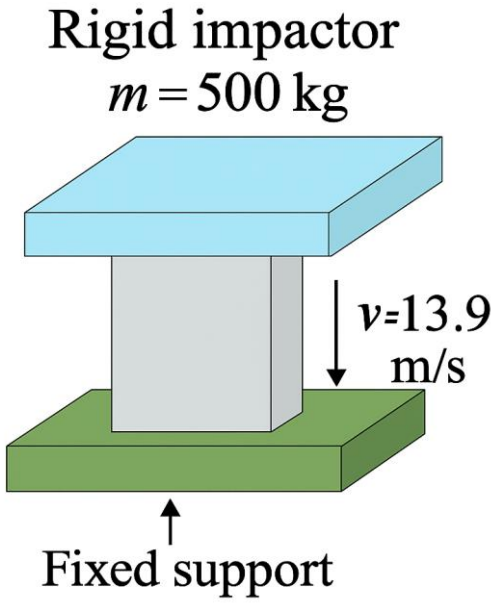
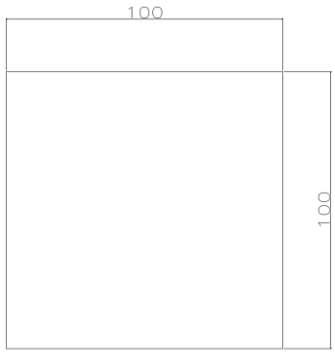
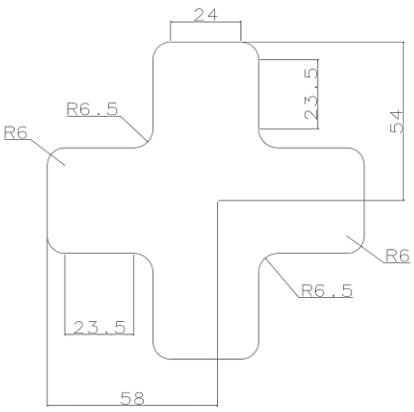


Figure 1. Image of the simulation model

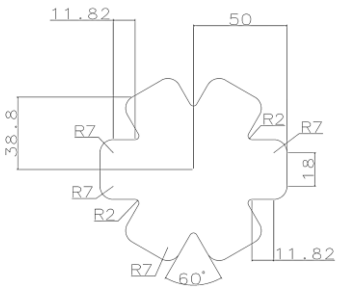
Firstly, a validation study was carried out to ensure the accuracy and reliability of the simulations. A basic square cross-section model was used for the verification study. After the energy absorption and crushing force values were obtained in the reference study, models with 3 different cross-sections as square, cross-section and flower cross-section were designed and simulations were performed by combining with 2 different materials. Then, thin-walled crash box structures were designed and included in the scope of the research. All crash boxes were designed to have equal cross-sectional circumferences with the same masses.



(a)



(b)



(c)

Figure 2. Dimensions of thin-walled structures a) square shape, b) plus shape, c) flower shape

In the simulations, the velocity was defined only in the direction of impact with the upper moving part, while other directions were limited. Fixed support was applied to the lower part and rigid material behaviour was defined with the upper moving part. The lower part and the upper part were bonded and the shell thickness factor was set to 1. Flexible material behaviour was entered into the crushing box to observe deformation and energy absorption performance values. The mesh structure created in FEM analyses is an important parameter that directly affects the accuracy and quality of the analysis. In this study, multizone method was used in the mesh structure and quadruple/triple element groups were formed with reference to the literature. Body sizing assignment was entered at the top and bottom. Reducing the element sizes increases the quality of the mesh structure and therefore the realism of the analysis. However, it also significantly increases the analysis times. After network independence studies, the general mesh size was set to 5 mm. Body sizing and the multiZone mesh method were applied to crashing box as the element size was 2.5 mm. In the analyses, the inputs of the collision times of all crash boxes to be deformed by 100 mm were used. The Average Element Quality value, which is one of the basic mesh criterion methods in Ansys and evaluated between 0 and 1, is higher than 0.7, indicating that the accuracy of the simulation is high. In this study, the average element quality value was found to be 0.99.

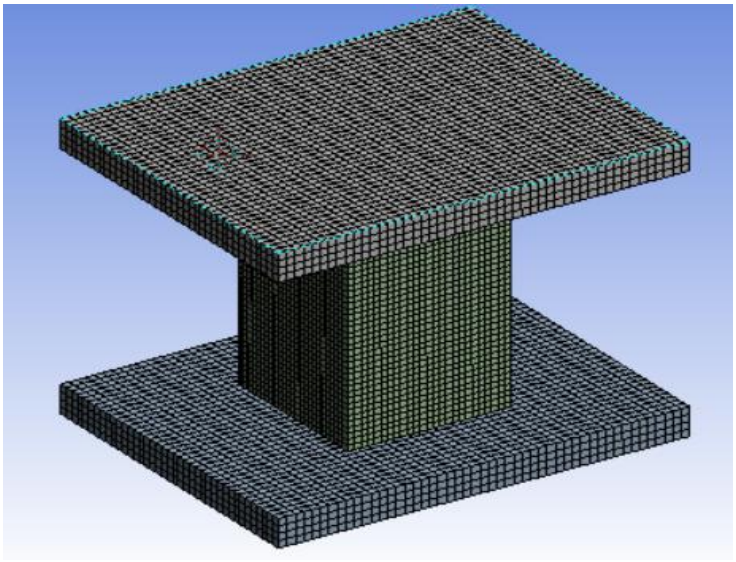


Figure 3. Mesh structure of the simulation model

Frictional contact is one of the most important factors affecting crash performance. At the moment of collision, this factor both causes the temperature to increase and affects the progress of the absorbed energy. In the simulation, frictional contact was determined when evaluating the contact of different parts with each other. However, the collision contact inside the crash box was not ignored and friction values for body interactions were also defined. Considering the literature, dynamic and static friction coefficients were determined as 0.2 and 0.3 respectively (Ahmad & Thambiratnam, 2009). Directional deformation, Energy probe (internal), Force reaction outputs were requested to get the analysis results.

FINDINGS AND DISCUSSION

Validation process findings

In crush analyses, from the moment the collision starts, the total kinetic energy of the system starts to convert into internal energy as the crash box deforms and crushes, but the total energy never changes. This progression in energy change is an important parameter in the accuracy of the simulation. The increase in internal energy and decrease in kinetic energy are consistent in all analyses performed in this study. In addition, while the accuracy of the study is supported by the stable energy transfer and high quality network structure in the simulations, a validation study was carried out by taking into account the work. In the validation study, the most basic model of the reference study, the square-sectioned thin-walled collision box model, was used (Yıldızhan et al., 2024). In the reference study, AL6061-T6, one of the two materials used in the current study, was used and therefore the evaluations made in the validation study were carried out on this material. The results of the simulations performed specifically for this model were compared with the reference study. The comparison of the two studies is shown in Table 2.

Table 2. Comparison of baseline and current simulation results

	EA(J)	**SEA (kJ/kg)**	**PCF (kN)**	**MCF (kN)**
Reference Study (Yıldızhan et al., 2024)	2141.8	12.39	116.95	21.418
Current Work	2230	12.96	124.2	22.3

Error rate (%)	4.1	4.6	6.1	4.1

Error rates in numerical studies should be below 10%. Otherwise, the accuracy of the simulation results may be questioned. As can be seen from Table 2, the error values in this validation study are 6.1% and below. These low values indicate the high accuracy and reliability of the analyses.

Comparison of combinations according to SEA (kJ/kg)

After the validation studies, combinations of thin-walled crash boxes were simulated according to the specified boundary conditions. 100 mm deformation scenarios, the energy absorbed by the combinations and the masses of the thin-walled crash box are shown in Table 3.

Table 3. Comparison of absorbed energy values of thin-walled crush boxes

Combinations	**EA(J)**	**Mass (kg)**
AL-S	2230	0.172
AL-S1	4077	0.172
AL-S2	5830	0.172
DP600-S	6193	0.51
DP600-S1	10751	0.5 1
DP600-S2	13139	0.51

When the simulation results are examined, the highest absorbed energy value is obtained in the DP600-S2 combination with 13139 J, while the lowest value is seen in the AL-S combination with 2230 J. The absorbed energy values of steel materials are higher than aluminium, but it is clear that steel masses are higher than aluminium. On the other hand, a significant increase in the absorbed energy value was obtained in both materials as the geometrical cross sections were changed. In combinations of two different materials, the combinations with flower cross-sections absorbed almost five times more collision energy than the combinations with square cross-sections. As the geometry changes, the material remains the same and the mass remains constant, the increased absorbed energy value is one of the most important positive results of this study. This simulation output is evaluated by the SEA value, which is the value of absorbed energy per unit mass. SEA values of the combinations are shown in Figure 4.

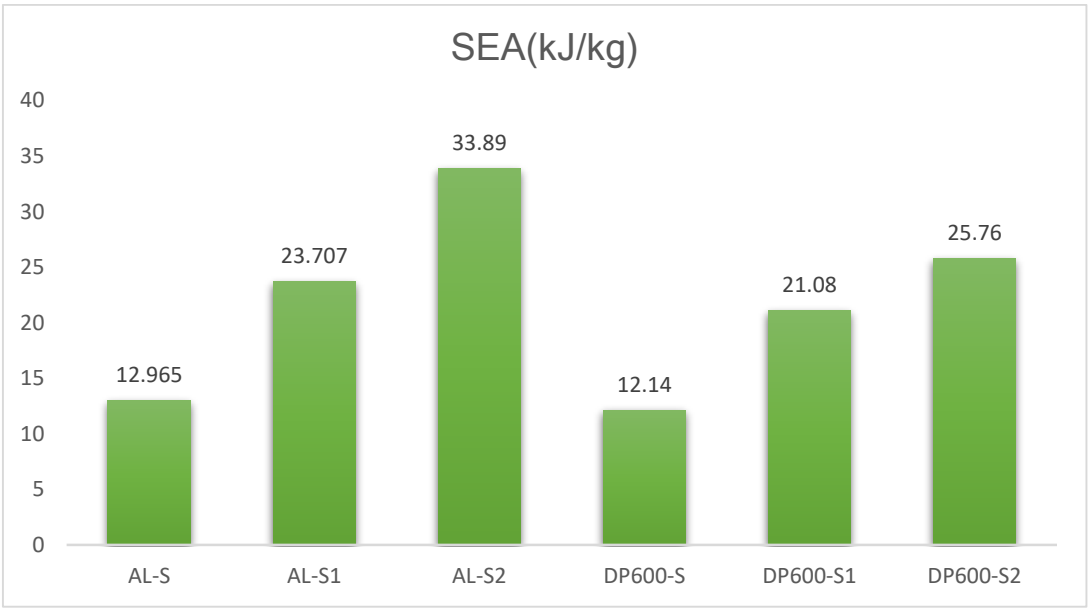


Figure 4. SEA values of combinations

When SEA values were analysed, the highest SEA value was obtained in AL-S2 combination with 33.89 kJ/kg, while the lowest value was seen in DP600-S combination with 12.14 kJ/kg. While it was understood that the SEA values of AL-6061-T6 material were higher than the others, when the results were evaluated according to the geometries, the SEA values of the flower section combinations were higher than the other models for both materials. When the combinations were analysed according to the flower cross-section geometry, the highest SEA value in the study was 33.89 kJ/kg in AL-S2 combination and 25.76 kJ/kg in DP600-S2 combination. When this situation is evaluated, it is determined that the SEA value in AL-S2 is 31.56% higher than DP600-S2. When comparing the plus sections, the AL-S1 combination yielded a value of 23.707, while the DP600-S1 yielded a value of 21.08 kJ/kg. When evaluating this situation, the value of the DP600-S1 section was 11.08% less than the value of the AL-S1 section. When comparing square cross-sections, the AL-S combination yielded a value of 12.965 kJ/kg, while the DP600-S yielded a value of 12.14 kJ/kg. When evaluating this situation, the value of the DP600-S cross-section was 6.36% less than that of the AL-S cross-section. Considering the results on AA-6061-T6 material, the square section combination is 12.965 kJ/kg, the plus section is 23.707 kJ/kg, the bloom is 33.89 kJ/kg. According to these results, it is understood that AL-6061-T6 material is more flexible than DP600 and has higher energy absorption capability (Akar et al., 2023). Although the strength of steel materials is higher, it is observed that the absorption performance of collision energy per unit mass is lower. In both materials, square cross-section geometries have lower SEA values than cross-section geometries. This result is in parallel with the results in the study of Gao et al. (2016). In addition, as in the absorbed energy values, SEA values also increased as the geometric cross-section changed. The reason for this parallel increase is that the cross-sectional circumference of each geometry is the same. The same cross-sectional circumference ensures that the mass remains the same in models where the same materials are defined. Thus, the crash performance of individual geometries can be directly evaluated.

Comparison of combinations according to PCF (kN)

The reaction force of the thin-walled crash box at the moment of impact is one of the important outputs of the process. Because this force is actually parallel to the collision force felt by the passenger in the vehicle at the time of the collision. Therefore, a high PCF value is undesirable.

The graph of PCF values obtained in the simulations of square section structure combinations is given in Figure 5.

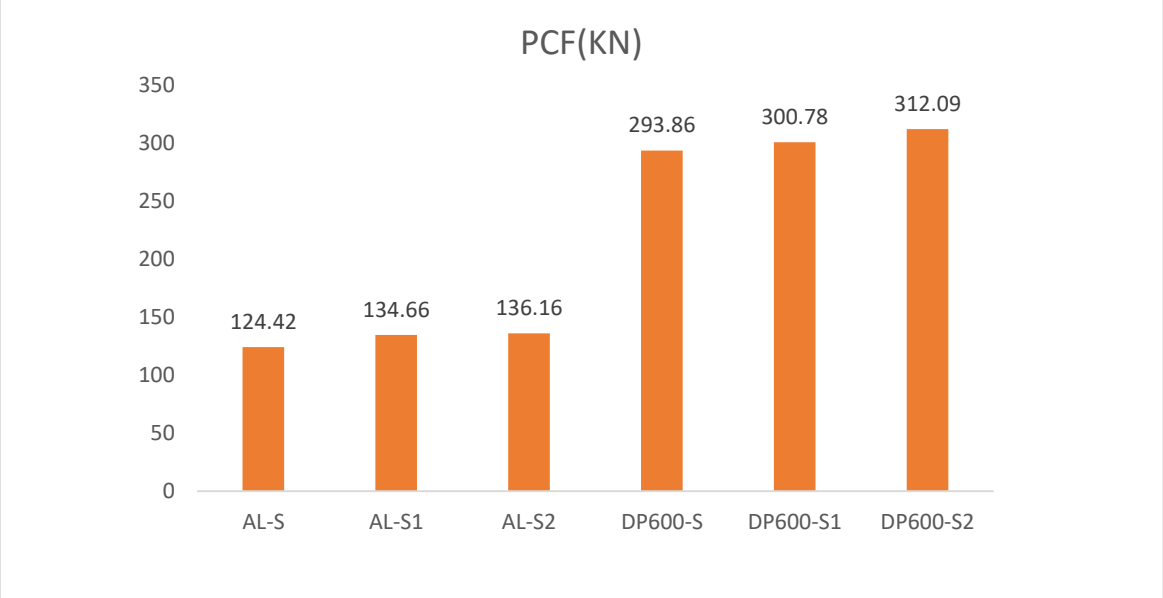


Figure 5. PCF values of combinations

When the results are analysed, the highest PCF value was obtained in DP600-S2 combination with 312.09 kN, while the lowest value was observed in AL-S combination with 124.2 kN. It is noteworthy that the PCF values of DP600 material are very high compared to other material. The PCF value of AL-S2 is 1.11% higher than the PCF value of AL-S1 model. When comparing the PCF values of the plus sections, the value of the AL-S1 model was measured as 134.66 kN, while the value of the DP600-S1 model was measured as 300.78 kN. When this situation is evaluated, it is seen that the value of the DP600-S1 model is 55.23% higher than the value of the AL-S1 model. When comparing the PCF values of the flower sections, the value of the AL-S2 model was measured as 136.16 kN, while the value of the DP600-S2 model was measured as 312.09 kN. When this situation is evaluated, it is seen that the value of the DP600-S2 model is 56.37% higher than the value of the AL-S2 model. Considering the effect of geometry on the PCF values, the highest values were observed in the models with floral cross-sections, while the lowest PCF values were found in the combinations with square cross-sections. In addition, one of the other interesting results was that the PCF value increased as the geometrical pattern in the cross-section of the boxes changed. The trend did not change in DP600, the material with the highest peak force between the two materials. The values of the flower cross-section geometry in AL6061-T6 material were close to those of the plus cross-section geometry but slightly lower, while the maximum forces started to decrease in square cross-sections. The low PCF values of AL-6061-T6 were one of the positive results for the material. The easily deformable and flexible nature of aluminum ensures that peak forces remain low. Although it absorbed less energy in the same geometry, it showed better crash performance due to its light weight per unit mass and fine grain structure.

Comparison of combinations according to CLE

The MCF value is the ratio of energy absorbed in a collision to deformation in a collision. The results of this parameter vary depending on the deformation characteristics of the combinations when absorbing energy in the collision process. The MCF results of the thin-walled crushing boxes in the study are presented in Table 4.

Table 4. MCF values of combinations

AL-6061-T6 Combinations	MCF (kN)	DP600 Combinations	MCF (kN)
AL-S	22.3	**DP600-S**	61.93
AL-S1	40.77	**DP600-S1**	107.51
AL-S2	58.3	**DP600-S2**	131.39

Since the deformations are equal in this study, the MCF values coincide with the energy absorption values given in Table 4. The ratio of MCF to PCF gives the CLE value and this parameter provides the most important results in terms of the crash performance of the models, independent of the mass of the thin-walled crash box. While the absorbed energy is expected to increase during the collision process, peak reaction force values are desired to be low. The CLE value is shown as the parameter formed by these two parameters together and gives the clearest idea about the impact properties of thin-walled crash boxes. The graph of the CLE values calculated as a result of the simulation of the structure models made in the study is shown in Figure 6.

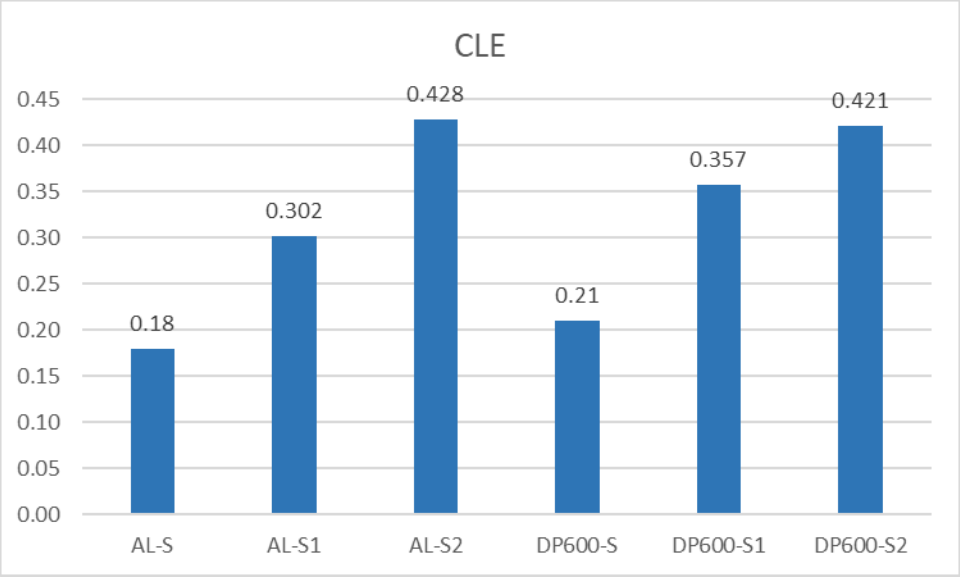


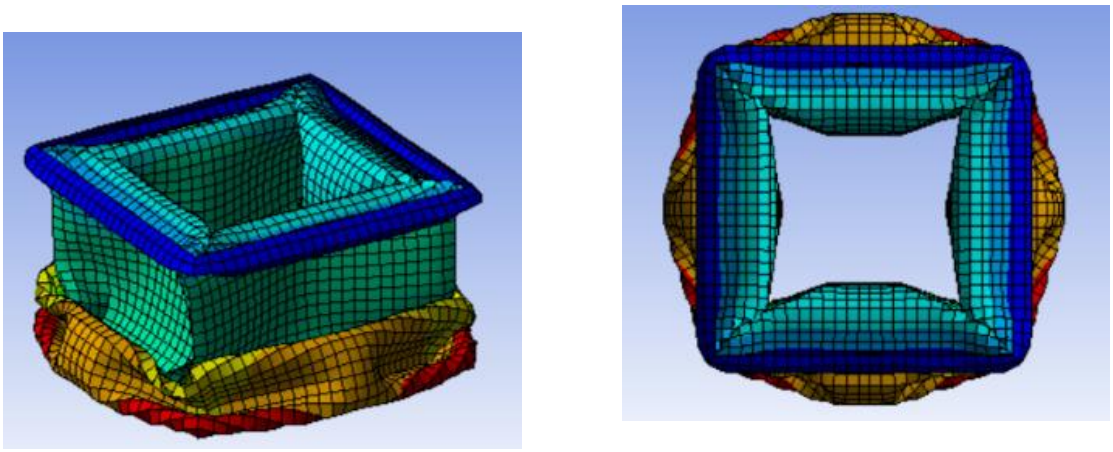
Figure 6. CLE values of combinations

When the results were evaluated according to the material, it was found that there was an increasing trend in AL6061-T6 and DP600 materials. When the results were evaluated according to the geometries, DP600 steel gave a result of 1.64% less than the AL6061-T6 aluminium alloy material in flower cross-section geometries. When the CLE values are evaluated among each other, the output of 0.428 was obtained in the cross-sectional geometry with AL-S2 coded AL6061-T6 material. When comparing square sections, the AL-S section

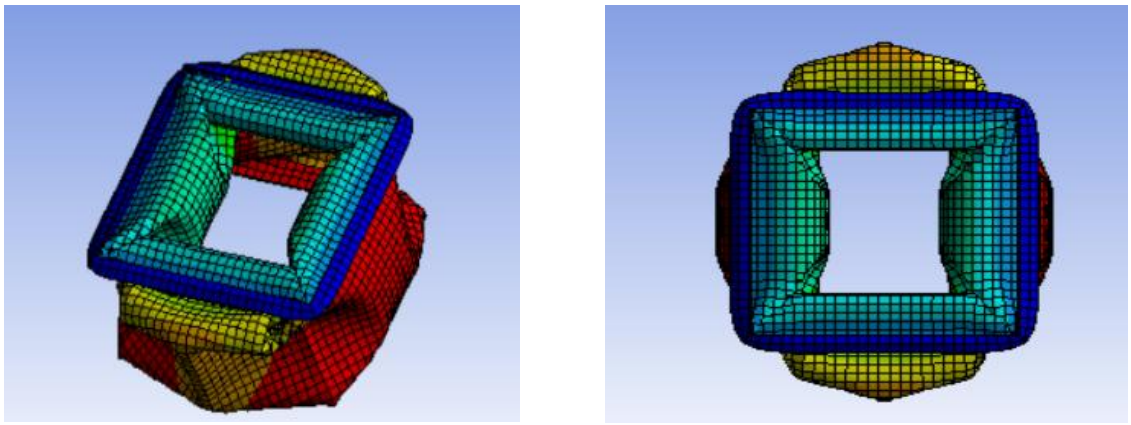
yielded a value of 0.179, while the DP600-S model gives a value of 0.21. When evaluating this situation, the AL-S model yielded a result that was 14.76% lower than the DP600-S model. When the plus sections are compared, the AL-S1 model yields a value of 0.302, while the DP600-S1 model has a value of 0.357. When this situation is evaluated, the AL-S1 model gives a result that is 15.41% less than the DP600-S1 model.

Deformations of models

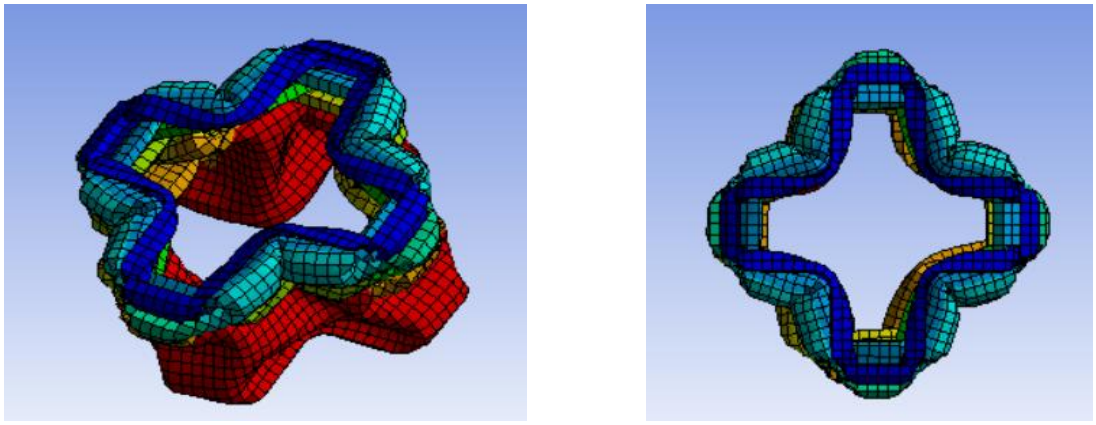
In the study, when deformation images were examined, it was clear that models made from DP600 exhibited more regular and symmetrical crushing behaviour compared to models made from AL6061-T6. Due to its lower yield strength, the AL6061-T6 material experiences early buckling and localised collapse, while DP600 exhibits a more controlled and layered deformation pattern. In square cross-sections, the AL6061-T6 model undergoes unstable deformation with lateral expansion at the base, while the DP600 model maintains its geometric integrity and forms a more stable collapse mode. The distribution of deformation zones is more homogeneous in DP600, directly contributing to higher energy absorption capacity. Notably, clear folding lines and symmetrical buckling are observed in DP600 models. This demonstrates that high-strength steels provide better deformation control under impact. Visual analysis confirms that material properties significantly influence the nature of structural collapse. Models produced with DP600 offer a more predictable deformation process with improved energy distribution. As a result, DP600 provides a distinct structural advantage in terms of deformation behaviour. The DP600 structure, thanks to its higher yield strength and strain hardening properties, withstands impact for longer before completely collapsing, thus providing more controlled energy absorption. AL6061-T6, despite being lighter, breaks down earlier and absorbs less energy, which indicates lower impact resistance for applications requiring high impact resistance. Deformation images of all combinations are shown in Figure 7.



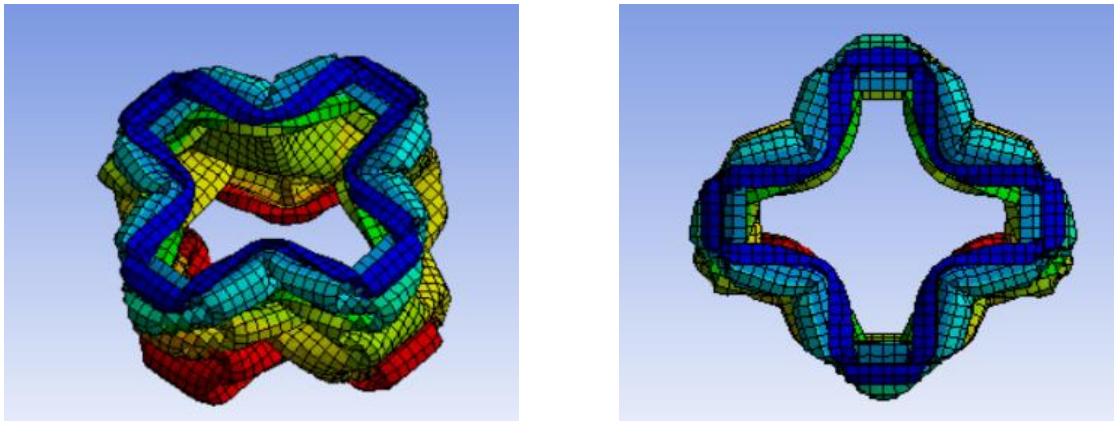
a)



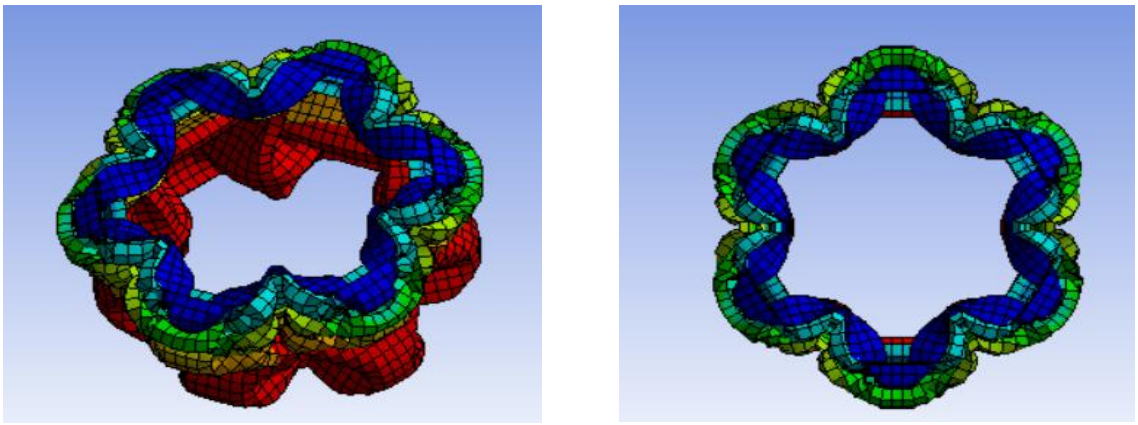
b)



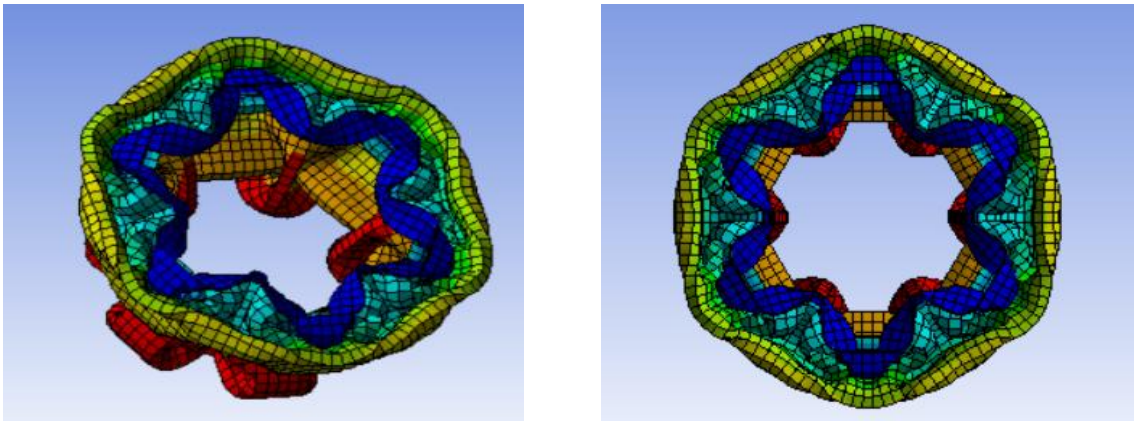
c)



d)



e)



f)

Figure 7. Deformation images of models a) AL-S, b) DP600-S, c) AL-S1, d) DP600-S1, e) AL-S2, f) DP600-S2

CONCLUSIONS

Thin-walled crash boxes are critical structural elements that increase occupant safety due to their high energy absorption capacity in the event of a collision. These structures reduce the force transmitted to other parts of the vehicle by damping the impact through deformation. This study aims to improve the energy absorption performance of crash boxes by using different geometries (square, plus and flower cross-section) and materials. The effect of geometry and material selection on crash performance was emphasised and the importance of reaching the optimum design by considering the balance of lightness, cost and performance was revealed. The findings shed light on future geometric optimisation studies. The results obtained after all these studies and the suggestions made for future studies on this subject are listed below.

- Although aluminium alloy 6061-T6 material absorbs less energy than DP600 steel, it has the highest SEA value due to its light weight. When EA values are compared, it is determined that AL6061-T6 material absorbs half as much energy compared to DP600 steel.

- The best crash performance independent of mass is seen in DP600 material, but it is reported that DP600 steel lags behind other materials in terms of SEA value, which represents the mass-dependent absorption energy.
- While the PCF level was the highest in the floral section structures, the lowest PCF was obtained in the square section models. It should be noted that the PCF value increases as the geometric model in the section changes, but this increase is not very high. When the plus section models and square section models were compared with each other, superior results were found in both SEA and MCF values of the plus section models. The PCF values of the plus-section models were lower than the square-section models, but this is a positive situation in terms of crash performance.

In summary, it was found that as the bending in the section increases, the absorbed energy increases but the peak force also increases. AL6061-T6, a flexible alloy, showed better collision energy absorption performance depending on the mass. The results obtained in the study conclude that the performance of collision boxes can be increased with the combination of different materials and different cross-section models.

REFERENCES

Abramowicz W, Jones N. (1984). Dynamic Axial Crushing of Circular Tubes. International Journal of Impact Engineering. 2. 263-281. 10.1016/0734-743x (84)90010-1.

Abramowicz W., Jones N. (1986). Dynamic Progressive Buckling of Circular and Square Tubes. International Journal of Impact Engineering. 4. 243-270. 10.1016/0734-743x (86)90017-5.

Abramowicz W, Jones N. (1997). Transition from Initial Global Bending to Progressive Buckling of Tubes Loaded Statically and Dynamically. International Journal of Impact Engineering. 19. 415-437. 10.1016/s0734-743x (96)00052-8.

Adanur Ö., Varol F. (2023). Investigation of The Effect of Friction Force on The Energy Absorption Characteristics of Thin-Walled Structures Loaded with Axial Impact Force. Materials Today Communications. 36. 106420. 10.1016/j.mtcomm.2023.106420

Ahmad Z., Thambiratnam D.P. (2009). Crushing Response of Foam-Filled Conical Tubes under Quasi-Static Axial Loading. Materials and Design. 30. 2393–2403. 10.1016/j.matdes.2008.10.017

Akar M.A., Kumlu U., Yıldızhan S. (2023). Numerical Investigation of Crash Behavior of Vehicle Side Door Beams under High-Speed Pole Side Impacts. Proceedings of the Institution of Mechanical Engineers. Part D: Journal of Automobile Engineering. 237. 3408–3418. 10.1177/09544070221145523

Ali M., Ohioma E., Kraft F., Alam K. (2015). Theoretical, Numerical, and Experimental Study of Dynamic Axial Crushing of Thin-Walled Pentagon and Cross-Shape Tubes. Thin-Walled Structures. 94. 253-272. 10.1016/j.tws.2015.04.007.

Alipour, R., Farokhi Nejad A., Izman S. (2015). The Reliability of Finite Element Analysis Results of the Low Impact Test in Predicting the Energy Absorption Performance of Thin-Walled Structures. Journal of Mechanical Science and Technology. 29. 2035–2045. 10.1007/s12206-015-0424-3.

Ascenção F.A., Silveira M.E., Pockszevnicki B.C. (2021). Evaluation of the Effects of the Forming Process on the Simulation of a Crash Test of an Automotive Bumper. SAE Technical Paper.

Deulgaonkar V. R., Kulkarni M. S., Khedkar S., Kharosekar S., Sadavarte V. (2020). Crash Analysis of Bus Body Structure Using Finite Element Analysis: International Journal of Vehicle Structures and Systems 12. 312–316. 10.4273/ijvss.12.3.17.

Gao, Q., Wang L., Wang Y., Wang C. (2016). Crushing Analysis and Multiobjective Crashworthiness Optimization of Foam-Filled Ellipse Tubes under Oblique Impact Loading. Thin-Walled Structures. 100, 105–112. 10.1016/j.tws.2015.11.020

Johnson, G.R. and Cook, W.H. (1983) A Constitutive Model and Data for Metals Subjected to Large Strains, High Strain Rates, and High Temperatures. Proceedings 7th International Symposium on Ballistics, The Hague, 19-21 April 1983, 541-547.

Kaya, D., Özyurt E. (2022). Design and Optimization of Impact Attenuator for a Formula SAE Racing Car. Sigma Journal of Engineering and Natural Sciences. 40. 390–401. 10.14744/sigma.2022.00041.

Lesuer, D.R., Kay G.J., LeBlanc M.M. (2001). Modeling Large Strain, High Rate Deformation in Metals. UCRL-JC-134118. Livermore, CA: Lawrence Livermore National Laboratory.

Lopes R., Ramos N.V., Cunha R., et al. (2023). Coach Crashworthiness and Failure Analysis During A Frontal Impact. Engineering Failure Analysis. 151. 107369 10.1016/j.engfailanal.2023.107369

Marzbanrad, J., Mehdikhanlo M., Saeedi Pour A. (2009). An Energy Absorption Comparison of Square, Circular, and Elliptic Steel and Aluminum Tubes under Impact Loading. Turkish Journal of Engineering and Environmental Science. 33. 159–166. 10.3906/muh-0904-11.

Nia A.A., Hamedani J.H. (2010). Comparative Analysis of Energy Absorption and Deformations of Thin-Walled Tubes with Various Section Geometries. Thin-Walled Structures. 48. 946-954. 10.1016/j.tws.2010.07.003.

World Health Organization, (2018). *Global Status Report on Road Safety 2018*.

Xu, F., Yu K., Hua L., Niu X. (2022). Crashworthiness Design of Crash Box Filled with Negative Poisson's Ratio Based on Horn Structure. Mechanics of Advanced Materials and Structures. 29. 6403–6420. 10.1080/15376494.2021.1978594.

Yıldızhan S., Kumlu U., Akar M.A., Keskin A., Hukumdar O. (2025). Numerical Crashworthiness Analysis of Improved Elliptical Cross-Section Straight and Tapered Thin-Walled Crashing Boxes. Mechanics Based Design of Structures and Machines. 53. 4294–4311. 10.1080/15397734.2024.2447759

CRASHWORTHINESS ANALYSIS OF HORIZONTAL AND VERTICAL ELLIPTICAL CROSS-SECTIONAL BEAMS IN VEHICLE DOORS

Umut KUMLU

Çukurova University, Faculty of Engineering, Department of Automotive Engineering, Adana, Turkey

ORCID ID: https://orcid.org/0000-0001-7624-6240

Ömer HÜKÜMDAR

Çukurova University, Faculty of Engineering, Department of Automotive Engineering, Adana, Turkey

ORCID ID: https://orcid.org/0000-0002-0806-3562

Mikail KERSİN

Çukurova University, Faculty of Engineering, Department of Automotive Engineering, Adana, Turkey

ORCID ID: https://orcid.org/0009-0006-5996-3479

Mustafa Atakan AKAR

Çukurova University, Faculty of Engineering, Department of Automotive Engineering, Adana, Turkey

ORCID ID: https://orcid.org/0000-0002-0192-0605

Ali KESKİN

Çukurova University, Faculty of Engineering, Department of Automotive Engineering, Adana, Turkey

ORCID ID: https://orcid.org/0000-0002-1089-3952

Abstract

Side impacts are among the most critical types of vehicle crashes due to the confined distance between the door structure and the occupants, resulting in a high probability of injury. In response to this, automotive engineers are focusing on innovative door beam designs that enhance crash performance. This study investigates twelve different configurations of door beams using two primary cross-sectional designs: horizontal elliptical (HE) and vertical elliptical (VE). Beam designs were varied by angle (10°, 20°, 25°) and wall thickness (1.4 mm and 1.8 mm), and all structures were modeled using AL5083-H116 material. Three-dimensional modeling was performed using CATIA, and side collision simulations were conducted at 32 km/h using the ANSYS Explicit Dynamics module. Crashworthiness performances of beams was evaluated based on Specific Energy Absorption (SEA), peak and plastic deformation, and

maximum reaction force. The lowest plastic deformation was observed in the AA25HE18 configuration with 46.6 mm, while the lowest reaction force, also observed in AA25HE14, was 20276 N. These results identify the AA25HE14 design as the most efficient configuration providing excellent energy absorption while maintaining favorable structural integrity and impact response.

Keywords: Vehicle side door beams, AL5083-H116, side collision, finite element analysis, crash energy absorption

Introduction

In recent years, the number of injuries and fatalities resulting from vehicle collisions has shown a noticeable rise. While front end collisions are often assumed to be the most lethal, studies indicate that side impacts are associated with a significantly higher fatality rate (Ceyhan & Yıldız, 2023; Xu et al., 2022). Despite the implementation of numerous traffic regulations worldwide, preventing road accidents remains a persistent challenge (Akar et al., 2023). Consequently, efforts have increasingly shifted toward minimizing the severity of crash consequences rather than merely focusing on prevention. In the automotive sector, safety regulations for passenger vehicles play a crucial role in reducing fatalities (Ghandianlou & Abdullah, 2013). These standards are designed to ensure maximum protection for both occupants and pedestrians during collisions, prompting manufacturers to develop crash-optimized designs (Dhaneesh & Prabakaran, 2016). Among all types of impacts, frontal, rear, and lateral side collisions are considered the most dangerous due to the limited crumple zones. In such impacts, the proximity of the vehicle door to the occupant significantly elevates the risk of severe injury (Long et al., 2019). This spatial limitation means that parts of the body such as the head, neck, ribs, shoulders, and legs are more vulnerable in side collisions compared to frontal crashes, where components like the engine, bumper, and hood absorb a considerable portion of the impact energy (Nemani & Arakerimath, 2015; Saraf & Bajaj, 2017). Side door beams, which are designed to reinforce the door structure, exhibit slight outward bending upon impact. These beams absorb and redirect the collision energy, playing a key role in safeguarding the passenger compartment (Černiauskas et. al., 2010). However, safety performance varies between manufacturers, prompting the establishment of regulatory bodies to assess and rate vehicle safety levels. In Europe, this responsibility is carried out by Euro NCAP, while in the United States it falls under the domain of NHTSA. These organizations not only test safety performance but also help shape production standards and guide consumer choices. Euro NCAP conducts side crash evaluations through two main test scenarios: the Mobile Deformable Barrier (MDB) test and the Pole Impact test. In the MDB test, a moving barrier collides with the stationary vehicle at 60 km/h, whereas in the pole test, the vehicle crashes into a rigid pole with a diameter of 254 mm at 32 km/h (Euro NCAP, 2020a; Euro NCAP, 2020b). A review of the literature reveals various studies aimed at improving the crashworthiness of side door beams. For instance, Dhaneesh and Prabakaran (2016) used LS-DYNA to simulate side impacts with different materials, achieving a 40% improvement in energy absorption and a 25% reduction in deformation. More et al. (2020) examined different materials and cross-sections, concluding that M-shaped beams made from AISI 1008 steel exhibited superior energy absorption and strength. Similarly, Ponnadai (2018) evaluated ten cross-sectional designs and three materials, identifying circular beams made of cast alloy steel and AISI 1060 as the most effective in reducing deformation and enhancing energy absorption. Building on the gaps identified in previous research, this study investigates the crash performance of door beams designed with elliptical cross-sections. This study investigates 12 different configurations of door beams using two primary cross-sectional designs: horizontal elliptical (HE) and vertical elliptical (VE). Beam designs were varied by angle (10°, 20°, 25°) and wall thickness (1.4 mm and 1.8 mm),

and all structures were modeled using AL5083-H116 material. Three-dimensional modeling was performed using CATIA, and side collision simulations were conducted at 32 km/h using the ANSYS Explicit Dynamics module. Crashworthiness performances of beams was evaluated based on Specific Energy Absorption (SEA), peak and plastic deformation, and maximum reaction force.

Material

To accurately capture the behavior of materials under high-speed collision conditions, the Johnson-Cook material model was employed within the finite element analysis framework. This model is particularly suitable for dynamic simulations as it accounts for strain hardening, strain rate sensitivity, and thermal softening effects, which are all significant factors during crash scenarios. The Johnson-Cook model describes the flow stress as a function of plastic strain, strain rate, and temperature, and is represented by the following equations (Johnson & Cook, 1983):

$$\sigma = (A+B\varepsilon_p{}^{n}) \cdot (1+C.\ln\frac{\dot{\varepsilon}}{\dot{\varepsilon_0}}) \cdot (1-(T^*)^m) \quad (1)$$

$$T^* = [\frac{T-T_0}{T_m-T_0}] \quad (2)$$

In these equations, the term *a* represents the initial yield stress of the material, while *b* and *n* define the strain hardening behavior. The parameter *C* expresses the sensitivity of the material to strain rate, and *m* indicates how the material softens with increasing temperature. The plastic strain is denoted by ε_p, the plastic strain rate by ε, and the reference strain rate by $\dot{\varepsilon}_0$. The normalized temperature T^* is calculated using the current temperature *T*, the reference (room) temperature T_0, and the melting temperature T_m.

In this study, AL5083-H116 was selected as the material for the door beams due to its favorable characteristics under dynamic loading. This high-strength marine-grade aluminum alloy offers excellent corrosion resistance, good ductility, and high energy absorption capacity, making it highly suitable for automotive crash applications. The Johnson–Cook material parameters and mechanical properties of AL5083-H116 used in this study were adopted from the literature, specifically based on the work by Rai et al. (2021), which investigated the behavior of this alloy under dynamic loading conditions. The Johnson-Cook parameters and mechanical properties of AL5083-H116 used in the simulations are presented in Table 1.

Table 1. Features of material

Material Features	**Aluminum 5083-H116**
Density (kg/m^3)	2650
Young's Modulus (MPa)	72000
Poisson ratio	0.33
Initial Yield Stress (A) (MPa)	167
Hardening Constant (B) (MPa)	596
Hardening Exponent (n)	0.551
Strain Rate Constant (C)	0.001
Thermal Softening Exponent (m)	0.859
Melting Temperature (T_m)(°C)	570
Reference Strain Rate ($\dot{\varepsilon}_0$)	1

Method

In this study, CATIA V5 R21 was employed as the Computer-Aided Design (CAD) software to generate the geometric models of the door beams and the impact setup. The ANSYS Workbench platform, which operates based on the Finite Element Method (FEM), was utilized for the analysis phase. Ensuring seamless integration between the CAD environment where the geometry is defined and the FEM based simulation environment is essential for achieving accurate and efficient design and analysis workflows. This integration not only accelerates the design analysis cycle but also contributes to cost reduction and improvements in product quality.

Engineers commonly utilize CAD tools to construct detailed models and CAE (Computer-Aided Engineering) systems to perform structural and performance analyses. The transfer of CAD-based designs into FEM software facilitates the idealization and preparation of the geometry for simulation. This methodology enables early evaluation and optimization of design alternatives prior to physical prototyping, resulting in significant savings in both development time and resources.

The support beams were modeled with a length of 900 mm and placed at angles of 10°, 20°, and 25°. In addition, The semi-major axis dimension of the ellipse is determined as 24 mm and the semi-minor axis is determined as 15 mm. These combinations of beam length and inclination were specifically selected to evaluate their influence on energy absorption performance during impact simulations. Variations in beam geometry, such as increased length and angle, can significantly affect deformation behavior and energy dissipation capacity. These parameters are expected to contribute to a more effective distribution of collision forces, thereby enhancing occupant safety. Angels and lengths of beams is shown in Figure 1.

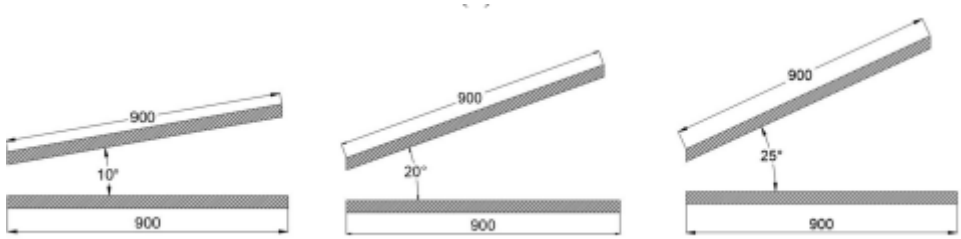


Figure 1. Angles and lengths of upper and lower beams

To simulate a side impact scenario, the model incorporated **horizontally and vertically elliptical cross-sectional beams**, representing innovative structural door reinforcements. A **rigid cylindrical pole with a diameter of 254 mm** was used as the impactor, in accordance with **Euro NCAP pole test protocols**. The elliptical geometry allowed for a comparative evaluation of orientation effects on crash performance under identical boundary and loading conditions. A three-dimensional view of the beams and the impacting object is presented in Figure 3.

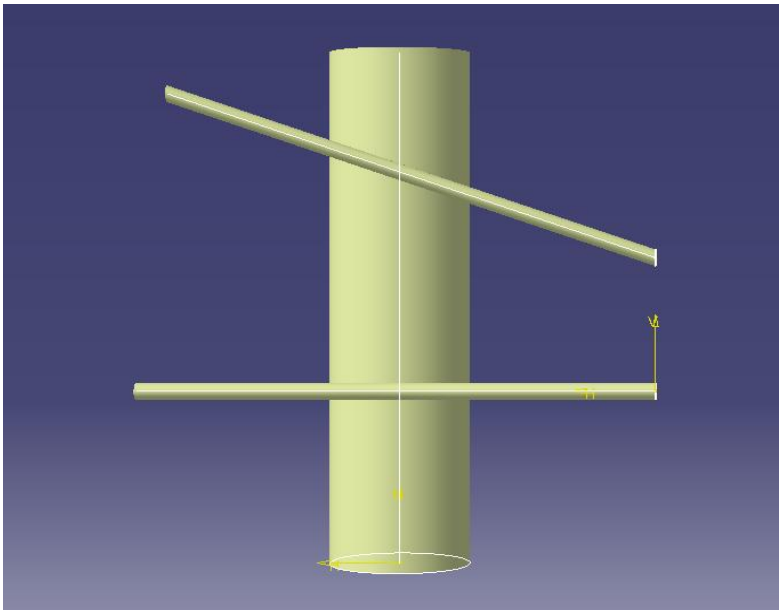


Figure 3. The view of the model platform design used in the simulations

To ensure a fair comparison in terms of crash performance, the elliptical cross-sectional designs used in this study were geometrically calibrated to possess the same cross-sectional circumference. This equivalence guarantees mass consistency among different cross-sectional configurations, which is crucial for evaluating crashworthiness under equal material and weight conditions.

In the context of vehicle side collisions, understanding how impact energy is dissipated is essential to evaluating crashworthiness. During a collision, the kinetic energy of the moving impactor is partially transformed into internal energy through the deformation of the structure it strikes. This energy conversion mechanism reflects how effectively a structural component, such as a door beam, absorbs crash energy.

The absorbed energy (Ue), which is the portion of kinetic energy converted into deformation energy, can be expressed as:

$$U_e = \frac{1}{2}\int_V \sigma \cdot \varepsilon \cdot dV = \frac{1}{2} \cdot K_{eq} \,.\, \delta^2_{\max} \tag{5}$$

Where:

- σ is the stress tensor,
- ε is the strain tensor,
- K_{eq} is the equivalent stiffness of the structure
- δ^2_{max} is the maximum deformation experienced by the beam.

This equation implies that the energy absorbed by a beam is directly related to its stiffness and the square of its maximum deformation. The law of energy conservation further states that the total initial kinetic energy of the impactor is equal to the sum of its post-impact kinetic energy and the absorbed energy by the structure:

$$\frac{1}{2} m_p \cdot v_1^2 = \frac{1}{2}\left(m_p\right) \cdot v_2^2 + \frac{1}{2} . \delta^2_{\max} \tag{6}$$

Where:

- m_p is the mass of the impactor,

- v_1 is the initial velocity before impact,
- v_2 is the rebound velocity after impact.

SEA is a widely used crashworthiness metric, defined as the absorbed energy per unit mass of the structure:

$$SEA = \frac{U_e}{m} \quad (7)$$

Where m is the total mass of the deformed beam. SEA is especially significant in automotive applications where minimizing weight while maximizing energy absorption is a design priority.

Simulation Model

In this study, boundary conditions were defined to realistically simulate the behavior of horizontally and vertically elliptical cross-sectional beams under side impact. The ends of all elliptical beams were fully fixed to ensure that deformation would primarily occur in the central region during impact. The cylindrical impactor was modeled as a rigid body to eliminate any deformation on its side and ensure complete energy transfer to the elliptical beam. The motion of the impactor was constrained in all directions except for the impact axis, allowing linear movement toward the center of the beam.

The mesh configuration was carefully arranged using a combination of quadrilateral and triangular elements generated through the multizone method. Following a mesh convergence study, the element size was determined to be 5 mm. This decision was based on the Average Element Quality (AEQ), a meshing criterion in ANSYS, which ranges between 0 and 1. A value above 0.7 indicates that the mesh quality is sufficient to produce accurate simulation results. In the experimental setup, the mesh structure applied to model AA10HE14 yielded an AEQ value of 0.9898 with 26410 elements and 26580 nodes. Due to the geometric simplicity of the collision models, a high AEQ value was achieved. Figure 4 illustrates a sample mesh structure and the direction of impact.

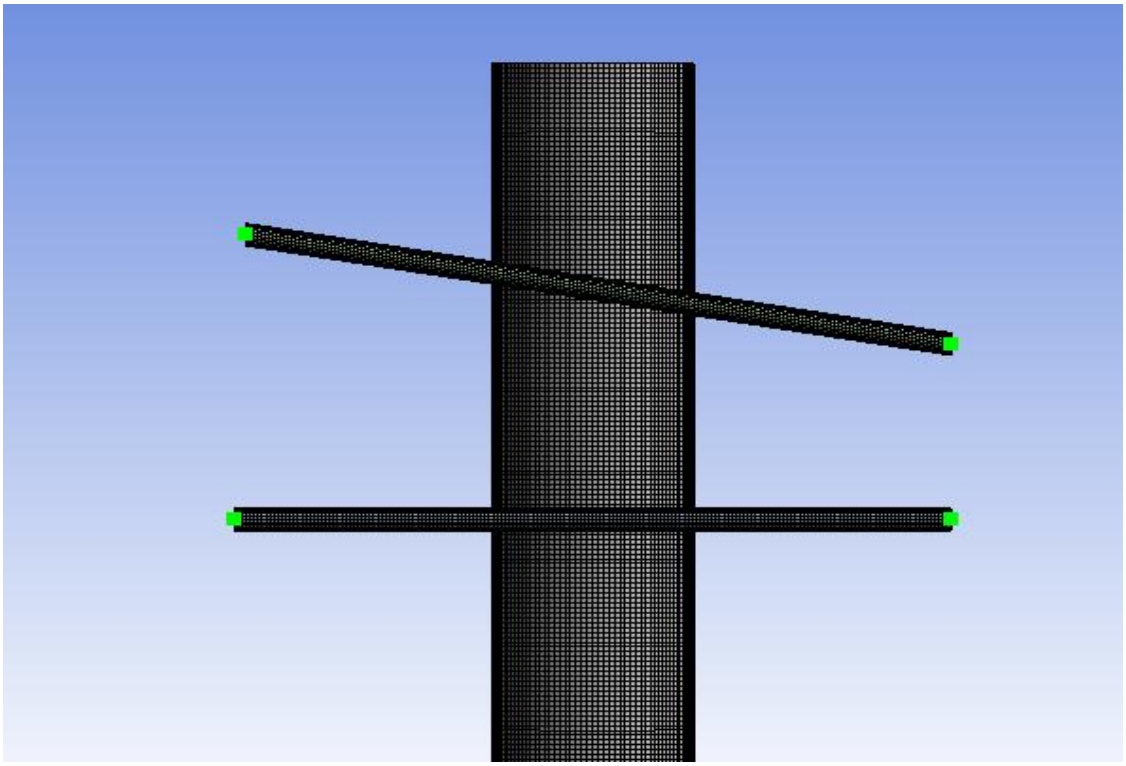


Figure 4. Mesh structure

Frictional contact was defined between the colliding surfaces. The interaction between the impact pole and the rigid wall was modeled using kinetic and dynamic friction coefficients of 0.2 and 0.1, respectively values frequently adopted in the literature. The total simulation time was set to 20 milliseconds, which was sufficient for complete kinetic energy transfer during the collision process.

The crash simulations aimed to examine how different angle combinations influence the deformation modes, energy absorption capacity, and structural strength of the elliptical beams. All simulation combinations created are coded for comparison purposes. Table 2 presents the coded combinations of support beams used in this study.

Table 2. Codes of beam combinations

Codes	Expansions of codes
AA10HE14	Aluminum 5083-H116 beam with a 10° angle, horizontally oriented elliptical cross-section, and 1.4 mm wall thickness.
AA20HE14	Aluminum 5083-H116 beam with a 20° angle, horizontally oriented elliptical cross-section, and 1.4 mm wall thickness.
AA25HE14	Aluminum 5083-H116 beam with a 25° angle, horizontally oriented elliptical cross-section, and 1.4 mm wall thickness.
AA10VE14	Aluminum 5083-H116 beam with a 10° angle, vertically oriented elliptical cross-section, and 1.4 mm wall thickness.
AA20VE14	Aluminum 5083-H116 beam with a 20° angle, vertically oriented elliptical cross-section, and 1.4 mm wall thickness.
AA25VE14	Aluminum 5083-H116 beam with a 25° angle, vertically oriented elliptical cross-section, and 1.4 mm wall thickness.
AA10HE18	Aluminum 5083-H116 beam with a 10° angle, horizontally oriented elliptical cross-section, and 1.8 mm wall thickness.
AA20HE18	Aluminum 5083-H116 beam with a 20° angle, horizontally oriented elliptical cross-section, and 1.8 mm wall thickness.
AA25HE18	Aluminum 5083-H116 beam with a 25° angle, horizontally oriented elliptical cross-section, and 1.8 mm wall thickness.
AA10VE18	Aluminum 5083-H116 beam with a 10° angle, vertically oriented elliptical cross-section, and 1.8 mm wall thickness.
AA20VE18	Aluminum 5083-H116 beam with a 20° angle, vertically oriented elliptical cross-section, and 1.8 mm wall thickness.
AA25VE18	Aluminum 5083-H116 beam with a 25° angle, vertically oriented elliptical cross-section, and 1.8 mm wall thickness.

Results and Discussion

Crash simulations were conducted to evaluate the crashworthiness performance of door beams with horizontally and vertically elliptical cross-sections under lateral impact conditions. All beams were designed with equal cross-sectional areas to ensure mass consistency and subjected to the same boundary and loading conditions. The graph of SEA values representing the energy absorbed regardless of mass is shown in Figure 5.

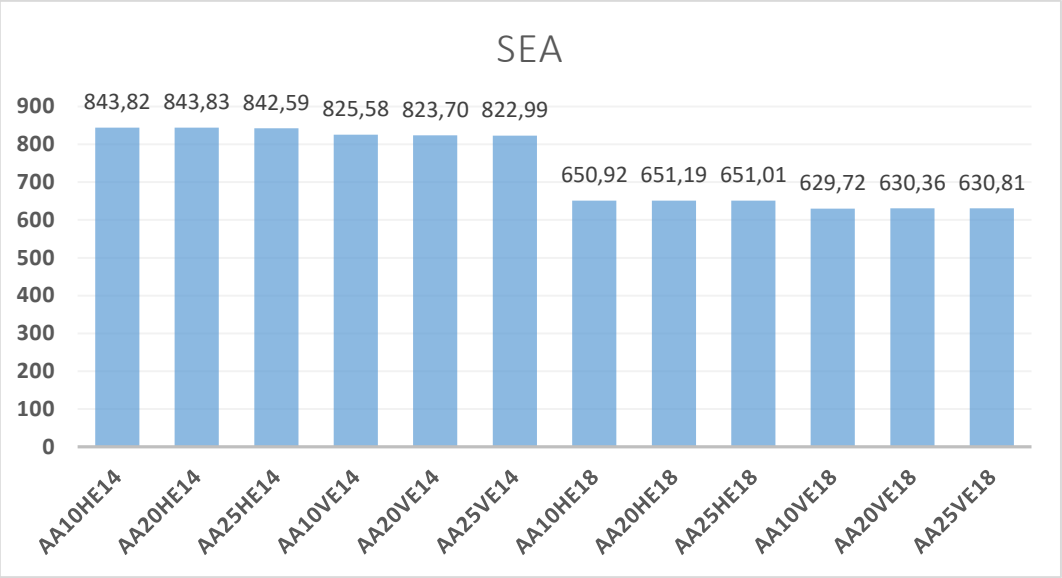


Figure 5. SEA comparison of combinations

As illustrated in Figure 5, the highest SEA value was achieved by the AA20HE14 configuration, with a recorded SEA of 843.83 J/kg. Conversely, the lowest SEA was found in the AA10VE18 configuration, with 629.717 J/kg, indicating reduced energy absorption efficiency in vertically oriented elliptical beams at lower inclination angles. While the SEA values across elliptical beam configurations did not show extreme variation, a subtle performance difference was observed between horizontally and vertically oriented beams. Notably, the horizontal elliptical configurations consistently demonstrated better SEA values compared to their vertical counterparts, suggesting a more effective deformation mechanism aligned with the direction of impact.

In addition to SEA, the study evaluated plastic and peak deformation metrics. Plastic deformation reflects permanent shape change, while peak deformation includes both plastic and elastic components, offering insight into overall beam flexibility and crash tolerance. These findings underscore the importance of beam orientation and angle in determining crash response and structural efficiency. Figure 6 illustrates the comparative deformation behaviors of each configuration, highlighting the mechanical advantages of optimized elliptical cross-section geometries under side impact loading.

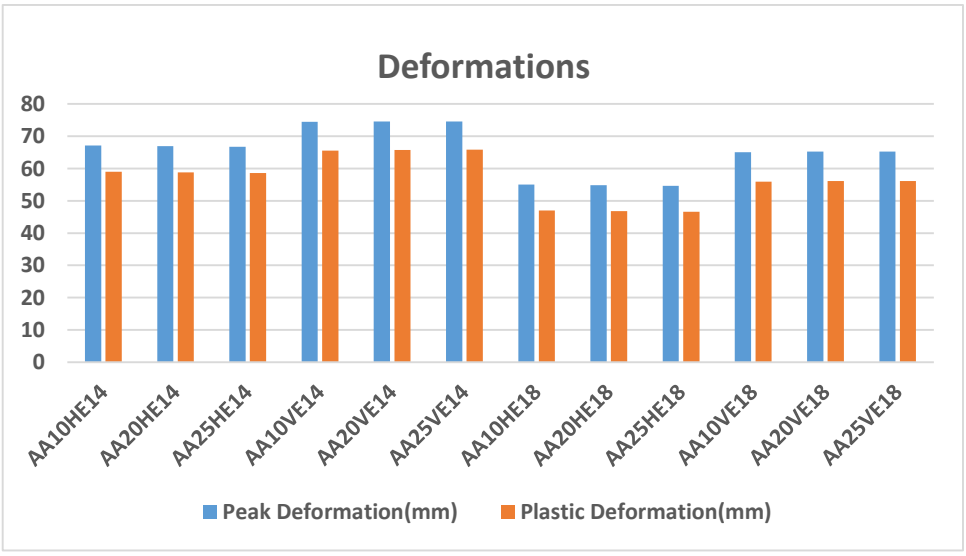


Figure 6. Peak and plastic deformations of beams

Table 3. Peak and plastic deformation values

Codes	Peak Deformation	Plastic Deformation
AA10HE14	67.176	59.026
AA20HE14	66.98	58.768
AA25HE14	66.757	58.557
AA10VE14	74.437	65.561
AA20VE14	74.569	65.776
AA25VE14	74.561	65.682
AA10HE18	55.032	46.98
AA20HE18	54.873	46.833
AA25HE18	54.639	46.603
AA10VE18	65.075	55.948
AA20VE18	65.217	56.101
AA25VE18	65.223	56.11

As shown in Figure 6 and Table 3, the highest peak deformation was recorded in the AA20VE14 configuration, reaching 74.569 mm, whereas the lowest peak deformation was observed in the AA25HE18 configuration with a value of 54.639 mm. These results suggest that the vertically elliptical beam inclined at 20° experienced more deformation compared to the horizontally elliptical beam at 25°, indicating a stiffer and structurally stronger performance for the latter design.

Regarding plastic deformation, the AA20VE14 configuration again exhibited the highest value at 65.776 mm, whereas the AA25HE18 configuration showed the lowest plastic deformation with 46.603 mm. These values confirm that vertical elliptical beams tend to undergo more extensive permanent deformation than their horizontal counterparts under identical loading conditions.

Considering that both the lowest peak and plastic deformation values belong to the AA25HE18 configuration which contains two horizontally oriented elliptical beams with increased thickness this design demonstrated the best resistance to both elastic and plastic deformation, making it the most structurally robust combination. In contrast, vertically elliptical beams at smaller inclination angles exhibited higher flexibility but lower resistance to deformation.

Furthermore, circular cross-section beams, which were used as reference models in the study, consistently showed intermediate deformation values when compared to horizontal and vertical elliptical sections. This reinforces the idea that elliptical geometries particularly horizontal orientations with optimized thickness can provide enhanced crash performance by minimizing structural distortion. However, it should not be forgotten that the increase in deformation is parallel to the increase in absorbed energy.

The last evaluated parameter in this study is the maximum reaction force, which indicates the force transmitted to the driver during impact. For this reason, high values are not preferred by automobile designers. In the simulations, this value was obtained from fixed measurement points. Table 4 shows the maximum reaction force results for the tested combinations.

Table 4. Maximum reaction force values of combinations

Combinations	Maximum Reaction Force (N)
AA10HE14	20417
AA20HE14	20393
AA25HE14	20276
AA10VE14	23033
AA20VE14	22943
AA25VE14	22899
AA10HE18	22286
AA20HE18	22286
AA25HE18	22305
AA10VE18	25679
AA20VE18	25573
AA25VE18	25354

The combination that exhibited the highest maximum reaction force was AA10VE18, with a value of 25679 N, while the lowest force was recorded in AA25HE14, with 20276 N. When these two extreme values are compared, it is observed that the AA10VE18 configuration produces approximately 1.26 times more reaction force than AA25HE14.

The second lowest value belongs to the AA10HE14 configuration with 20417 N, which is also within the HE14 group. This suggests that HE type sections, especially when combined with thinner wall thickness and larger impact angles, tend to produce lower reaction forces.

On the other hand, combinations with VE-type sections, particularly AA10VE18 and AA25VE18, show significantly higher reaction forces. The reason for this can be attributed to the geometry and stiffness of VE sections, which likely provide greater resistance upon impact. This causes the force transmitted to the system and hence to the driver to increase.

Moreover, increasing the thickness from 1.4 mm to 1.8 mm generally results in higher reaction forces across both HE and VE profiles, indicating that thicker profiles absorb and resist more impact force, but at the cost of transferring more of that force back to the driver.

Overall, it can be concluded that cross-section type, wall thickness, and impact angle play crucial roles in the reaction force outcome. Combinations that include VE sections with higher thickness consistently yield higher reaction forces, while HE sections at higher angles and lower thickness perform better in terms of reducing driver-perceived force.

Conclusion

Side impacts represent a critical threat to passenger safety due to the limited distance between the door structure and vehicle occupants. Door reinforcement beams serve as essential structural elements that dissipate and distribute impact energy, thereby mitigating the risk of injury. In this study, the crashworthiness performance of twelve elliptical beam configurations was investigated using finite element simulations. The evaluation focused on key parameters including SEA, peak and plastic deformations, and maximum reaction forces.

The results reveal that although all configurations possessed equal mass, variations in cross-sectional geometry and wall thickness led to distinct performance outcomes. Notably, the AA20HE14 configuration exhibited the highest SEA value and one of the lowest reaction forces, suggesting its superior efficiency in absorbing crash energy per unit mass.

Deformation analyses demonstrated that vertically oriented elliptical beams, particularly the AA20VE14 configuration, showed higher flexibility with greater peak and plastic

deformations. Conversely, the AA25HE18 configuration recorded the lowest deformation values, indicating higher structural rigidity and effective energy dissipation capabilities.

Regarding reaction forces VE-type beams with increased wall thickness (e.g., AA10VE18, AA25VE18) produced the highest transmitted forces, which are generally undesirable from a passenger safety perspective. In contrast, HE type beams with thinner walls and greater inclination angles consistently resulted in lower reaction forces, pointing to a more favorable crash response.

In summary, the findings underscore the significant influence of cross-sectional orientation, inclination angle, and wall thickness on crash performance. Horizontally oriented elliptical beams, particularly those with thinner walls and middle level angles, offer a well-balanced combination of energy absorption capacity and minimized force transmission. These insights can guide the optimization of vehicle door beam designs and contribute to the development of safer automotive structures.

References

Akar, M. A., Kumlu, U., & Yıldızhan, Ş. (2023). Numerical investigation of crash behavior of vehicle side door beams under high-speed pole side impacts. *Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering*, 237(14), 3408-3418.

Ceyhan, M., & Yildiz, B. (2023). Investigation of Crash Performance of Multi-Cell Crash-Boxes. *C.U. Journal of the Faculty of Engineering*, 38(3), 613-621.

Černiauskas, E., Keršys, A., Lukoševičius, V., & Sapragonas, J. (2010). Investigation of anti-intrusion beams in vehicle side doors. *Mechanics*, 86(6), 11-16.

Dhaneesh, K. P., & Prabakaran, B. (2016). Study and Advanced Concept For Side Impact Protection Beams to Reduce The Injury Of The Occupant Using CAE. *International Journal of Mechanical and Production Engineering*, 4(5), 55-60.

European New Car Assessment Programme (Euro NCAP). (2020). Oblique Pole Side Impact Testing Protocol.

European New Car Assessment Programme (Euro NCAP). (2020). Side Impact Mobile Deformable Barrier Testing Protocol.

Ghadianlou, A. & Abullah S.B. (2013). Crashworthiness Design of Vehicle Side Door Beams Under Low-Speed Pole Side Impacts. *Thin-Walled Structures*, 67, 25–33.

Johnson, G.R. and Cook, W.H. (1983). A Constitutive Model and Data for Metals Subjected to Large Strains, High Strain Rates, and High Temperatures. Proceedings 7th International Symposium on Ballistics, The Hague, 19-21 April 1983, 541-547.

Long, C. R., Yuen, S. C. K., & Nurick, G. N. (2019). Analysis of A Car Door Subjected to Side Pole Impact. *Latin American Journal of Solids and Structures*. 16 (8), 1-17.

More, K. C., Patil, G. M., Belkhede, A. A. (2020) Design and analysis of side door intrusion beam for automotive safety, *Thin-Walled Structures*, 153, 106788

Nemani, R., & Arakerimath, R. R. (2015). Taguchi based design optimization of side impact beam for energy absorption. *International Journal for Advanced Research in Engi-neering and Technology*, 3(9), 100-104.

Ponnadai, S. (2018). Analysis of Side Impact Beams in Car Side Door. Kaunas University of Technology.

Rai, R., Kumar, G., Dagar, S., Somashekar, V., Mboreha, C. A., & Modi, P. (2021). Numerical Simulation of Ballistic Impact on Aluminium 5083-H116 Plate with Johnson Cook Plasticity Model. *Materials Today: Proceedings*, *46*, 10619-10627.

Saraf, S., & Bajaj, P. (2017). Design & experimentation of side impact beam for Hyundai Verna. *International Research Journal of Engineering and Technology (IRJET)*, 4 (6), 62-69.

Xu, J., Li, Y., Ge, D., Liu, B., & Zhu, M. (2011). Experimental investigation on constitutive behavior of PVB under impact loading. International Journal of Impact Engineering, 38(2-3), 106-114.

DEVELOPMENT AND EVALUATION OF HEAT-RESISTANT FLEXIBLE SILICONE-BASED COMPOSITES WITH BORON AND METAL OXIDE ADDITIONS FOR NEUTRON SHIELDING APPLICATIONS

Bünyamin AYGÜN

Agri Ibrahim Cecen University, Vocational School, Department of Electronics and Automation, Agri, Türkiye

ORCID ID: https://orcid.org/0000-0002-9384-1540

Akın AKINCIOĞLU

Agri Ibrahim Cecen University, Central Researching Laboratory, Agri, Türkiye

ORCID ID: https://orcid.org/0000-0002-6473-6338

Abdulhalik KARABULUT

Atatürk University, Science Faculty of Physics, Department of Atom and Molecule, Erzurum, Türkiye

ORCID ID: https://orcid.org/0000-0003-2290-9007

Önder ŞİMŞEK

Atatürk University, Faculty of Education, Department of Mathematics & Science, Erzurum, Türkiye

ORCID ID: https://orcid.org/0000-0002-9285-1755

Gülşen TOZSİN

Atatürk University, Faculty of Engineering Department of Metallurgical and Materials, Erzurum, Türkiye

ORCID ID: https://orcid.org/0000-0001-5653-9919

ABSTRACT

Introduction and Purpose: The development of flexible, lightweight, and thermally durable materials for neutron radiation shielding is critical in advanced nuclear and defense applications. In this study, novel composite shielding materials (KM1, KM2, KM3) were produced using 330 °C heat-resistant silicone mastic enriched with boron-based compounds (colemanite and boron oxide), chromium oxide (Cr_2O_3), and iron oxide (Fe_2O_3), reinforced with different fabrics such as aramid fiber and coated fiberglass fabrics. The aim was to evaluate their neutron attenuation performance and compare it to various conventional shielding materials.

Materials and Methods: Composite samples were prepared using additives such as chromium oxide (Cr_2O_3), colemanite ($2CaO{\cdot}3B_2O_3{\cdot}5H_2O$), iron oxide ($Fe_2O_3$), and silicone mastic, in combination with either fiberglass fabric, polyurethane-coated or Teflon-coated fiberglass

fabrics, and aramid fiber. Neutron attenuation properties such as neutron transmission factor, half-value layer (HVL), mean free path (MFP), and effective removal cross-section (ΣR) were assessed using Monte Carlo simulations (GEANT4 and FLUKA). Experimental fast neutron absorption dose rates were measured using a ^{241}Am-Be neutron source and a BF_3 detector.

Results: The KM3 sample, containing a combination of Teflon-coated fiberglass and aramid fiber, achieved the best neutron attenuation performance, with the highest effective removal cross-sections (ΣR: 0.5615 in GEANT4, 0.5649 in FLUKA) and the shortest mean free path (1.508 mm). When compared to reference materials — including paraffin (P), ordinary concrete (OC), hematite-serpentine concrete (H-SC), ilmenite-limonite concrete (I-LC), basalt-magnetite concrete (B-MC), ilmenite concrete (IC), and fiber-based materials (K1–K3) — all three KM composites (KM1, KM2, KM3) exhibited superior or comparable neutron shielding capabilities, while offering added flexibility and thermal durability.

Discussion and Conclusion: This study demonstrated that flexible, boron-rich composite materials reinforced with heat-resistant silicone mastic can provide efficient neutron shielding, surpassing or rivaling the performance of conventional and heavy concretes. The KM3 formulation, in particular, shows great promise for use in portable shielding applications where thermal stability, elasticity, and enhanced neutron absorption are required. The developed composites are intended to be suitable for various neutron radiation protection applications, including protective clothing, coating of concrete and steel components in nuclear reactors, nuclear shelters, radiotherapy rooms, transportation and storage of spent nuclear waste, and protective layering for military, aerospace, marine, and space vehicles.

Key Words: Neutron; Composite materials; Silicone mastic; Aramid fiber; GEANT4; FLUKA.

Acknowledgements: This study was supported by the TÜBİTAK 1001 project number 123F152.

DEVELOPMENT OF FLEXIBLE SILICONE MASTIC-BASED COMPOSITES ENRICHED WITH BORON MINERALS, LIF, AND FEB FOR NEUTRON SHIELDING APPLICATIONS AND EVALUATION OF THEIR ATTENUATION PERFORMANCE

Bünyamin AYGÜN

Agri Ibrahim Cecen University, Vocational School, Department of Electronics and Automation, Agri, Türkiye

ORCID ID: https://orcid.org/0000-0002-9384-1540

Akın AKINCIOĞLU

Agri Ibrahim Cecen University, Central Researching Laboratory, Agri, Türkiye

ORCID ID: https://orcid.org/0000-0002-6473-6338

Nergiz YILDIZ YORGUN

Van Yüzüncü Yıl University, Faculty of Science, Department of Physics, Van, Türkiye

ORCID ID: https://orcid.org/0000-0002-2515-1994

Zeynep ITIR NAMLITÜRK

Atatürk University, Science Faculty of Physics, Department of Atom and Molecule, Erzurum, Türkiye

ORCID ID: https://orcid.org/0009-0006-1558-838X

ABSTRACT

Introduction and Purpose: The pursuit of flexible, thermally stable, and lightweight materials for efficient neutron radiation shielding has become a critical necessity in modern nuclear technology, space exploration, and defense systems. In this study, four advanced composite structures (KMA, KMB, KMC, KMD) were systematically engineered by incorporating boron-rich compounds—colemanite and ulexite—into a high-temperature resistant silicone matrix. These matrices were further reinforced with various fabric types, including fiberglass, aramid, and surface-coated fiberglass fabrics (polyurethane or Teflon). The principal objective was to investigate the neutron attenuation behavior of these composites and benchmark their performance against standard reference materials.

Materials and Methods: The composites were formulated using 20 wt% colemanite ($2CaO{\cdot}3B_2O_3{\cdot}5H_2O$), 15 wt% ulexite ($NaCaB_5O_9{\cdot}8H_2O$), 10 wt% lithium fluoride (LiF), 5 wt% ferroboron (FeB), and 50 wt% silicone mastic. Each KM formulation differed in its fabric reinforcement: KMA: fiberglass + aramid fiber, KMB: polyurethane-coated fiberglass + aramid fiber KMC: fiberglass + Teflon-coated fiberglass, KMD: polyurethane-coated fiberglass + Teflon-coated fiberglass. The neutron shielding efficiency was assessed through both Monte

Carlo simulations (GEANT4 and FLUKA) and experimental measurements involving a ^{241}Am-Be neutron source and a BF_3 detector. Critical shielding parameters such as half-value layer (HVL), mean free path (MFP), and effective removal cross-section (ΣR) were determined.

Results: The simulations and experimental findings revealed that KMA displayed the most favorable shielding characteristics, achieving the highest ΣR values (0.5848 in GEANT4, 0.6036 in FLUKA) and the shortest MFP (1.709 mm). KMB and KMC followed with moderately high attenuation capabilities, while KMD showed the least effectiveness among the four, though still comparable to conventional concrete-based shields. Importantly, all KM-series composites demonstrated superior or at least equivalent neutron shielding capacity relative to traditional materials such as paraffin, ordinary concrete, and various magnetite- or ilmenite-based concretes.

Discussion and Conclusion: The integration of boron-based mineral additives into silicone-based polymer matrices, combined with technical fabric reinforcements, presents a promising approach for the design of next-generation neutron shielding materials. Especially the KMA composite, featuring a hybrid of fiberglass and aramid fibers, emerged as a leading candidate for applications requiring both high neutron attenuation efficiency and material flexibility. These materials show strong potential for implementation in areas such as protective garments, radiation shielding coatings in nuclear facilities, medical radiology rooms, and protective structures in aerospace and defense systems.

Key Words: Neutron; Composite materials; Silicone mastic; Aramid fiber; GEANT4; FLUKA.

Acknowledgements: This study was supported by the TÜBİTAK 1001 project number 123F152.

BIAS REDUCTION OF UTO ESTIMATOR

Selma TOKER KUTAY
Çukurova University, Faculty of Arts and Sciences, Department of Statistics, Adana, Turkey
ORCID ID: https://orcid.org/ 0000-0002-4557-1646

Gülesen ÜSTÜNDAĞ ŞİRAY
Çukurova University, Faculty of Arts and Sciences, Department of Statistics, Adana, Turkey
ORCID ID: https://orcid.org/0000-0002-7652-5220

Nimet ÖZBAY
[3]Çukurova University, Faculty of Arts and Sciences, Department of Statistics, Adana, Turkey
ORCID ID: https://orcid.org/ 0000-0003-3840-3107

ABSTRACT

Introduction and Purpose: UTO is a two-parameter estimator that represents advantages of two biasing parameters and offers a noteworthy solution to multicollinearity. First biasing parameter originated from ridge estimator is employed for eliminating the multicollinearity while second biasing parameter originated from Liu estimator is for reducing length, variance and bias of the Liu estimator. Although the UTO estimator has several merits, it can carry a significant amount of bias as a disadvantage. This amount of bias needs to be reduced to an acceptable level because reduced bias is a desirable property for an estimator. The principal objective of this paper is to concentrate on the bias reduction process for the UTO estimator.

Materials and Methods: Subtracting bias of any estimator from itself is a bias reduction technique that provides an almost unbiased form of that estimator. We apply this bias reduction method to the UTO estimator to find almost unbiased UTO estimator. Theoretical comparisons are examined according to bias and mean square error criterion. Moreover, classical and mathematical programming methods are suggested to determine the biasing parameters of the almost unbiased UTO estimator. After the theoretical study about the almost unbiased UTO estimator, we analyze a real data set to explore the effect of the biasing parameters chosen by our proposed methods on the performance of the almost unbiased UTO estimator.

Results: As a result of the data analysis, the almost unbiased UTO estimator outperforms its competitors with regard to the mean square error criterion and squared bias when we use biasing parameters that are computed by both the classical and mathematical programming methods.

Discussion and Conclusion: The current study focuses on definition of the almost unbiased UTO estimator. In conclusion, using the almost unbiased UTO estimator in applied research is beneficial because of its impressive performance.

Key Words: Bias reduction, Mathematical programming, Multicollinearity, UTO estimator

EXAMINATION OF FLEXIBLE INTERIOR SOLUTIONS ON EDUCATIONAL BUILDINGS

ESNEK İÇ MEKAN ÇÖZÜMLERİNİN EĞİTİM YAPILARI ÜZERİNDEN İRDELENMESİ

Ayşe SUNGURLU

Arş. Gör., Alanya Üniversitesi, Mühendislik ve Doğa Bilimleri Fakültesi, İç Mimarlık ve Çevre Tasarımı Bölümü, Alanya, Türkiye.

https://orcid.org/ 0000-0003-3823-5553

Anıl SÜVARİ

Doç. Dr., Alanya Üniversitesi, Mühendislik ve Doğa Bilimleri Fakültesi, İç Mimarlık ve Çevre Tasarımı Bölümü, Alanya, Türkiye.

https://orcid.org/ 0000-0002-1390-2236

ABSTRACT

In the face of today's rapidly changing social, technological and environmental conditions, the sustainability of spatial organizations necessitates the development of space designs based on flexible design principles. Spaces that can adapt to changing user needs over time, are reconfigurable and have multifunctional features have become a fundamental requirement in the contemporary design approach. This approach, which gained momentum during the COVID-19 pandemic, combined with the effects of digitalization on social life, has led to radical transformations in the use of space and has caused the concept of flexibility to come to the fore again in design literature. Flexibility is a comprehensive design strategy that is not limited to movable partition elements or modular systems, but is addressed through the capacity for transformability and functional diversification that encompasses all components of the space. Flexible space solutions developed in line with this strategy increase the physical capacity of the spatial volume, while also contributing to the creation of environmental conditions that can be adapted to different life scenarios. Educational structures are complex structures that require multidimensional evaluation processes in the context of pedagogical goals, psychosocial needs and technological equipment. In these structures, the interior design has the potential to produce flexible solutions that allow for various usage scenarios through the holistic integration of equipment elements, movable furniture, the organization of carrier systems, installation infrastructure and structural components. In the study, design criteria for providing flexibility in educational structures were defined; how these criteria were applied was examined through different examples. In this context, the proposals presented are aimed to contribute to the design of multifunctional and sustainable spatial organizations that can adapt to changing living conditions.

Keywords: Interior Design, Space, Flexibility, Flexible Design, Educational buildings.

ÖZET

Günümüzün hızla değişen toplumsal, teknolojik ve çevresel koşulları karşısında mekânsal organizasyonların sürdürülebilirliğini sağlayabilmesi, esnek tasarım ilkelerine dayanan mekân kurgularının geliştirilmesini zorunlu kılmaktadır. Zamana bağlı olarak farklılaşan kullanıcı ihtiyaçlarına uyum sağlayabilen, yeniden yapılandırılabilir ve çok işlevli özellikler taşıyan mekânlar, çağdaş tasarım anlayışında temel bir gereklilik hâlini almıştır. COVID-19 pandemisi sürecinde ivme kazanan bu yaklaşım, dijitalleşmenin toplumsal yaşamdaki etkileriyle birleşerek mekân kullanım biçimlerinde köklü dönüşümlere yol açmış ve esneklik kavramının tasarım literatüründe yeniden gündeme gelmesine neden olmuştur. Esneklik, hareketli bölücü elemanlar ya da modüler sistemlerle sınırlı kalmayan, mekânın tüm bileşenlerini kapsayan dönüşebilirlik ve işlevsel çeşitlenme kapasitesi üzerinden ele alınan kapsamlı bir tasarım stratejisidir. Bu strateji doğrultusunda geliştirilen esnek mekân çözümleri, mekânsal hacmin fiziksel kapasitesini artırmakla birlikte, farklı yaşam senaryolarına uyarlanabilir çevresel koşulların oluşturulmasına da katkı sunmaktadır. Eğitim yapıları, pedagojik hedefler, psikososyal gereksinimler ve teknolojik donanım bağlamında çok boyutlu değerlendirme süreçlerini gerektiren karmaşık yapılardır. Bu yapılarda iç mekân tasarımı, donatı elemanları, hareketli mobilyalar, taşıyıcı sistemlerin organizasyonu, tesisat altyapısı ve yapısal bileşenlerin bütüncül entegrasyonu aracılığıyla çeşitli kullanım senaryolarına olanak tanıyan esnek çözümler üretme potansiyeline sahiptir. Çalışmada, eğitim yapılarında esnekliğin sağlanmasına yönelik tasarım ölçütleri tanımlanmış; farklı örnekler üzerinden bu ölçütlerin nasıl uygulandığı incelenmiştir. Bu doğrultuda sunulan önerilerin, dönüşen yaşam koşullarına uyum sağlayabilen, çok işlevli ve sürdürülebilir mekânsal organizasyonların tasarımına katkı sunması hedeflenmektedir.

Anahtar Kelime: İç Mekân Tasarımı, Mekân, Esneklik, Esnek Tasarım, Eğitim yapıları.

RELATIONSHIP BETWEEN HOMOCYSTEINE LEVELS AND INSULIN RESISTANCE IN OBESE PEOPLE

OBEZLERDE HOMOSİSTEİN DÜZEYELERİ İLE İNSÜLİN DİRENCİ ARASINDAKİ İLİŞKİ

Doç. Dr. Mehmet ÖZDİN

Karasu Devlet Hastanesi, Biyokimya.

ABSTRACT

Obesity is a significant public health problem in our country as well as in developed and developing countries. Body mass index (BMI) is calculated as the ratio of body weight (kg) to height (m^2). The World Health Organization (WHO) recommends using BMI in the diagnosis of obesity, and a BMI above 30 kg/m2 is considered obesity. Fat tissue, particularly accumulated in the abdominal region, reduces the effect of insulin on cells, causing insulin resistance. This complicates blood sugar regulation, leading the pancreas to produce more insulin. Insulin resistance occurs when the normal amount of insulin produced by the pancreas fails to meet the necessary or sufficient response in fat, muscle, and liver cells. The Homeostatic Model Assessment of Insulin Resistance (HOMA-IR) is calculated using the formula HOMA-IR = Insulin x FBG (mg/dl)/405. Homocysteine is a sulfur-containing amino acid involved in methionine metabolism.

In this study, it was aimed to investigate the homocysteine levels and insulin resistance values in obese patients and to reveal the relationship between these two values. The patients included in the study were 73 patients who applied to the internal medicine outpatient clinics of Sakarya Education and Research Hospital between 01.01.2023 and 31.12.2024, and the data were retrospectively performed by examining the file data recorded in the information processing system. The patient and control groups were matched in terms of age and gender. The patients were divided into two groups as those with and without insulin resistance. Among the patients whose file records were examined, patients with homocysteine levels, BMI measurements, and fasting and postprandial blood sugar profiles were included in the study. The patient and control groups were matched in terms of age and gender. Patients were divided into two groups as those with and without insulin resistance. Among the patients whose file records were reviewed, patients with homocysteine levels, BMI measurements, fasting and postprandial blood sugar profiles were included in the study. Patients with diabetes, hypertension, congestive heart failure, those with hepatic and renal dysfunction, and those receiving treatments that may affect lipids were excluded from the study. Homocysteine levels in patients with insulin resistance (18.50±6.60 μmol/l) were significantly higher than those in patients without insulin resistance (14.80±4.50 μmol/l) (p=0.015). In addition, the BMI of patients with insulin resistance (31.50±3.80) was statistically significantly higher than that of patients without insulin resistance (27.50±5.80) (p=0.001). When the cases were evaluated in terms of FBG, TBG, total cholesterol, triglyceride, LDL-cholesterol, HDL-cholesterol, no significant difference was detected. Since insulin resistance is a risk factor for cardiovascular diseases, the detection of hyperhomocysteinemia as another risk factor in patients with insulin resistance suggests that these patients require closer monitoring

Keywords: Homocysteine, obesity, insulin resistance

ÖZET

Obezite gelişmiş ve gelişmekte olan ülkelerde olduğu gibi ülkemizde de oldukça önemli bir halk sağlığı sorunudur. Beden kitle indeksi (BKİ) vücut ağırlığının (kg) boya (m^2) oranıyla hesaplanır. Dünya sağlık örgütü de (WHO) obezite tanısında BKİ kullanılmasını önermekte ve BKİ düzeyinin 30 kg/m^2 üzerinde olması obezite olarak kabul edilmektedir. Özellikle karın bölgesinde biriken yağ dokusu, insülinin hücreler üzerindeki etkisini azaltarak insülin direncine neden olur. Bu durum, kan şekerinin düzenlenmesini zorlaştırarak pankreasın daha fazla insülin üretmesine yol açar. İnsülin direnci, pankreas tarafından üretilen normal miktarda insülinin yağ, kas ve karaciğer hücrelerinde gerekli veya yeterli cevap alamamasıdır. İnsülin Direncinin Homeostatik Model Değerlendirmesi (HOMA-IR); HOMA-IR= İnsülin x AKŞ (mg/dl)/405 formülü ile hesaplanmıştır. Homosistein, metionin metabolizmasında görev alan ve yapısında sülfür içeren bir aminoasiddir.

Bu çalışmamızda; obez hastalarda homosistein düzeyleri ve insülin direnci değerleri araştırılarak bu iki değer arasındaki ilişkiyi ortaya çıkarmak amaçlanmıştır. Çalışmaya aldığımız hastalar 01.01.2023 – 31.12.2024 tarihleri arasında Sakarya Eğitim ve Araştırma Hastanesi dahiliye polikliniklerine başvuran 73 hastaya ait veriler olup, bilgi işlem sisteminde kayıtlı dosya verileri incelenerek retrospektif olarak gerçekleştirildi. Hasta ve kontrol grupları yaş ve cinsiyet açısından uyumlu idi. Hastalar insülin direnci olanlar ve olmayanlar olarak iki gruba ayrıldı. Dosya kayıtları incelenen hastalardan, homosistein düzeyleri, BKİ ölçümleri, açlık ve tokluk kan şekeri profili olan hastalar çalışmaya dahil edildi. Diyabet, hipertansiyon, konjestif kalp yetersizliği olanlar, hepatik ve renal fonksiyonlarda bozukluk saptananlar, lipidler üzerine etkisi olan tedavi alan hastalar çalışma dışı bırakıldı. İnsülin direnci olan hastaların homosistein düzeyi (18.50±6.60 µmol/l) insülin direnci olmayan hastalardan (14.80±4.50 µmol/l) anlamlı olarak yüksekti ($p=0.015$). Ayrıca insülin direnci olan hastaların BKİ (31.50±3.80), insülin direnci olmayan hastalardan (27.50±5.80) istatistiksel olarak anlamlı yüksekti ($p=0.001$). Olgular AKŞ, TKŞ, total kolesterol, trigliserid, LDL-kolesterol, HDL-kolesterol, açısından değerlendirildiğinde ise anlamlı bir fark tespit edilmedi. İnsülin direncinin kardiyovasküler hastalıklar için bir risk olduğundan, insülin direnci olanlarda başka bir risk faktörü olarak hiperhomosisteineminin tespit edilmesi bu hastaların daha yakından izlenmesi gerektirdiğini düşündürmektedir.

Anahtar Kelimeler: Homosistein, obezite, insülin direnci

AN OVERVIEW OF THE DEVELOPMENT OF ROBOTIC SYSTEMS IN AGRICULTURE BETWEEN 2015 AND 2025

Res. Asst. Osman Mert YAZ

Erciyes University, Faculty of Agriculture, Department of Biosystems Engineering, Kayseri, Turkey

ORCID ID: https://orcid.org/0009-0003-3367-6656

Res. Asst. Özlem BAHAR

Kırşehir Ahi Evran University, Faculty of Agriculture, Department of Plant Protection, Kırşehir, Turkey

ORCID ID: https://orcid.org/0009-0002-2246-8790

Assoc. Prof. Dr. Melih YILAR

Kırşehir Ahi Evran University, Faculty of Agriculture, Department of Plant Protection, Kırşehir, Turkey

ORCID ID: https://orcid.org/0000-0001-5963-4743

Assoc. Prof. Dr. Bahadır DEMİREL

Erciyes University, Faculty of Agriculture, Department of Biosystems Engineering, Kayseri, Turkey

ORCID ID: https://orcid.org/0000-0002-2650-1167

ABSTRACT

The rapid advancement of technology over the past decade has significantly impacted the agricultural sector, leading to the widespread adoption and development of robotic systems in agriculture. This study systematically reviews academic literature published between 2015 and 2025 on the use of agricultural robotics. Over the past ten years, extensive research has been conducted in key areas such as harvesting robots, spraying drones, autonomous tractors, and artificial intelligence (AI)-based decision support systems. These innovations have introduced new opportunities in agricultural production, especially in terms of productivity, precision, and sustainability. In harvesting applications, robotic systems developed for crops such as apples, strawberries, and tomatoes have shown improved success rates and efficiency. Unmanned aerial vehicles (drones) used in spraying have enabled precision application techniques, resulting in reduced pesticide usage. Autonomous tractors and field robots have minimized the reliance on manual labor while enhancing operational safety. Furthermore, AI-powered decision support systems have begun to offer intelligent recommendations to farmers regarding irrigation, fertilization, and disease management based on big data analysis. This review provides a comprehensive overview of recent developments in the field of agricultural robotics, including the methodologies and technical aspects of current systems. It also identifies gaps in the literature and outlines potential future research directions.

Keywords: Agricultural robotics, Precision agriculture, Harvesting robots, Drones, Autonomous tractors, Artificial intelligence, Decision support systems.

ÖZET

Son on yılda teknolojinin hızlı ilerlemesi, tarım sektörünü önemli ölçüde etkilemiş ve tarımsal robotik sistemlerin yaygın olarak benimsenmesine ve geliştirilmesine yol açmıştır. Bu çalışma, 2015 ile 2025 yılları arasında yayımlanmış akademik literatürü sistematik olarak incelemektedir. Son on yılda, hasat robotları, ilaçlama dronları, otonom traktörler ve yapay zekâ (YZ) tabanlı karar destek sistemleri gibi temel alanlarda kapsamlı araştırmalar yürütülmüştür. Bu yenilikler, özellikle verimlilik, hassasiyet ve sürdürülebilirlik açısından tarımsal üretimde yeni fırsatlar sunmuştur. Hasat uygulamalarında, elma, çilek ve domates gibi ürünler için geliştirilen robotik sistemler başarı oranları ve etkinlik bakımından önemli ilerlemeler kaydetmiştir. İlaçlamada kullanılan insansız hava araçları (dronlar), hassas uygulama tekniklerini mümkün kılarak pestisit kullanımını azaltmıştır. Otonom traktörler ve tarla robotları ise manuel iş gücüne olan bağımlılığı en aza indirirken operasyonel güvenliği artırmıştır. Ayrıca, büyük veri analizine dayalı YZ destekli karar sistemleri, çiftçilere sulama, gübreleme ve hastalık yönetimi konusunda akıllı öneriler sunmaya başlamıştır. Bu derleme, tarımsal robotik alanındaki güncel gelişmeleri, mevcut sistemlerin yöntemsel ve teknik yönlerini kapsayacak şekilde kapsamlı bir bakış açısıyla sunmaktadır. Ayrıca literatürdeki boşlukları belirleyerek gelecekte yapılabilecek araştırmalar için potansiyel yönelimleri ortaya koymaktadır.

Anahtar Kelimeler: Tarımsal robotik, Hassas tarım, Hasat robotları, Dronlar, Otonom traktörler, Yapay zekâ, Karar destek sistemleri.

GİRİŞ

Dünya genelinde artan nüfus, azalan tarım iş gücü ve sürdürülebilir gıda arzı ihtiyacı, tarımda otomasyon ve robotik teknolojilere olan ilgiyi her zamankinden fazla artırmıştır. Birleşmiş Milletler Gıda ve Tarım Örgütü (FAO) projeksiyonlarına göre 2050 yılında dünya nüfusunu besleyebilmek için gıda üretiminin bugüne kıyasla yaklaşık %70 oranında artması gerekecektir [1]. Tarım arazilerinin kısıtlılığı ve kırsal alanda çalışan nüfusun azalması, üretimde verimlilik artışını zorunlu kılmaktadır [2]. Bu çerçevede, tarımsal üretimde robotik sistemler ve otomasyon uygulamaları kritik bir çözüm alanı olarak ortaya çıkmıştır. Tarım robotları; tekrarlayan, yoğun emek gerektiren veya insan için tehlikeli olabilecek birçok görevi otonom bir şekilde yerine getirme potansiyeliyle dikkat çekmektedir [3]. Örneğin, hasat robotları ve akıllı ilaçlama sistemleri sayesinde hem iş gücünden tasarruf sağlanabilmekte hem de insan maruziyetinden kaynaklı sağlık riskleri azaltılmaktadır. Bunun sonucunda hassas tarım yaklaşımı güçlenmekte, girdi optimizasyonu ve çevresel sürdürülebilirlik alanlarında önemli kazanımlar elde edilebilmektedir [4].

Bununla birlikte, tarımsal ortamlardaki değişkenlik ve zorluklar, robotik uygulamaların geliştirilmesinde önemli engeller de ortaya çıkarmıştır [5]. Açık tarla koşullarında ışık, sıcaklık, toprak yapısı gibi çevresel faktörler sürekli değişmekte; bitkilerin yapısı ve konumu rastgelelik göstermektedir. Bu durum, tarım robotlarının algılama ve gezinme sistemlerinin endüstriyel robotlara kıyasla çok daha esnek ve akıllı olmasını gerektirmektedir [3]. Son yıllarda ilerleyen sensör teknolojileri (ör. RTK-GPS, LiDAR, hiperspektral kameralar) ve derin öğrenme tabanlı yapay zekâ algoritmaları, bu zorlukların aşılmasına yardımcı olmaya başlamıştır. Bununla beraber, halen büyük ölçekli uygulamaların önünde; yüksek sistem maliyetleri, zorlu arazi koşullarında güvenilirlik problemleri ve yapay zekâ entegrasyonundaki yetersizlikler gibi engeller bulunmaktadır [1].

Bu derleme makalesinde, 2015–2025 yılları arasında tarım robotikleri alanındaki gelişmeler incelenmektedir. Giriş bölümünün ardından çalışma kapsamında ele alınan alt alanlar açıklanmaktadır. Tarımsal robotik sistemler alt kategorilere ayrılarak (hasat robotları, ilaçlama dronları, otonom traktörler ve yapay zekâ tabanlı karar destek sistemleri) son on yıldaki mevcut durum ve teknik ilerlemeler örnek çalışmalarla ortaya konmaktadır. Tartışma bölümünde literatürde tespit edilen eksiklikler, karşılaşılan teknolojik engeller ve gelecekteki fırsatlar değerlendirilmekte; Sonuç kısmında ise genel bir değerlendirme ile gelecek perspektifine yer verilmektedir.

HASAT ROBOTLARI

Bitkisel üretimde hasat işleminin otomasyonu, son yıllarda tarım robotikleri alanında en yoğun çalışılan konuların başında gelmektedir. Hasat robotları özellikle meyve ve sebze tarımında, dalından toplama sürecini otonom hale getirmeyi amaçlayan sistemlerdir. Son on yılda elma, çilek, domates, biber, kuşkonmaz ve salatalık gibi farklı ürünler için pek çok prototip ve pilot ticari deneme geliştirilmiştir [6-7]. Hasat robotları çalışma prensibi bakımından “toplu hasat” (bir bitkinin üzerindeki tüm ürünlerin aynı anda toplanması) ve “seçici hasat” (olgunlaşan ürünlerin tek tek seçilerek toplanması) şeklinde iki gruba ayrılabilir. Özellikle seçici hasat yapan robotlar için verimlilik ölçütleri; bir ürünü koparma süresi ve belirlenen ürünlerin başarıyla toplanma oranı gibi metriklerle tanımlanmaktadır [8-9]. Literatürde bildirilen en hızlı elma toplama robotlarının bir elmayı yaklaşık 7–9 saniyede hasat edebildiği, başarı oranlarının ise %85–90 bandına ulaştığı görülmektedir [8]. Benzer şekilde, domates hasadında en hızlı robotik sistemin ortalama bir domatesi 23 saniyede toplayabildiği, en yüksek başarım oranının ise %87 seviyesinde olduğu rapor edilmiştir [5-9]. Küçük meyvelerde (ör. çeri domates) bu süre meyve salkımı başına 8 saniyeye kadar inebilmektedir [5]. Bunun yanında, portakal gibi narenciye ürünlerinde ticari prototiplerin her bir meyveyi 2–3 saniyede toplayabildiği belirtilmiştir [9]. Bu veriler, robotik hasatta önemli hız ve verim artışlarının sağlandığını gösterse de, halen pek çok sistemin insan işçiler kadar hızlı veya hassas olamadığını da ortaya koymaktadır. Nitekim kapsamlı bir inceleme, günümüz hasat robotlarının henüz insan iş gücüyle tam rekabet edemediğini; en büyük sorunların bitkilerdeki yaprak ve dalların meyveyi gizlemesi (algılama zorluğu) ve narin ürünlerde zedelenme riski olduğunu vurgulamıştır [10-11].

Robotik hasat sistemlerinin geliştirilmesinde ağaç veya bitki üzerindeki ürünü tespit etme, robot kolunun hareket planlaması ve uygun uç efektör ile meyvenin nazikçe koparılması gibi ardışık zorluklar bulunmaktadır [5-12]. Görüntü işleme tabanlı algılama teknikleriyle meyve tespiti yapılmakta, ardından robotik kol ürüne doğru yönlendirilmekte ve kavrama-koparma işlemi gerçekleştirilmektedir [13]. Son on yıldaki çalışmalar, bu adımların her birine yönelik önemli ilerlemeler kaydetmiştir. Örneğin, derin öğrenme tabanlı nesne tanıma algoritmaları olgun meyvelerin yapraklar arasından yüksek doğrulukla tespitini mümkün kılarken; gelişmiş hareket planlama algoritmaları robot kolun dallarla çarpışmadan en uygun yolu izlemesini sağlamaktadır. Uç efektör tasarımında ise meyveyi vakumla çekip koparan emici aparatlar ile parmak benzeri kıskaç mekanizmaları yaygın olarak denenmektedir [14-15]. Bu sayede her ürünün yapısına en uygun hasat yöntemi araştırılmaktadır. Sonuç olarak, son on yılda hasat robotları alanında önemli ilerlemeler elde edilmiş; özellikle çilek ve elma gibi meyvelerde birçok akademik prototip başarılı şekilde ticari deneme aşamasına geçmiştir [3-16]. Yine de tam otonom hasadın yaygınlaşması için algılama güvenilirliğinin daha da artırılması, çoklu meyve kümelerinin tek seferde toplanabilmesi ve hasar oranının minimize edilmesi gibi konularda araştırmalar devam etmektedir.

İLAÇLAMA DRONLARI (HASSAS PESTISIT UYGULAMALARI)

Tarımsal ilaçlama faaliyetlerinde insansız hava araçları, özellikle son 5–10 yılda hızlı bir yaygınlık kazanmıştır. İHA (drone) tabanlı püskürtme sistemleri, tarlalarda pestisit ve gübre uygulamalarında yeni bir hassas tarım çözümü olarak öne çıkmaktadır. Geleneksel traktör veya uçaklarla yapılan ilaçlamaya kıyasla dronlar, hedefe yönelik ve düşük hacimli uygulamalara imkan tanımaktadır. Son yıllarda geliştirilen ileri teknolojili tarım dronları, RTK-GPS ile santimetre seviyesinde konumlama yapabilmekte; yüksek çözünürlüklü kameralar ve sensörler ile arazide hassas haritalama gerçekleştirerek sadece ihtiyaç duyulan bölgelere ilaç püskürtme olanağı sunmaktadır [17-18]. Bu sayede ilaçlama esnasında hem kimyasal tasarrufu sağlanmakta hem de su kaynakları ve yararlı böcekler gibi hedef dışı unsurların kirlenmesi önlenmektedir [17]. Nitekim gelişmiş püskürtme sistemleriyle donatılmış dronlar sayesinde pestisit kullanımında geleneksel yöntemlere göre %30'a varan oranda azalma sağlandığı bazı çalışmalarda rapor edilmiştir [2-17]. Dronların bir diğer önemli avantajı da eğimli araziler veya makine girmesi zor alanlar gibi insan uygulamasının zor olduğu koşullarda etkinlik göstermesidir. Örneğin, çeltik tarlaları veya bağ alanlarında dron ile ilaçlama, hem zamandan tasarruf hem de homojen uygulama sağlamaktadır. Ayrıca drone kullanımı, çiftçilerin tehlikeli kimyasallara doğrudan maruz kalmasını azaltarak iş güvenliğine de katkı sunmaktadır [17-18].

Literatürde tarımsal dron teknolojilerinin geliştirilmesine ilişkin pek çok çalışma bulunmaktadır. Özellikle püskürtme nozul tasarımı, uçuş irtifası ve hızının damlacık dağılımına etkisi, rüzgâr driftinin minimizasyonu gibi konular araştırılmıştır. İleri seviye dron platformlarında, yerleşik lidar ve ultrasonik sensörlerle bitki yüksekliği ve yoğunluğu algılanarak adaptif uçuş ve değişken oranlı uygulama yapılması mümkün hale gelmektedir. Bu sayede her bölgede gereken optimum ilaç dozajı uygulanabilmektedir. Hassas konumlama ve otomatik uçuş rotası planlama özellikleri ile dronlar, tarla üzerinde önceden belirlenmiş desenlerde uçarak hiçbir alanı atlamadan ya da çakışma olmadan püskürtme yapabilmektedir. Örneğin, RTK destekli İHA sistemleri sayesinde herbisit uygulamalarında önemli oranlarda kimyasal tasarruf sağlandığı ve ilaçlamanın doğruluğunun belirgin şekilde iyileştiği gösterilmiştir [1-17]. Dronlarla entegre yapay zekâ uygulamaları da giderek önem kazanmaktadır; görüntü tanıma algoritmaları ile zararlı bitki veya hastalık odakları tespit edilip sadece bu noktalara nokta atışı ilaçlama yapılması mümkün olmaktadır [19].

Öte yandan, tarım dronlarının kullanımında henüz standartlaşmamış veya araştırılması gereken noktalar mevcuttur. Örneğin, farklı uçuş irtifalarında ve nozzle tiplerinde ilaç dağılım uniformluğu farklılık gösterebilir; rüzgârın etkisiyle ilaç damlacıklarının sapma mesafeleri hesaplanmalıdır. Ayrıca, batarya kapasiteleri dronların uçuş süresini sınırlamakta, geniş alanların tek şarjla ilaçlanmasını zorlaştırmaktadır. Bu konular üzerinde çalışmalar sürmekte olup gelecekte daha uzun ömürlü piller veya güneş enerjili dron istasyonları gibi çözümler ön görünmektedir. Sonuç olarak, ilaçlama dronları tarımda hassas pestisit uygulamaları son on yılda hızla gelişmiştir. Birçok ülkede regülasyonların netleşmesiyle birlikte ticari kullanım alanı genişlemekte ve çiftçiler arasında benimsenme oranı artmaktadır. Bu eğilimin devam etmesiyle, yakın gelecekte tarım arazilerinde otonom dron filolarının rutin olarak ilaçlama ve izleme görevleri yapması beklenmektedir.

OTONOM TRAKTÖRLER VE TARLA ROBOTLARI

Tarım makinelerinin otonom hale getirilmesi, büyük ölçekli tarımda iş gücü verimliliğini artırmak ve operasyonları hassaslaştırmak adına kritik bir hedeftir. Otonom traktörler, GPS destekli otomatik dümenleme sistemlerinden tamamen sürücüsüz çalışan traktörlere kadar uzanan bir yelpazede son on yılda önemli gelişmeler kaydetmiştir. Günümüz modern traktör modellerinde entegre otomatik yönlendirme sistemleri uzun süredir kullanılagelse de 2015

sonrasında yapay zekâ ve sensör füzyonu ile desteklenen gerçek anlamda otonom traktör prototipleri ortaya çıkmaya başlamıştır. Bu araçlar, üzerlerindeki çoklu kamera sistemleri, LiDAR sensörleri ve radar üniteleri sayesinde çevrelerini 360° algılayabilmekte; engelleri tanıyıp durabilmekte veya etraflarından dolaşabilmektedir. Örneğin, yakın zamanda tanıtılan tam otonom bir tarla traktörü, altı çift stereo kamera ile çevresel algılama yapmakta ve derin öğrenme algoritmaları kullanarak saniyede yüzlerce görüntüyü işleyecek şekilde tasarlanmıştır [10]. Bu sistem, traktörün önüne çıkabilecek hayvan, insan, kaya gibi engelleri milisaniyeler içinde tespit edip durmasını sağlayabilmektedir [1-10]. Ayrıca RTK-GNSS destekli hassas konumlama sayesinde traktör, sanal bir geo-çit (geofence) içinde önceden belirlenen güzergâhların dışına çıkmadan, doğrulukla tarla işleri yapabilmektedir [4-10]. Otonom traktörlerin ilk uygulama alanları genellikle sürme, ekim ve ilaçlama gibi tekrarlı ve yapılandırılmış tarla operasyonları olmuştur. Özellikle insansız traktörlerle toprak işleme (ör. pullukla sürüm) çalışmaları başarılı prototiplerle gösterilmiştir. Bu sayede çiftçiler, bir traktörü insansız modda çalıştırırken diğer işlere odaklanabilmekte veya aynı anda birden fazla otonom aracı yönetebilmektedir [2].

Büyük tarla robotları dışında, yabancı ot mücadelesi, bitki izleme gibi işler için daha küçük otonom tarla robotları da yaygınlaşmaktadır. Özellikle sıra arası yabancı ot temizleme robotları, kamera tabanlı görüntü işleme ile yabani otları kültür bitkilerinden ayırt ederek mekanik olarak sökme veya mikro-dozaj herbisit püskürtme yapabilmektedir. Literatürde, yapay görme sistemine entegre edilmiş MATLAB-PLC tabanlı kontrol mekanizmasıyla çalışan ve sensör verisine göre sadece gerekli yerlere herbisit uygulayan akıllı traktör ataşmanları geliştirilmiştir [19-20]. Bu tür akıllı ilaçlama sistemleri, gereksiz kimyasal kullanımını azaltarak hem ekonomik hem çevresel fayda sağlamaktadır. Ayrıca ticari olarak da Blue River Technology'nin "See & Spray" gibi sistemleri, algıladıkları otlara hedefe yönelik sprey yaparak %80'in üzerinde herbisit tasarrufu vadetmiştir. Yine tarla izleme robotları, tarlada otonom gezinerek bitki sağlığını izleyen, hassas sensörlerle veri toplayan platformlar şeklinde gelişmektedir. Örneğin, fenotipleme robotları seralarda veya deneme tarlalarında bitkilerin büyümesini, yaprak alanını, hastalık belirtilerini görüntüleyip kaydederek araştırmacılara veri sağlamaktadır [5].

Otonom tarla araçlarının kullanımında en büyük motivasyonlardan biri, tarımda azalan insan iş gücü açığını kapatmak ve 7/24 çalışabilen sistemler ile operasyonel verimliliği artırmaktır. Gerçekten de otonom traktörler uygun planlama ile gece gündüz kesintisiz çalışabilir, böylece ideal ekim veya hasat zaman pencereleri daha iyi değerlendirilebilir. Ek olarak, insansız sistemler sayesinde operatörlerin uzun saatler traktör sürmesinden kaynaklanan yorgunluk veya dikkatsizlik problemleri de bertaraf edilebilir. Güvenlik açısından da otonom araçların düzenli ve öngörülebilir şekilde hareket etmesi iş kazalarını azaltma potansiyeline sahiptir. Ancak tüm bu faydaların yanında, teknolojik ve pratik bazı engeller de mevcuttur. Örneğin, otonom araçların karışık tarla koşullarında (ör. çamur, engebeli arazi) çekiş ve denge sorunları, GPS sinyalinin kesildiği durumlarda yedekleme sistemleri, birden fazla otonom makinenin koordinasyonu ve tarla içindeki insanların algılanıp güvenliğin sağlanması gibi konular halen aktif araştırma alanlarıdır. Regülasyon boyutunda ise, tamamen sürücüsüz traktörlerin tarlada veya yolda kullanımına ilişkin yasal çerçeveler birçok ülkede yeni yeni oluşmaktadır. Buna bağlı olarak, güvenlik standartlarının belirlenmesi ve çiftçilerin bu teknolojilere güven duyup benimsemesi zaman alabilecektir.

YAPAY ZEKÂ TABANLI KARAR DESTEK SISTEMLERI

Yapay zekâ (YZ) ve makine öğrenmesi destekli karar destek sistemleri, tarımsal üretimde veri analizine dayalı akıllı öneriler sunarak verimliliği arttırmayı hedefleyen bir diğer önemli yenilik

alanıdır. Son on yılda, tarımda dijitalleşme ile birlikte tarlalardan toplanan verinin hacmi büyük oranda artış göstermektedir (sensör ağları, uydu görüntüleri, drone verileri, meteorolojik kayıtlar vb.). Bu "büyük veri" ancak yapay zekâ teknikleri ile anlamlı bilgiye dönüştürülebilmektedir. Makine öğrenmesi algoritmaları, geçmiş verilerden öğrenerek geleceğe dair tahminler yapabildiği için tarımda öngörü ve optimizasyon problemlerinde sıkça kullanılmaya başlanmıştır [3-19]. Örneğin, AI tabanlı bir karar destek sistemi; belirli bir tarlanın toprak nemi, hava durumu, bitki su tüketimi gibi verileri kullanarak sulama zamanlaması konusunda çiftçiye öneri sunabilmektedir. Aynı şekilde, bitki gelişim modeli ve toprak besin analizine dayalı olarak gübreleme miktarını optimize edecek tavsiyelerde bulunabilir. Yapılan araştırmalar, AI destekli akıllı sulama sistemlerinin su kullanımını kayda değer oranda azaltırken verimi koruyabildiğini göstermektedir. Örneğin, düşük maliyetli sensörler ve bulanık mantık algoritmalarıyla gerçek zamanlı çalışan otonom bir sulama sistemi, insan kontrollü sulamaya kıyasla su tüketimini yaklaşık %30 oranında azaltmayı başarmıştır [19]. Benzer şekilde, hastalık erken uyarı sistemleri, yaprak görüntülerini derin öğrenme ile analiz ederek henüz gözle görülür yayılma olmadan çiftçiyi uyarabilmekte; bu sayede hastalığın yayılmadan önleyici ilaçlama yapılmasına imkan tanımaktadır.

Yapay zekâ tabanlı karar destek sistemlerinin tarımda uygulama alanları oldukça çeşitlidir: ürün rekolte tahmini, zararlı tahmin modülleri, pazar fiyat öngörüleri, ekim desen planlaması gibi konularda akademik çalışmalar mevcuttur [19-21]. Örneğin, bir çalışma makine öğrenimi teknikleriyle iklim değişkenlerini ve önceki verim verilerini kullanarak buğday verimini yüksek doğrulukla tahmin etmiş; bir diğerinde otonom bir sistem sera iklim kontrolünü AI ile optimize ederek hem enerji tasarrufu hem verim artışı sağlamıştır. Derin öğrenme tabanlı görüntü analiz sistemleri de tarımda karar destek amaçlı sıkça kullanılmaktadır: drone ile çekilen arazinin çok bantlı görüntülerini işleyerek bitki stresini tespit eden ve sulama tavsiyesi veren sistemler, veya yaprak analiziyle besin noksanlığı teşhisi koyan uygulamalar bunlara örnek verilebilir [19]. Ayrıca, çiftçiler için geliştirilen mobil uygulamalar ve web platformları aracılığıyla bu AI destekli öneriler pratik kullanıma sunulmaktadır. Kullanıcı dostu arayüzlerle çiftçiler tarlalarının durumunu izleyip sistemin ürettiği önerileri (örneğin "önümüzdeki 3 gün sulama yapmayın, toprak nemi yeterli" gibi) görebilmektedir.

Her ne kadar yapay zekâ tarımda büyük bir potansiyel barındırsa da mevcut literatürde bazı kısıtlar olduğu da belirtilmektedir. Bunların başında, veri kısıtlılığı ve kalite sorunları gelmektedir [3]. Pek çok AI modeli, yüksek miktarda ve çeşitli koşulları temsil eden verilerle eğitilmediğinde istenen genel performansa ulaşamıyor. Tarım özelinde kamuya açık büyük veri setlerinin azlığı, araştırmacıları zorlarken; özel sektör tarafından toplanan verilerin paylaşılmaması da ilerlemeyi yavaşlatabiliyor. Bunun yanında, geliştirilen AI modellerinin yorumlanabilirlik (explainability) eksikliği de çiftçilerin güven duymasını zorlaştırabilir. Bir karar destek sistemi "bugün sulama yapmayın" dediğinde, bunun arkasındaki nedenlerin anlaşılır şekilde sunulması benimsenme açısından önemli olacaktır. Literatürde bu soruna yönelik Açıklanabilir Yapay Zekâ (XAI) yaklaşımları tartışılmaktadır [1-21]. Son olarak, AI tabanlı öneri sistemlerinin tarla koşullarına tam entegre olabilmesi için uygun IoT altyapısının kurulması gerekmektedir. Sensör ağları, bulut bilişim ve iletişim teknolojilerinin kırsal alanda yaygınlaşması, bu sistemlerin başarısında belirleyici olacaktır.

TARTIŞMA

Son on yılda tarımda robotik ve otomasyon sistemlerinde önemli teknolojik atılımlar gerçekleşmiş olmakla birlikte, mevcut literatür incelendiğinde halen tam olarak çözüme kavuşmamış bazı sorunlar ve iyileştirme alanları olduğu görülmektedir. Literatürdeki bilgi

boşlukları ve teknolojik engeller, her bir alt uygulama özelinde farklılık göstermekle birlikte ortak bazı başlıklarda toplanabilir.

Algılama güvenilirliği tarım robotlarının en kritik meselelerinden biri olmaya devam etmektedir. Açık tarla ortamı robotik algılayıcılar için son derece değişken ve belirsizliklerle doludur [4]. Bitkilerin yaprak, dal ve meyvelerinin karmaşık bir arka plan oluşturması, nesne tanıma algoritmalarının hatasına yol açabilmektedir. Örneğin hasat robotları, yaprakların kısmen örttüğü meyveleri tespit etmekte zorlanabilir veya yanlışlıkla arka planı meyve sanabilir. Bu sorunu aşmak için son yıllarda derin öğrenme ile eğitilmiş gelişmiş görüntü işleme modelleri kullanılsa da eğitim verisi eksikliği önemli bir kısıt olarak durmaktadır [3]. Kamuya açık kapsamlı tarımsal görüntü veri setlerinin olmayışı, araştırmacıların her seferinde kendi verisini toplamasını gerektirmekte, bu da modellerin genellenebilirliğini sınırlamaktadır. Tartışılan bir çözüm, farklı araştırma gruplarının veri paylaşımına gitmesi ve ortak veri setleri oluşturarak algoritmaları bunlar üzerinde standardize etmesidir. Ayrıca yapay veriler üretmek üzere veri artırma (data augmentation) ve sentetik veri oluşturma teknikleri de bir çözüm olarak literatürde önerilmektedir.

Bir diğer önemli başlık, enerji ve güç yönetimidir. Mobil tarım robotlarının pil ömrü, özellikle dronlar ve küçük tarla robotları için kısıtlayıcı olmaktadır. Dronların tipik uçuş süresi 20–30 dakika civarında olup geniş alanların tek seferde ilaçlanmasını engellerken; elektrikli tahrikle çalışan tarla robotları da uzun süreli operasyonlarda şarj gereksinimi duymaktadır. Bu sorunu çözmek üzere güneş panelli robotlar, değiştirilebilir batarya istasyonları veya kablosuz enerji aktarımlı sistemler gibi yenilikçi fikirler ortaya atılmıştır. İlerleyen batarya teknolojileri (ör. yeni nesil lityum veya katı hal pilleri) de robotların çalışma süresini uzatmada kritik rol oynayacaktır.

Ekonomik boyut da tartışılması gereken bir faktördür. Gelişmiş tarım robotları ve otonom sistemler, yüksek Ar-Ge maliyetleri nedeniyle pahalı cihazlar olup küçük ölçekli çiftçiler için erişilebilir olmayabilir. Literatürde, teknolojik gelişmenin hızlanmasıyla birim maliyetlerin düşeceği ve zamanla robotların ekonomik açıdan daha cazip hale geleceği yönünde öngörüler vardır. Özellikle işçilik maliyetlerinin yüksek olduğu veya tarım işçisi bulmanın zorlaştığı bölgelerde, robotların geri ödeme süresi daha makul düzeylere inebilecektir. Bununla birlikte, kamu destekleri ve hibe programları ile çiftçilerin bu teknolojileri edinmesinin teşvik edilmesi de bir çözüm olarak sunulmaktadır.

Her alt alana özgü teknik engellere bakıldığında, hasat robotları için en büyük sorunlardan birinin farklı ürün ve ağaç yapılarının çeşitliliği olduğu söylenebilir. Tek bir robotik platformun farklı meyve türleri için kullanılabilmesi zordur; her ürün için ayrı optimizasyon ve mekanizma gerekebilmektedir. Bu da her birine ayrı Ar-Ge yatırımı anlamına gelir. İlaçlama dronları konusunda ise düzenlemeler ve saha uygulama protokollerinin eksikliği dile getirilmektedir. Dronların kalibrasyonu, dozaj ayarı, rüzgâr limitleri gibi konularda standartlar henüz tam oturmamıştır. Otonom traktörler için güvenlik en büyük tartışma konusudur; devasa kütleli bir aracın hatasız çalışacağından emin olunması gerekir. Bu kapsamda, çiftlik ortamında otonom araçların insanlı araçlarla veya insanlarla birlikte güvenle çalışabilmesi için sensör ve yazılım güvenilirliğinin ispatlanması gerekmektedir. Yapay zekâ karar destek sistemlerinde ise yukarıda bahsedilen veri ve güven problemlerine ek olarak, çiftçilerin bu sistemleri kullanma eğilimleri de araştırma konusudur. Teknolojiye aşinalık ve güven, bu sistemlerin sahada etkin şekilde kullanılabilmesi için kritik görülmektedir.

Tüm bu zorluklar aynı zamanda yeni fırsatlar ve araştırma alanları da yaratmaktadır. Örneğin, farklı robotik platformların entegre çalışması geleceğin önemli bir trendi olarak görülmektedir. Bir senaryoya göre, insansız bir traktör tarlada ilerlerken önden giden drone ile çevre taraması yapabilecek; veya bir yapay zekâ karar destek sistemi ile tarladaki robotik ekipman gerçek

zamanlı haberleşip anlık kararlar alabilecektir. Bu çeşit çoklu-robot ve AI entegrasyonu, literatürde verimlilik artışı için önerilen yaklaşımlardandır [1-3]. Örneğin, bir çalışmada bulut tabanlı bir DSS'nin tespit ettiği hastalık probleminin anında tarladaki otonom robota iletilerek müdahale edilmesi vizyonu sunulmuştur [21]. Bu tip uçtan uca otomasyon yaklaşımları, gelecekte tarımda maksimum verimlilik ve sürdürülebilirlik açısından büyük potansiyel taşımaktadır [1-3].

Özetle, tarım robotikleri literatürü son on yılda büyük atılımlar yapmış olsa da algılama, enerji, maliyet, standartlar ve veri paylaşımı gibi alanlarda aşılması gereken engeller mevcuttur. Tartışma bağlamında, bu engellerin üstesinden gelmek için disiplinler arası işbirliği, kamu-özel sektör ortak projeleri ve araştırma yatırımlarının artırılması önerilmektedir. Zira tarımda robotik sistemlerin tam potansiyeline ulaşması, yalnızca mühendislik ilerlemelerine değil, aynı zamanda kabul edilebilirlik, eğitim ve destekleyici politikalar gibi sosyal ve ekonomik faktörlere de bağlı olacaktır.

SONUÇ

Tarımda robotik sistemlerin 2015–2025 arasındaki gelişimi, tarımsal üretimde yeni bir çağın habercisi niteliğindedir. Geride bıraktığımız on yıl, hasattan ilaçlamaya, sürüden sulamaya pek çok alanda önemli ilerlemelere sahne olmuştur. Hasat robotları akademik prototip düzeyinden çıkarak belirli ürünlerde ticari denemelere ulaşmış, insansız hava araçları tarla ilaçlamasında yaygın bir araç haline gelmeye başlamış, otonom traktörler konseptinin büyük üreticiler tarafından benimsenmesiyle sürücüsüz tarım makineleri gerçeğe yaklaşmıştır. Yine yapay zekâ tabanlı sistemler, büyük veri analizini tarıma entegre ederek çiftçilere somut faydalar sunar duruma gelmiştir. Tüm bu gelişmeler, üretimde verimlilik, hassasiyet ve sürdürülebilirlik açısından umut vadetmektedir.

Bununla birlikte, mevcut durum bir başlangıç olarak görülmelidir. Önümüzdeki on yılın, tarım robotiklerinde çok daha fazla yeniliğe ve atılıma sahne olacağı öngörülmektedir [1-16]. Sensör teknolojilerinin ucuzlayıp yaygınlaşması, yapay zekâ algoritmalarının daha güçlü hale gelmesi ve bilişim altyapılarının kırsalda gelişmesiyle, robotik sistemlerin tarla koşullarına adaptasyonu hızlanacaktır. Muhtemeldir ki yakın gelecekte akıllı robotlar tıpkı birer "çiftlik işçisi" gibi tarım işletmelerinin ayrılmaz bir parçası olacaktır. Özellikle hedefe yönelik yabancı ot kontrolü, otomatik hasat, toprak analizine dayalı gübreleme ve gerçek zamanlı ürün izleme gibi uygulamalarda robotların kullanımı sıradan hale gelebilir. Bu süreçte, araştırmacılar ve mühendisler kadar tarım üreticileri ve politika yapıcılara da görev düşmektedir. Teknolojinin çiftçi ihtiyaçlarına uygun geliştirilmesi, kullanımının yaygınlaştırılması için eğitim faaliyetleri ve uygun teşvik mekanizmalarının kurulması önem arz etmektedir.

Sonuç itibariyle, tarımın robotik ve yapay zekâ ile buluşması, insanlığın en temel ihtiyacı olan gıda üretimini daha verimli, güvenli ve sürdürülebilir kılma yolunda önemli bir adımdır [5]. Gelecek yıllarda disiplinler arası işbirlikleri ve inovasyon ekosisteminin desteğiyle tarım robotik sistemlerinin yaygınlaşıp olgunlaşacağı ve dünya genelinde tarımsal üretimde etkin rol oynayacağı değerlendirilmektedir.

KAYNAKÇA

[1] Duckett T, Pearson S, Blackmore S, Grieve B, Chen WH, Cielniak G, et al. Agricultural robotics: The future of robotic agriculture. arXiv preprint. 2018; arXiv:1806.06762.

[2] Bechar A, Vigneault C. Agricultural robots for field operations: Concepts and components. Biosystems Engineering. 2016;149:94–111. doi:10.1016/j.biosystemseng.2016.06.014

[3] Cheng C, Fu J, Su H, Ren L. Recent advancements in agriculture robots: benefits and challenges. Machines. 2023;11(1):48. doi:10.3390/machines11010048

[4] Fountas S, Mylonas N, Malounas I, Rodias E, Hellmann Santos C, Pekkeriet E. Agricultural robotics for field operations. Sensors. 2020;20(9):2672. doi:10.3390/s20092672

[5] Spagnuolo M, Todde G, Caria M, Furnitto N, Schillaci G, Failla S. Agricultural robotics: a technical review addressing challenges in sustainable crop production. Robotics. 2025;14(2):9. doi:10.3390/robotics14020009

[6] Baeten J, Donné K, Boedrij S, Beckers W, Claesen E. Autonomous fruit picking machine: A robotic apple harvester. Field and Service Robotics, 2008;42:531-539. (Conference Proceedings)

[7] Bulanon DM, Kataoka T. Fruit detection system and an end effector for robotic harvesting of Fuji apples. Agric Eng Int: CIGR Journal. 2010;12(1):203-210.

[8] Kahya E, Arın S. Elma meyvesinin fizikomekanik özelliklerinin robotik hasada etkisi. Akademik Ziraat Dergisi. 2019;8(1):43-50. doi:10.29278/azd.593607

[9] Navone A, Martini M, Chiaberge M. Autonomous Robotic Pruning in Orchards and Vineyards: a Review. arXiv Preprint. 2025 May 12; arXiv:2505.07318.

[10] Rondelli V, Franceschetti B, Mengoli D. A review of current and historical research contributions to the development of ground autonomous vehicles for agriculture. Sustainability. 2022;14(15):9221. doi:10.3390/su14159221

[11] Silwal A, Davidson JR, Karkee M, Mo C, Zhang Q, Lewis K. Effort towards robotic apple harvesting in Washington State. 2016 ASABE Annual International Meeting; Orlando, Florida; 2016. doi:10.13031/aim.20162460869

[12] Özgüven MM, Tan M, KözkurT C, Yardım MH, Özsoy M. Çok amaçlı tarım robotunun geliştirilmesi. GOÜ Ziraat Fakültesi Dergisi. 2016;33(Ek Sayı):108-116.

[13] Günen MA. Nokta bulutu verisi kullanılarak elma bahçesinden meyve tespiti. El-Cezerî Journal of Science and Engineering. 2022;9(1):253-265. doi:10.31202/ecjse.962269

[14] He L, Sun Y, Chen L, Feng Q, Li Y, Lin J, Qiao Y, Zhao C. Advance on Agricultural Robot Hand–Eye Coordination for Agronomic Task: A Review. Engineering. 2025. doi:10.1016/j.eng.2025.01.022

[15] Mahmoudi S, Davar A, Bist RB, Wang D. Leveraging imitation learning in agricultural robotics: a comprehensive survey and comparative analysis. *Frontiers in Robotics and AI*. 2024. doi:10.3389/frobt.2024.1441312

[16] Moshayedi AJ, Khan AS, Yang Y. Robots in Agriculture: Revolutionizing Farming Practices. EAI Endorsed Transactions on AI and Robotics. 2024 Jun; (1):1. doi:10.4108/airo.5855

[17] García-Munguía A, Guerra-Ávila PL, Islas-Ojeda E, Flores-Sánchez JL, Vázquez-Martínez O, García-Munguía O. A review of drone technology and operation processes in agricultural crop spraying. Drones. 2024;8(11):674. doi:10.3390/drones8110674

[18] Oliveira LFP, Moreira AP, Silva MF. Advances in Agriculture Robotics: A State-of-the-Art Review and Challenges Ahead. Robotics. 2021;10(2):52. doi:10.3390/robotics10020052

[19] Liakos KG, Busato P, Moshou D, Pearson S, Bochtis D. Machine learning in agriculture: a review. Sensors. 2018;18(8):2674. doi:10.3390/s18082674

[20] Karadöl H, Aybek A. Yabancı otların değişken düzeyli ilaçlanmasına yönelik MATLAB ve PLC arası OPC haberleşmesi kullanılarak geliştirilen bir kontrol sistemi. Tekirdağ Ziraat Fakültesi Dergisi. 2017;14(2):17-25.

[21] Asolo E, Gil-Ozoudeh I, Ejimuda C. AI-Powered Decision Support Systems for Sustainable Agriculture using AI-Chatbot Solution. Journal of Digital Food Energy & Water Systems. 2024;5(1):1-10. doi:10.36615/2ar4w994

ARTIFICIAL INTELLIGENCE ASSISTED WEED CONTROL IN THE LAST DECADE: ADVANCES IN CEREAL PRODUCTION AREAS, ADVANTAGES, CHALLENGES AND FUTURE PERSPECTIVES

Res. Asst. Özlem BAHAR

Kırşehir Ahi Evran University, Faculty of Agriculture, Department of Plant Protection, Kırşehir, Turkey

ORCID ID: https://orcid.org/0009-0002-2246-8790

Res. Asst. Osman Mert YAZ

Erciyes University, Faculty of Agriculture, Department of Biosystems Engineering, Kayseri, Turkey

ORCID ID: https://orcid.org/0009-0003-3367-6656

Assoc. Prof. Dr. Bahadır DEMİREL

Erciyes University, Faculty of Agriculture, Department of Biosystems Engineering, Kayseri, Turkey

ORCID ID: https://orcid.org/0000-0002-2650-1167

Assoc. Prof. Dr. Melih YILAR

Kırşehir Ahi Evran University, Faculty of Agriculture, Department of Plant Protection, Kırşehir, Turkey

ORCID ID: https://orcid.org/0000-0001-5963-4743

ABSTRACT

Weeds in agricultural production are a critical problem that threatens crop yield and quality. In particular, in cereal fields such as wheat, if uncontrolled, weeds can cause yield losses of up to 48–60%. Traditional weed control methods (mechanical hoeing, hand weeding, and extensive herbicide use) have significant limitations in terms of both labor requirements and environmental impacts. Moreover, intensive herbicide use has accelerated the evolution of herbicide-resistant weed species, with 266 weed species worldwide now resistant to at least one herbicide. Over the last decade, artificial intelligence (AI) and related technologies such as image processing, machine learning, and robotics have enabled revolutionary advances in agricultural weed management. This review comprehensively examines the SCI-, Scopus- and Web of Science–indexed literature on AI-assisted weed control from 2015 to 2025. In particular, it addresses the advantages (e.g. precision spraying that can save up to 50% of herbicide use, providing environmental and economic benefits), disadvantages, and adoption of AI applications in cereal production. The results indicate that deep learning–based image recognition systems can distinguish weeds with high accuracy, and autonomous robotic systems offer the possibility of herbicide-free weed control in the field. However, widespread adoption remains limited due to barriers such as high system costs, complex field conditions, and farmer

acceptance. This study highlights knowledge gaps in the existing literature and suggests research directions for more widespread and effective use of AI-assisted weed control in the future. Studies conducted in Turkey are evaluated separately, detailing the status of AI-based weed control in the country. The findings reveal that despite the great potential offered by AI in weed management, further research and infrastructure development are needed to ensure the effective and ethical use of these technologies in the field.

Keywords: Weed, artificial intelligence, herbicide, control, technology, deep learning

ÖZET

Tarımsal üretimde yabancı otlar, ürün verimini ve kalitesini tehdit eden kritik bir sorundur. Özellikle tahıl alanlarında yabancı otlar, buğday gibi ürünlerde önlem alınmadığı takdirde verimde %48-60'a varan kayıplara yol açabilmektedir. Geleneksel yabancı ot kontrolü yöntemleri (mekanik çapalama, elle yolma ve yaygın herbisit kullanımı) hem işgücü gereksinimi hem de çevresel etkiler açısından önemli kısıtlara sahiptir. Ayrıca, yoğun herbisit kullanımı dirençli yabancı ot türlerinin evrimini hızlandırmış ve dünya çapında 71 ülkede 266 yabancı ot türü en az bir herbisite dayanıklılık kazanmıştır. Son on yılda yapay zekâ (YZ) ve buna bağlı görüntü işleme, makine öğrenmesi ve robotik teknolojiler, tarımsal yabancı ot yönetiminde devrim niteliğinde gelişmeler sağlamıştır. Bu derlemede, 2015-2025 döneminde YZ destekli yabancı ot kontrolüne ilişkin SCI, Scopus ve Web of Science indeksli literatür kapsamlı bir biçimde incelenmiştir. Özellikle tahıl üretim alanlarında YZ uygulamalarının avantajları (örn. hassas ilaçlama ile %50'ye varan herbisit tasarrufu, çevresel ve ekonomik kazanımlar), dezavantajları ve kullanım sıklığı ele alınmıştır. Sonuçlar, derin öğrenme tabanlı görüntü tanıma sistemlerinin yabancı otları yüksek doğrulukla ayırt edebildiğini ve otonom robotik sistemlerin tarlalarda herbisitsiz mücadele imkânı sunduğunu göstermektedir. Bununla birlikte, sistemlerin yüksek maliyeti, tarla koşullarındaki karmaşıklık ve çiftçi adaptasyonu gibi engeller nedeniyle yaygın kullanımının henüz sınırlı kaldığı anlaşılmaktadır. Bu çalışmada, mevcut literatürdeki bilgi boşlukları vurgulanmakta ve gelecekte YZ destekli yabancı ot mücadelesinin daha yaygın ve etkili kullanımı için araştırma yönelimleri önerilmektedir. Türkiye özelinde yapılan çalışmalar da ayrı bir başlık altında değerlendirilmiş ve ülkemizde YZ ile yabancı ot kontrolünün durumu detaylandırılmıştır. Elde edilen bulgular, yapay zekânın yabancı ot yönetiminde sunduğu büyük potansiyele rağmen, bu teknolojilerin sahada etkin ve etik kullanımı için daha fazla araştırma ve altyapı geliştirilmesine ihtiyaç duyulduğunu ortaya koymaktadır.

Anahtar Kelimeler: Yabancı ot, yapay zekâ, herbisit, mücadele, teknoloji, derin öğrenme.

GİRİŞ

Tarımsal ekosistemlerde yabancı otlar, ekinlerle su, besin ve ışık için yarışarak dünya genelinde ortalama %34 oranında verim kayıplarına neden olan önemli bir sorundur [1-2]. Bu sorun özellikle buğday, arpa, mısır gibi tahıl üretimi yapılan alanlarda daha da kritik hale gelmektedir. Örneğin, buğday tarlalarında yoğun yabancı ot istilası, bitkilerin tane doldurma dönemini aksatır ve sonuçta ürün kalitesini ve verimini ciddi ölçüde düşürür [3-4]. *Echinochloa crus-galli, Avena fatua* gibi dar yapraklı yabancı ot türleri morfolojik olarak buğday gibi tahıllara çok benzer özellikler gösterdiğinden, tarla koşullarında tanınmaları ve ayrıştırılmaları güçtür. Bu morfolojik benzerlik, geleneksel yöntemlerle yabancı ot-ürün ayrımını zorlaştırarak mücadelenin etkinliğini azaltmaktadır [4].

Yabancı otlarla mücadelede geleneksel yöntemler, uzun yıllardır çiftçiler tarafından uygulanmaktadır. Mekanik yöntemler (sürme, çapa vb.) yabancı otları fiziksel olarak uzaklaştırırken toprağı da işleyerek erozyona zemin hazırlayabilir [1]. Elle yolma oldukça emek ve iş gücü gerektiren bir işlemdir, günümüzde tarımda işgücü kıtlığı nedeniyle sürdürülebilir değildir [2]. En yaygın yöntem olan kimyasal mücadele ise hız ve etki açısından avantajlı olsa da aşırı ve bilinçsiz kullanımla çevre kirliliği, toprak ve su kaynaklarının kirlenmesi ve ürünlerde kimyasal kalıntı gibi ciddi sorunlar yaratmaktadır [2-3]. Ayrıca geniş spektrumlu herbisitlerin yıllar içinde yoğun kullanımı, hedef yabancı ot popülasyonlarında herbisit direnci gelişimini tetiklemektedir. Nitekim 1950'lerden beri öngörülen bu direnç sorunu günümüzde büyük bir boyuta ulaşmış; 1990'larda herbisit dirençli transgenik ekinlerin yaygınlaşmasıyla artan herbisit kullanımı sonucu, dünya çapında yüzlerce yabancı ot türü bir veya daha fazla etken maddeye karşı direnç kazanmıştır. 2021 itibariyle 71 ülkede toplam 266 yabancı ot türünün 165 farklı herbisite direnç geliştirdiği rapor edilmiştir [1]. Bu durum, herbisitlere aşırı bağımlılığın uzun vadede sürdürülemez olduğunu ve daha entegre, yenilikçi yaklaşımlara ihtiyaç duyulduğunu göstermektedir.

Sürdürülebilir yabancı ot yönetimi için son yıllarda iki önemli yaklaşım öne çıkmaktadır. Birincisi Entegre Yabancı Ot Yönetimi (Integrated Weed Management, IWM): Kültürel, mekanik, biyolojik ve kimyasal yöntemleri bir arada kullanarak herbisit kullanımını en aza indirmeyi hedefler. İkincisi ise Alan-spesifik (hassas) yabancı ot yönetimi (Site-Specific Weed Management, SSWM): Tarla içinde yabancı ot yoğunluğundaki konumsal değişkenliği dikkate alarak sadece ihtiyaç duyulan yer ve zamanda müdahale etmeye odaklanır. Hassas tarım prensipleriyle uyumlu olan SSWM, GPS, uzaktan algılama ve coğrafi bilgi sistemleri gibi teknolojileri kullanarak yabancı ot haritalaması yapmakta; böylece ilaçlama gibi işlemler yalnızca yoğun yabancı ot görülen noktalarda uygulanarak hem çevreye salınan kimyasal miktarı azaltılmakta hem de maliyet düşürülebilmektedir. Nitekim aralıklı (sadece yabancı ot bulunan yerlere) herbisit uygulaması, konvansiyonel tam alana püskürtme yöntemine kıyasla %90'ı aşan oranlarda herbisit tasarrufu sağlayabilmektedir [1].

Entegre ve hassas yabancı ot kontrolünün etkin biçimde uygulanabilmesi için en kritik ihtiyaç, tarla koşullarında yabancı otların doğru şekilde tespiti ve ayırt edilmesidir [5]. İnsan işgücü ile yapılan tarla taramaları hem yavaş hem de subjektif olduğundan geniş alanlarda pratik değildir. Bu noktada, son yıllarda tarımda yapay zekâ teknolojileri devreye girmektedir. Yapay zekâ (YZ), makine öğrenmesi ve özellikle görüntü tanımada önemli bir yer edinen derin öğrenme algoritmaları sayesinde karmaşık görsel verilerden anlamlı bilgiler çıkarabilmektedir. Tarım alanında YZ uygulamaları, hassas tarım konsepti altında sulama optimizasyonundan ürün verim tahminine kadar pek çok alanda kullanılmaktadır. Özellikle yabancı ot yönetimi konusunda YZ, görüntü işleme ile yabancı ot tanıma, otonom ilaçlama sistemleri, robotik yabancı ot sökme makineleri ve insansız hava araçları (İHA) ile tarama gibi yenilikçi çözümlerin merkezinde yer almaktadır. YZ algoritmaları sayesinde tarladaki bitkilerin gerçek zamanlı olarak taranıp yabancı otların belirlenmesi, hatta hassas konumlarının saptanması mümkün hale gelmiştir. Böylece, sadece yabancı otlara yönelik nokta atışı ilaçlama (spot spraying) veya mekanik imha gerçekleştirerek hem kimyasal kullanımını hem de işçilik ihtiyacını minimuma indirmek hedeflenmektedir [6].

Bu derlemenin amacı, son 10 yılda (2015-2025) yapay zekâ ile yabancı ot kontrolü konusunda gerçekleştirilen akademik çalışmaları kapsamlı bir şekilde incelemektir. Özellikle tahıl üretimi yüksek olan alanlarda (buğday tarlaları vb.) YZ uygulamalarının ne düzeyde kullanıldığı, hangi teknolojik yaklaşımların denendiği, avantajları ve dezavantajları ile karşılaşılan engellerin neler olduğu literatür ışığında değerlendirilendirilmiştir. Ayrıca Türkiye'de yabancı ot kontrolünde yapay zekâ kullanımına ilişkin gerçekleştirilen akademik çalışmalar ayrı bir başlık altında ele alınarak, küresel bağlam içinde ülkemizin durumu irdelenmiştir. Giriş bölümünde

sunulan arka plan doğrultusunda, YZ tabanlı yaklaşımların yabancı ot yönetiminde ortaya çıkış nedenleri ve önemine değinilmiş olup, bundan sonraki bölümlerde literatürde rapor edilen bulgular tematik alt başlıklar halinde sunulacak, takiben tartışma ve sonuç bölümlerinde genel değerlendirme yapılacaktır.

YAPAY ZEKÂ İLE YABANCI OT TEŞHİSİ VE HARİTALAMA

YZ destekli yabancı ot kontrolünün ilk ve en önemli adımı, yabancı otların tespiti ve tanımlanmasıdır. Geleneksel görüntü işleme teknikleri, belirli renk eşikleri, doku veya şekil özellikleri kullanarak yabancı ot-ürün ayrımı yapmaya çalışmıştır. Ancak bu yöntemler genellikle elle tanımlanmış özniteliklere dayalı olup ortamdaki ışık, bitki boyutu ve karmaşık arka plan koşullarında tutarlılığını yitirebilmektedir [5]. Örneğin, yalnızca renk veya şekil bilgisini kullanan klasik algoritmalar, buğday tarlasında yaprak yapısı buğdaya çok benzeyen yabani yulaf gibi yabancı otları doğru saptamakta zorlanmıştır [4]. Bu nedenle son on yılda araştırmacılar, derin öğrenme tabanlı görüntü tanıma tekniklerine yönelmişlerdir.

Derin öğrenme (deep learning), özellikle Evrişimli Sinir Ağları (Convolutional Neural Networks, CNN) aracılığıyla görüntülerden el ile tanımlanmamış özellikleri öğrenerek sınıflandırma yapabilmektedir. Tarım alanında derin öğrenmenin başarısı sayesinde, yabancı ot tespitinde dört temel yaklaşım öne çıkmıştır:

1- Görüntü sınıflandırma: Bir görüntüde yabancı ot var mı, yok mu ya da belirli bir bitki türü mü var sorusunu yanıtlar.

2- Nesne tespiti: Görüntü içerisinde her bir yabancı otun konumunu sınırlayıcı kutu ile tespit eder.

3- Semantik segmentasyon: Her pikseli yabancı ot veya ürün olarak sınıflandırarak ayrıntılı bir haritalama yapar.

4- Örnek bazlı segmentasyon: Hem nesne tespiti hem de piksel bazlı segmentasyonu bir araya getirerek tarladaki her bir yabancı ot bireyini maskeler.

Bu yaklaşımlar, derin öğrenmenin sağladığı güçlü özellik çıkarma yetenekleri sayesinde karmaşık arka planlarda dahi yüksek doğruluklar elde etmektedir [5].

Yabancı ot teşhisinde CNN modellerinin başarısı literatürde çeşitli çalışmalarla ortaya konmuştur. Örneğin, bir çalışmada ResNet, VGG16 ve DenseNet gibi farklı derin öğrenme modelleri kullanılarak çok sınıflı yabancı ot türü tanıma denemeleri yapılmış; VGG16 modeli, farklı yabancı ot türlerini %99'a varan doğruluk oranıyla sınıflandırarak en yüksek performansı sergilemiştir [7]. Bu sonuç, derin öğrenme tabanlı sistemlerin tarla koşullarında dahi çeşitli yabancı ot türlerini ayırt edebilecek genelleştirmeyi öğrenebileceğini göstermektedir. Bununla birlikte, yüksek doğruluk elde etmek için genellikle geniş ve çeşitli veri setlerine ihtiyaç duyulmaktadır. Literatürde son dönemde açık kaynaklı yabancı ot görüntü veri setleri oluşturulmaya başlanmıştır. Örneğin, Almanya'da geliştirilmiş bir veri seti, farklı gelişim evrelerinde yabancı ot görüntülerini içererek algoritmaların saha koşullarına daha iyi uyum sağlamasına katkı sunmuştur. Benzer şekilde Avustralya'dan DeepWeeds veri seti, farklı bölgelerin yabancı ot türlerini kapsamaktadır. Bu tür veri setleri, algoritmaların laboratuvar ortamından çıkarak gerçek tarla görüntülerinde de başarılı olmasına yardımcı olmaktadır. Teşhis sürecinde yalnızca RGB (görünür ışık) görüntüleri değil, hiperspektral veya derinlik (LIDAR) gibi farklı veri kaynakları da entegre edilmektedir. Çoklu-modelli (multi-modal) yaklaşımlar, tek bir görüntüden alınamayan bilgiyi sağlayarak tanıma başarımını artırır.

Örneğin, Çin'de yapılan bir araştırmada buğday tarlalarında yabancı ot tespiti için RGB kamera ile derinlik sensöründen gelen veriler birleştirilmiştir. RGB görüntüler, yabancı otların renk ve biçim bilgisini sunarken, derinlik sensörü bitkilerin yükseklik ve konum bilgisini vermiştir. Araştırmada, tek RGB görüntülerle çalışan modele kıyasla, RGB-D veriye dayalı derin öğrenme modelinin ortalama doğruluğu belirgin şekilde arttığı rapor edilmiştir. Özellikle buğday gibi bitki boyu ve yapısı mevsimsel olarak değişen bitkiler için, derinlik bilgisinin eklenmesi dar yapraklı otların bitkilerden ayırt edilmesini kolaylaştırmıştır [4].

İnsansız Hava Araçları (İHA veya drone) kullanımı da yabancı ot haritalama konusunda yaygınlaşmaktadır. İHA'lar, geniş tarım alanlarını kısa sürede tarayarak yüksek çözünürlüklü hava görüntüleri elde edebilmektedir. YZ destekli analiz yazılımları bu görüntüler üzerinde yabancı otların konumlarını tespit ederek yabancı ot yoğunluk haritaları çıkarabilmektedir [1]. Bu sayede çiftçiler, tarlalarının hangi bölgesinde yabancı ot yoğunluğunun kritik seviyede olduğunu görebilmekte ve sadece o bölgelere müdahale edebilmektedir. Örneğin, bir çalışmada İHA ile çekilen görüntüler üzerinden yabancı ot yaması tespiti yapılarak, sonrasında traktöre monte hassas ilaçlama sistemine bu konumlar yüklenmiş ve yalnızca yabancı ot bulunan noktalara püskürtme yapılması sağlanmıştır. Sonuç olarak tüm tarlayı düzeyli bir dozla ilaçlamaya kıyasla %80'in üzerinde herbisit tasarrufu elde edilmiştir. İHA tabanlı bu yaklaşım, özellikle geniş arazilerde ve erken dönem yabancı ot çıkışının tespitinde büyük avantaj sağlamaktadır. Erken dönem yabancı ot yönetimi, otların tohum bağlayarak çoğalmasını engellediği için çok kritik görülmektedir. Derin öğrenme yöntemleri, klasik şekil tabanlı bilgisayarlı görmeye kıyasla erken fenolojik evredeki küçük yabancı otları dahi güvenilir biçimde tespit edebilmektedir [1]. Özetle, YZ destekli yabancı ot teşhisinde son 10 yılda kaydedilen gelişmeler sayesinde, tarla bitkileri ve yabancı otlar görsel olarak güvenilir şekilde ayırt edilebilir hale gelmiştir. Bu gelişme, yabancı otla mücadelenin bir sonraki aşaması olan hedefe yönelik kontrol için sağlam bir temel oluşturmaktadır.

ROBOTİK VE OTONOM YABANCI OT KONTROL SİSTEMLERİ

Yabancı otların tanılanmasının ardından, asıl amaç bu istenmeyen bitkilerin ekinlere zarar vermeden ortadan kaldırılması veya etkisiz hale getirilmesidir. Yapay zekâ, bu aşamada insan müdahalesine gerek kalmadan çalışan otonom sistemlerin beyni konumundadır. Son yıllarda geliştirilen robotik yabancı ot kontrol makineleri, tarla üzerinde gezinerek yabancı otları mekanik araçlar, lazer veya lokal herbisit püskürtme ile imha edebilmektedir. Otonom tarla robotları, genellikle paletli veya tekerlekli küçük traktör boyutlarında araçlar olarak tasarlanmaktadır. Üzerlerinde yüksek çözünürlüklü kameralar, GPS, LIDAR ve bazen robot kol sistemleri bulunur. Bu robotlar, YZ tabanlı görüntü işleme yazılımları sayesinde sürekli olarak önlerindeki bitkileri tarar, ekin mi yoksa yabancı ot mu olduğunu gerçek zamanlı tespit eder [8]. Tespit ettiği yabancı otları yok etmek için farklı yöntemler kullanabilir; mekanik bir çapa ile kökünden sökme, küçük bir bıçak veya rotorla kesip parçalama, mikrodalga veya elektrik şoku uygulama ya da hedefe yönelik mikro-püskürtme ile sadece o bitkiye herbisit verme gibi. Örneğin, EcoRobotix adında ticari bir robot, kameraları ile 3 cm çaplı bir alandaki yeşil yabancı ot yaprağını tespit edip sadece o yaprağa birkaç damla herbisit damlatabilmektedir. Bu şekilde yapılan nokta atışı ilaçlama, konvansiyonel yöntemlere göre %90'a varan oranda daha az kimyasal kullanımı gerektirmektirmektedir [8]. Benzer şekilde, Blue River "See & Spray" teknolojisi, pamuk tarlalarında kamera ve YZ ile yabancı otları tanıyıp sadece yabancı ota püskürtme yaparak herbisit kullanımını düşürmüştür.

Robotik sistemlerin bir diğer yenilikçi yöntemi, herbisitsiz imha teknikleri kullanmalarıdır. Örneğin, lazerle yakma bunlardan biridir. YZ ile tanınan yabancı otun koordinatına odaklanan güçlü bir lazer ışını, saniyeler içerisinde bitkinin dokusunu tahrip ederek onu öldürmektedir [9].

Lazer tabanlı sistemler özellikle organik tarımda, kimyasal kullanmadan mücadele olanağı sunduğu için ilgi çekmektedir. Almanya'da prototipi geliştirilen "WeedLaser" isimli bir cihaz, sıra aralarında ilerleyerek yabancı otları lazerle yok etmiş ve yapılan denemelerde genç yabancı otlarda %80'in üzerinde başarı elde edilmiştir. Yine elektrik akımıyla yakma yönteminde, robot kol ucundaki bir elektrod yabancı ota dokundurulup yüksek voltaj vererek bitki hücrelerini patlatma prensibiyle çalışmaktadır. Bu yöntem, özellikle boyu kısa ve sık yabancı ot popülasyonlarında etkilidir. Hollanda'da geliştirilen "CEOL" robotu bu tekniği denemiş ve tarlada herbisitsiz yabancı ot temizliğini mümkün kılmıştır.

Robotik yabancı ot mücadelesinde bir diğer önemli araç, hassas püskürtme sistemleridir. Bu sistemler, genellikle traktöre monte edilen veya otonom platformlara entegre edilen akıllı ilaçlama düzenekleridir. Örneğin, kameralarla donatılmış akıllı ilaçlama memeleri, tarlada ilerlerken sürekli görüntü analizine tabi tutularak yalnız yabancı ot tespit edildiğinde kimyasal püskürtür [7]. Böylece herbisit kullanımı minimuma iner. North Carolina State University'de geliştirilen bir prototip, mısır tarlasında belirli yabancı ot türlerini tanıyıp herbisit uygulamasını otomatikleştirmiş ve klasik yöntemlere göre %70 daha az ilaçla eşdeğer kontrol sağlamıştır. Bu teknoloji, halihazırda ticari tarım makinesi üreticilerinin de ilgisini çekmiş ve bazı traktör şirketleri kameralı akıllı püskürtme ünitelerini pazara sunmaya başlamıştır.

Otonom sistemlerin başarısı, büyük ölçüde yapay zekâ algoritmalarının doğruluğu ve hızlı çalışmasına bağlıdır. Bir tarla robotunun saatte birkaç dönüm alanı tarayabilmesi için, YZ modelinin kameradan gelen görüntüleri anlık olarak işlemesi ve karar vermesi gerekir. Bu amaçla, günümüzde birçok sistemde GPU destekli yerleşik bilgisayarlar veya özel yapay zekâ çipleri kullanılmaktadır. Bazı tasarımlarda ise, robot üzerindeki kameraların görüntüleri kablosuz ağ üzerinden bulut sunuculara iletilip orada işlenmekte, sonuçlar robota geri gönderilmektedir. Ancak tarlalarda internet bağlantısının her zaman güvenilir olmaması nedeniyle, hesaplamanın mümkün mertebe cihaz üzerinde yapılması tercih edilir. Literatürde, robotik yabancı ot mücadelesinin tarıma potansiyel etkileri üzerine birçok çalışma bulunmaktadır. Genel olarak bu sistemlerin şu avantajları vurgulanmaktadır: Herbisit kullanımını büyük ölçüde azaltma (dolayısıyla üretim maliyetini düşürme ve çevresel yükü hafifletme), işgücü ihtiyacını azaltma (özellikle geniş alanlarda ve yoğun yabancı ot durumlarında insan gücü gereksinimini minimize etme), üründe selektiviteyi artırma(yalnız yabancı otları hedefleyip ekinlere zarar vermeme), ve arazi koşullarına daha hızlı yanıt verme (gerçek zamanlı tespit ve imha ile yabancı otların büyüyüp tohum vermeden kontrolü). Nitekim YZ destekli bir robotik sistem, hem görüntü tanımada hem de rotalama, operasyon kontrolü, veri kaydı gibi süreçlerde otonom karar vererek geleceğin gerçek zamanlı "akıllı" tarım makineleri vizyonunu bugünden sunmaktadır [1].

Öte yandan, robotik sistemler henüz yaygın ticarileşme aşamasına tam olarak geçebilmiş değildir. Birçok çalışma prototip geliştirme ve pilot tarla denemesi düzeyindedir. Bu prototiplerin önemli bir kısmı küçük ve orta ölçekli deneme alanlarında başarılı olsa da, büyük ölçekli çiftliklerde veya karmaşık arazi yapılarında uyarlanması mühendislik çözümleri gerektirmektedir. Örneğin, eğimli arazilerde robotun stabilitesi, çok sık ekilmiş veya çok boylu ürünler arasında navigasyon zorlukları, batarya ile çalışan sistemlerde uzun süreli operasyon kısıtı gibi sorunlar dile getirilmektedir. Ayrıca bir robotik cihazın birim araziyi tarama süresi, geleneksel traktörle geniş püskürtme yöntemi kadar hızlı olmayabilir; bu da pratikte zaman yönetimi açısından değerlendirilmektedir.

Özetle, YZ güdümlü robotik ve otonom sistemler yabancı ot mücadelesinde kimyasal ve mekanik yöntemlere yenilikçi bir alternatif olarak karşımıza çıkmaktadır. Küçük prototiplerden, traktör boyutlu entegre sistemlere kadar geniş bir yelpazede geliştirilen bu teknolojiler, tarımda iş yapış şekillerini kökten değiştirme potansiyeline sahiptir.

TAHIL ÜRETİM ALANLARINDA YZ UYGULAMALARI

Tahıl tarımı, dünya gıda güvenliğinin temelini oluşturduğundan yabancı ot kontrolünün kritik önem taşıdığı bir alandır. Tahıl tarlaları genellikle geniş ve düzlük arazilerdir; bu da yabancı otların alan içerisinde dağılımının heterojen olabileceği anlamına gelir. Hassas haritalama yöntemleriyle bir buğday tarlasında yabancı otların belli alanlarda yoğunlaştığı, bazı bölgelerde ise neredeyse hiç çıkmadığı saptanabilir. Bu tür veriler, çiftçilere yalnız problemli bölgelere müdahale etme imkânı verir. Örneğin, Fransa'da yapılan bir çalışmada buğday tarlalarında *Galium aparine* (yapışkan ot) ve *Papaver rhoeas* (gelincik) gibi yaygın yabancı otların belirli köşelerde yoğunlaştığı, tarlanın geri kalanında seyrek olduğu saptanmış; İHA tabanlı haritalama ile tam konumları belirlenen bu yabancı ot kümelerine traktörle sadece lokal herbisit uygulaması yapılarak %70 civarında ilaç ve iş gücü tasarrufu sağlanmıştır [10].

Tahıl alanlarında yabancı ot tespiti için derin öğrenme yöntemleri yoğun biçimde denenmektedir. Yukarıda bahsedilen örneklerde buğday tarlasında yabancı ot türlerinin algılanmasında YOLO (You Only Look Once) gibi gerçek zamanlı nesne tanıma algoritmalarının modifiye edilmiş sürümleri kullanılmıştır. YOLO ve benzeri modeller, tek bir sinir ağı ile görüntüyü tarayarak hem yabancı otların yerini tespit edebilmekte hem de tür teşhisi yapabilmektedir [11]. 2023 yılında yapılan bir araştırmada, YOLOv7 modelinin buğday tarlasında beş farklı yabancı ot türünü tanıması sağlanmış ve sonuçta modelin %85 üzeri bir ortalama doğrulukla yabancı otları doğru tespit ettiği rapor edilmiştir. Model bazı yabancı otları (*Avena fatua* gibi) buğdayla şekil benzerliği nedeniyle karıştırsa da geliştirilmiş bir eğitim stratejisiyle bu hatalar azaltılmıştır [12]. Bu tür sonuçlar, derin öğrenmenin tahıl tarımında pratik kullanım için yeterli doğruluk seviyelerine yaklaşmakta olduğunu göstermektedir.

Tahıl ürünleri, diğer bazı tarla bitkilerine kıyasla farklı bir zorluk seviyesi sunar. Ekim yoğunluğu fazladır ve bitkiler kısa sürede tüm zemini kaplar. Bu nedenle yabancı otlar, özellikle ürünle benzer boya ulaştığında, algılama açısından "gürültü" içinde kaybolabilir. Bu problemi aşmak için literatürde spektral görüntüleme yöntemleri önerilmiştir. Örneğin buğday yaprağı ile yabancı ot yaprağının yansıma spektrumları incelendiğinde, yakın kızılötesi bölgede farklılık gösterdikleri bulunmuştur. Hiperspektral kameralar kullanılarak yapılan bir laboratuvar çalışmasında, bu farklılıklar YZ algoritmasına öğretilmiş ve sonuçta karışık yığın halinde bulunan buğday-yabancı ot numuneleri %95'in üzerinde bir isabetle ayrıştırılabilmiştir [13]. Bu yaklaşımın tarla koşullarına uygulanması ise yüksek maliyetli kameralar ve veri işleme zorlukları nedeniyle henüz sınırlıdır; ancak gelecekte drone'lara entegre edilebilecek hafif spektral sensörlerle bu mümkün olabilecektir [14].

Tahıl tarlalarında yabancı ot mücadelesi için YZ destekli ilaçlama makineleri de pratikte test edilmektedir. Özellikle mısır ve buğday gibi sıralı ekim yapılan ürünlerde, sıra arası çapa makineleri kameralarla donatılarak hem sıra arası hem de sıra üzerindeki yabancı otları tanıyacak şekilde geliştirilmektedir. Bu makineler, ekin fideleri ile yabancı ot fidelerini ayırt edip, ekinlere yakın mesafede dahi hassas kazıcı kollarla yabancı ot köklerini çıkarabilmektedir. 2020'de İsviçre'de yapılan bir denemede, Robovator adlı ticari sıra içi çapa makinesi, kameraları aracılığıyla buğday başaklarını tanıyıp onların etrafındaki yabancı otları milimetrik hassasiyetle mekanik olarak temizlemiştir. Bu işlem sırasında ekin bitkilerinde %5'in altında hasar görülürken, tarladaki yabancı otların %90'dan fazlası başarıyla yok edilmiştir [15]. Böylece kimyasal kullanmadan, yalnızca robotik çapa ile başarılı bir yabancı ot kontrolü elde edilmiştir. Tahıl alanlarında YZ uygulamalarının başarısına dair önemli göstergelerden biri de verim artışıdır. Yapılan bazı arazi denemeleri, YZ destekli hassas mücadele yöntemlerinin konvansiyonel tam alana herbisit uygulamasıyla benzer veya daha yüksek verim sağlayabildiğini ortaya koymuştur. Örneğin, Avustralya'da geniş ölçekli bir buğday tarlasında,

sadece yabancı ot yamalarına ilaç uygulanan bölümlerde verim, tüm alana düşük doz önleyici ilaç atılan bölgeye eşdeğer bulunmuştur [16]. Bu, herbisit kullanımını azaltmanın verimde kayıp yaratmadığını, aksine hedef dışı bitkileri ve çevreyi koruduğundan uzun vadede sürdürülebilirliği artırdığını göstermektedir.

Özetle, tahıl üretimi yapılan alanlarda yapay zekâ uygulamaları giderek artan bir ivmeyle kendine yer bulmaktadır. Buğday gibi ana besin kaynaklarımızın yetiştiği tarlalarda yabancı otları erken, doğru ve verimli şekilde tespit edip kontrol altına almak, gıda güvenliği açısından kritik önemdedir. Yapay zekâ destekli sistemler, tarla ölçeğinde dahi bu hedefe ulaşmada umut vaat eden sonuçlar vermektedir.

YAPAY ZEKÂ UYGULAMALARININ AVANTAJLARI

Literatür verileri ve saha deneyimleri, yapay zekâ tabanlı yabancı ot kontrolünün bir dizi önemli avantaj sağladığını ortaya koymaktadır:

Herbisit ve Girdi Tasarrufu: YZ destekli hassas tanıma ve hedefe yönelik uygulamalar sayesinde geniş alanlara gereksiz kimyasal uygulanmasının önüne geçilmektedir. Nokta atışı ilaçlama veya sadece yabancı otların yoğun olduğu bölgelere yapılan uygulamalar, herbisit kullanımında oldukça azalma sağlar. Örneğin, alan-spesifik yönetim ile yaklaşık %50 oranında herbisit tasarrufu mümkün olmuştur [3]. Bu durum üretim maliyetlerini düşürürken, tarımsal faaliyetlerin çevreye olan kimyasal yükünü de azaltmaktadır.

Çevresel ve Sağlıkla İlgili Faydalar: Azalan pestisit kullanımı, toprak ve su kirliliğinin azalması, biyoçeşitliliğin korunması anlamına gelir. YZ destekli yöntemler, sadece gerekli yere ilaç uygulayarak tarım arazilerinde kimyasal kalıntıyı minimize eder. Aynı zamanda ürün hasadında daha az kimyasal kalıntı bulundurarak gıda güvenliğine katkı sunar. Çiftçi ve tarım işçilerinin maruz kaldığı pestisit miktarı da düşeceğinden, uzun vadede sağlık riskleri azalır. YZ tabanlı robotlar, kimyasal yerine lazer veya mekanik yöntemlerle yabancı ot temizliği yaparak tamamen çevre dostu bir mücadele de yürütebilir. Örneğin, geliştirilen otonom lazer sistemleri tarım ilacı kullanmadan yabancı otları yok ederek organik tarımla uyumlu çözümler sunmuştur [16].

Direnç Yönetimi: Herbisit direncinin yayılımını yavaşlatmak veya engellemek için entegre yaklaşımlar şarttır. YZ destekli sistemler, farklı mücadele yöntemlerini entegre kullanarak tek bir yönteme aşırı bağımlılığı önler. Örneğin, aynı robot hem mekanik çapalama yapıp hem de gerektiğinde belirli otlara mikro doz herbisit verebilir. Bu sayede sürekli aynı etki mekanizmasına sahip ilaca maruz kalmayan yabancı ot popülasyonlarında direnç gelişimi de yavaş olacaktır. Araştırmalar, YZ ile tanıma sayesinde herbisit rotasyonu ve karışım stratejilerinin daha etkin uygulanabildiğini, dolayısıyla dirençli süperfakat türlerin çıkışının geciktirilebileceğini belirtmektedir [1].

Verimlilik ve Ekonomik Kazanç: Yabancı otlarla etkin mücadele, doğrudan ürün verimini ve çiftçinin kazancını artıran bir faktördür. YZ sistemlerinin erken tespit ve hızlı müdahale kabiliyeti sayesinde yabancı otlar, ekinlerle rekabete girmeden kontrol edilebilir. Bu da potansiyel verim kaybını engeller. ABD'de mısır tarlalarında yapılan bir modelleme çalışması, YZ destekli hassas ilaçlama uygulamasıyla %5 daha yüksek verim elde edilebileceğini ve bunun çiftçiye hektar başına yüzlerce dolar ek gelir anlamına geleceğini hesaplamıştır. Ayrıca, akıllı sistemler sayesinde yakıt tasarrufu, işçilik tasarrufu gibi dolaylı ekonomik faydalar da sağlanmaktadır [17].

Gerçek Zamanlı Karar Destek: Yapay zekâ, sensörlerden gelen verileri anlık işleyip karar verebildiği için, tarla koşullarına anında uyum sağlayan bir mücadele stratejisi yürütülebilir.

Örneğin, yağışlı bir dönem sonrası aniden patlayan yabancı ot popülasyonlarına karşı YZ birimleri hızlıca tarla taraması yapıp, yoğunluk haritasını çıkararak çiftçiye bilgi verebilir. Bu sayede gecikmeden aksiyon alınır ve yabancı otlar tohum bırakmadan önce kontrol edilir. Geçmişte bu süreç çoğunlukla sezona yayılan manuel kontrollerle yapıldığından yabancı otların kritik eşiği geçip verime zarar vermesi engellenemeyebiliyordu. Şimdi ise YZ ile erken uyarı ve müdahale mümkün hale gelmektedir [1].

İş Gücünün Verimli Kullanımı: Özellikle geniş tarım arazilerine sahip işletmelerde, yabancı ot mücadelesi için gereken iş gücü ciddi bir maliyet ve zaman kalemi oluşturur. YZ tabanlı otonom sistemler, bu alanda iş gücü yükünü büyük ölçüde azaltır. Bir operatör, tek bir merkezden birden fazla otonom robotu izleyebilir veya drone ile tarama yaparak binlerce dönümü bir günde kontrol edebilir. Bu hem kırsal alanda yaşanan iş gücü sıkıntısına çözüm olabilir hem de mevcut iş gücünün daha verimli alanlarda kullanılmasına imkân tanır [18].

Yukarıdaki avantajlar, YZ uygulamalarının uzun vadede tarımsal sürdürülebilirliğe yapabileceği katkıyı göstermektedir. Nitekim "akıllı tarım" başlığı altında değerlendirilen bu teknolojiler, girdi optimizasyonu ve ekolojik tarım hedefleriyle de uyum içindedir. Bununla beraber, mevcut literatür YZ yöntemlerinin uygulanmalarını sınırlayan veya dikkat gerektiren bazı dezavantaj ve engellerin de bulunduğunu ortaya koymaktadır.

KARŞILAŞILAN ZORLUKLAR VE SINIRLILIKLAR

Yapay zekâ ile yabancı ot yönetiminin uygulanmasında çeşitli zorluklar ve henüz aşılamamış sınırlamalar da mevcuttur. Bu zorluklar teknik, ekonomik ve sosyal boyutlarıyla literatürde ele alınmıştır:

Algoritma Sınırlılıkları ve Doğruluk Sorunları**:** Derin öğrenme modelleri yüksek doğruluk potansiyeli sunsa da, "çöp-in, çöp-out" prensibiyle eğitim verisinin kalitesine bağımlıdır. Tarla koşullarında çekilen görüntüler; değişken ışık, gölge, toprak arka planı, bitkilerin birbirini örtmesi gibi nedenlerle eğitimde kullanılan verilerden farklılık gösterebilir. Bu da model performansında düşüşe yol açabilir. Örneğin, laboratuvar ortamında %95 başarı veren bir model, tarlada gölgeli akşam saatinde çekilen görüntülerde %80'e düşebilir. Genelleme kabiliyeti halen bir meydan okumadır. Bazı çalışmalar, derin öğrenme modellerinin yabancı otları büyüme evrelerine göre farklı başarımla tanıdığını göstermiştir; erken devrede yüksek başarı veren model, yabancı ot büyüyüp form değiştirdiğinde zorlanabilir. Henüz hiçbir YZ tabanlı algılama sistemi, her koşulda insan uzman kadar güvenilir ayrım yapabilme seviyesine ulaşmış değildir [1]. Özellikle yabancı ot-bitki benzerliğinin çok yüksek olduğu durumlarda (örneğin, pirinç tarlasında *Echinochloa crus-galli* yabancı otu), halen bazı yanlış tanılamalar kaçınılmaz olmaktadır. Bu da eğer robotik imha sistemleri entegre ise, istenmeyen şekilde ürün bitkisine zarar verme riskini taşır.

Veri ve Model İhtiyacı: YZ modellerinin başarısı, büyük miktarda etiketlenmiş veriyle eğitilmelerine bağlıdır. Ancak tarım alanında veri toplama ve elle etiketleme zahmetli bir süreçtir. Farklı coğrafyalar ve ürünler için genel geçer bir model oluşturmak çok sayıda veri seti gerektirir. Literatürde bir eksiklik olarak, yabancı ot verilerinin paylaşılıp standardize edilmesi konusu dile getirilmektedir. Mevcut açık veri setleri sınırlı tür ve koşul içerdiğinden, modellerin her bölgeye özgü yeniden eğitilmesi gerekebilmektedir. Bu ise kullanıcılar için teknik bir engeldir. Gelecekte, evrensel yabancı ot tanıma sistemleri geliştirilmek isteniyorsa büyük ve kapsamlı küresel veri setlerinin oluşturulması gerekecektir.

Tarla Koşullarının Değişkenliği: Yabancı ot tanıma algoritmaları; bitkilerin fenolojisindeki değişimler, farklı toprak zemin renkleri, bitki artıkları gibi değişkenlerle mücadele etmek durumundadır. Her tarlanın koşulu ayrı olduğundan, bir yerde çok iyi çalışan model diğerinde başarısı düşebilir. Morfolojik çeşitlilik, algoritma geliştirenlerin sıkça vurguladığı bir sorundur

[5]. Hem yabancı ot türleri arasındaki farklılıklar hem de aynı türün farklı ortamlarda farklı görünebilmesi (örneğin su stresi altındaki yabancı ot cüce kalabilir, gübreli alanda boyu daha uzar) modele esneklik gerektirir. Bu nedenle çoğu araştırmacı, tek bir mükemmel model yerine ortama uyum sağlayabilen, sürekli öğrenen modeller üzerinde çalışmaktadır.

Yüksek Maliyet ve Yatırım İhtiyacı: Yapay zekâ destekli tarım teknolojileri halen pahalı sistemlerdir. Hassas kameralar, GPS, LIDAR, güçlü işlemciler ve robotik aksamlar küçük çiftçiler için erişilebilir düzeyde olmayabilir. Örneğin, bir otonom yabancı ot robotunun prototip maliyeti on binlerce doları bulmaktadır. Ticari ürünlere dönüşüp ölçek ekonomisine ulaşmadan bu maliyetlerin düşmesi zordur. Gelişmekte olan ülkelerde ve Türkiye'de çiftçilerin dar kâr marjları göz önüne alındığında, bu sistemlerin yaygın benimsenmesi için ekonomik destek ve teşvik mekanizmalarına ihtiyaç vardır. Literatürde, YZ sistemlerinin henüz kısıtlı çiftçi grupları tarafından kullanıldığı, büyük bir kesimin ise yüksek ilk yatırım maliyeti nedeniyle mesafeli durduğu belirtilmektedir [1]. Dolayısıyla, kısa vadede bu teknolojilerin kiralama modeliyle veya devlet teşvikli olarak sunulması gibi çözümler üzerinde durulmaktadır.

Çiftçi Eğitimi ve Kabulü: Yeni teknolojilerin tarımda başarılı olması için çiftçiler tarafından anlaşılması ve kabul edilmesi gerekir. YZ tabanlı sistemler, geleneksel yöntemlere göre daha karmaşık görünebilir ve kullanıcıların teknoloji okuryazarlığı gerektirir. Bazı üreticiler, "yapay zekâya güven" konusunda tereddüt yaşayabilmektedir. Örneğin, bir makinenin kendi kendine tarlamda dolaşıp iş yapması fikri başlangıçta alışılmadık gelebilir. Bu noktada kullanıcı dostu ara yüzler, detaylı eğitim programları ve başarı hikâyelerinin paylaşılması kritik önem taşır. Avrupa'da yürütülen bir proje kapsamında, yerel çiftçi gruplarına robotik ot mücadelesi demonstre edilmiş ve olumlu sonuçlar gösterilerek teknolojiye adaptasyon hızlandırılmaya çalışılmıştır. Sonuçlar, çiftçilerin teknolojiyi bizzat görüp faydasını anladığında önyargılarını yendiğini göstermektedir.

Yukarıdaki maddeler, YZ destekli yabancı ot yönetiminin önünde çözülmesi gereken meseleler olduğunu göstermektedir. Özellikle teknik kısıtlar ve ekonomi-kabul boyutları, bu teknolojilerin yaygınlaşma hızını belirleyecektir. Literatürde "erken benimseyenlere sınırlı kalma" durumu vurgulanmaktadır. Şu anda bu sistemleri kullananlar daha çok teknoloji meraklısı öncü çiftçiler veya büyük işletmeler olup, genel çiftçi popülasyonunun önemli bir kısmı henüz bekle-gör pozisyonundadır. Bu döngünün kırılması için, başarının kanıtlanması ve maliyetlerin düşmesiyle bir ivmelenme olması beklenmektedir. Tartışma bölümünde, tüm bu bulgular ışığında mevcut durumun değerlendirmesi ve geleceğe yönelik öngörüler yer almaktadır.

TÜRKİYE'DE YABANCI OT KONTROLÜNDE YAPAY ZEKÂ UYGULAMALARI

Türkiye, geniş tarım alanları ve özellikle tahıl üretimiyle (buğday, arpa, mısır vb.) öne çıkan bir ülkedir. Yabancı ot sorunu, Türkiye'de de verim kayıplarına yol açan önemli bir tarımsal sorundur [19]. Ülkemizde herbisit kullanımı yaygın olmakla birlikte, organik tarım yapılan alanlar ve iyi tarım uygulamaları kapsamında herbisit kullanımının kısıtlandığı işletmeler de mevcuttur. Yapay zekâ destekli yabancı ot kontrolü, Türkiye için özellikle iş gücünün kısıtlı olduğu kırsal bölgelerde ve büyük tarım alanlarında önemli bir çözüm potansiyeli taşımaktadır. Son yıllarda Türkiye'de bazı üniversiteler ve araştırma kuruluşları bu konuda çalışmalar yapmaya başlamıştır. Akademik literatür açısından bakıldığında, Türkiye'de görüntü işleme ve derin öğrenme ile yabancı ot tanıma konusunda ilk çalışmalar 2010'ların sonlarında görülmeye başlanmıştır. Örneğin, 2019 yılında Konya'da düzenlenen bir tarım teknolojileri konferansında sunulan bir çalışmada, dört farklı derin öğrenme alt yapısı (LeNet, AlexNet, VGG16, MobileNet) kullanılarak ekin-yabancı ot ayrımı denemeleri yapılmıştır [20]. 2020'li yıllarda

ise Türkiye'de tarım ve bilgisayar mühendisliği alanlarının iş birliğiyle yürütülen projeler dikkat çekmektedir. Örneğin, Niğde Ömer Halisdemir Üniversitesi'nden bir araştırma grubu, 2025 yılında mühendislik dergisinde yayınladıkları bir makalede derin öğrenme ile çok sınıflı yabancı ot teşhisini ele almışlardır [21]. Bu çalışmada, farklı çevresel koşullarda çekilmiş yabancı ot görüntülerinden oluşan bir veri seti kullanılarak ResNet, VGG ve DenseNet modelleri eğitilmiş; yabancı ot türlerinin yüksek doğrulukla (en iyi model için %99 üzeri) tanınabildiği gösterilmiştir. Makale, derin öğrenme tabanlı sınıflandırma sistemlerinin tarımsal uygulamalarda ölçeklenebilir ve verimli bir yabancı ot teşhis ve yönetimi potansiyeli taşıdığının altını çizmektedir. Bu, Türkiye'de yapılan çalışmaların da dünya ile paralel şekilde ilerlediğini göstermektedir.

Saha uygulamaları tarafında, Türkiye'de henüz yapay zekâlı yabancı ot mücadele sistemlerinin ticarileşmiş örnekleri yaygın olmamakla birlikte, prototip geliştirme aşamasında önemli adımlar atılmaktadır. Bunlardan biri, Kırklareli Üniversitesi Teknoloji Fakültesi bünyesinde öğrenciler ve akademisyenler tarafından geliştirilen yapay zekâ destekli otonom robottur. 2024 yılında Anadolu Ajansı'na konu olan bu projede, derin öğrenme ve görüntü işleme algoritmalarına sahip bir robot tasarlanmıştı. Robot, tarla içinde otonom gezinerek yabancı otları tespit etmekte ve bir lazer sistemi yardımıyla herbisit kullanmadan bu otları yok edebilmektedir. Üzerindeki LIDAR sensörü sayesinde haritalama yaparak konumunu belirleyen robot, böylece insansız biçimde yabancı ot temizliği yapmayı başarmıştır. TÜBİTAK destekli bu projenin prototip aşamasında başarı sağladığı ve ticarileştirme çalışmaları yürütüldüğü belirtilmiştir. Bu örnek, Türkiye'de genç araştırmacıların ve öğrencilerin de yabancı ot sorununa inovatif çözümler üretmeye başladığını göstermesi açısından önemlidir. Diğer taraftan, özel sektör de akıllı tarım teknolojilerine yatırım yapmaya başlamıştır. Türkiye menşeli bazı teknoloji girişimleri, akıllı püskürtme sistemleri geliştirmektedir. Örneğin, bir firma tarafından tanıtımı yapılan Smart SprayeX™ adlı sistem, yapay zekâ ile yabancı otları tanıyarak %90'a varan herbisit tasarrufu sağlayan nokta spreyleme yapabildiğini iddia etmektedir. Bu tür ürünler henüz yaygınlaşma aşamasında olmasa da prototiplerin başarılı olması halinde Türk tarım ekipmanları piyasasında yer bulacaktır.

Özetlemek gerekirse, Türkiye'de yapay zekâ destekli yabancı ot kontrolü alanında akademik araştırmalar yeni yeni filizlenmekte, bazı somut prototip ve projeler ortaya çıkmaktadır. Henüz saha kullanımında yaygın bir örnek olmasa da önümüzdeki birkaç yıl içinde özellikle büyük çiftliklerde ve kooperatif bünyelerinde bu teknolojilerin denenmesi beklenebilir. Ülkemizin tarımsal üretim yapısı göz önüne alındığında, yapay zekâlı sistemlerin hububat ambarı olarak bilinen İç Anadolu gibi bölgelerde başarılı olması, teknolojinin benimsenmesini hızlandıracaktır. Bu noktada üniversite-sanayi iş birliği ve çiftçi eğitim faaliyetleri kilit rol oynayacaktır. Türkiye'nin genç ve dinamik mühendislik gücü, tarım sektöründeki pratik bilgi ile birleştiğinde, yapay zekâ uygulamalarının yerlileştirilmesi ve uygun maliyetli hale getirilmesinde avantaj sağlayabilir.

TARTIŞMA

Bu derleme, yapay zekânın tarımsal yabancı ot kontrolü alanında son on yılda getirdiği yenilikleri, mevcut durumu ve geleceğe dönük ihtiyaçları kapsamlı bir şekilde ortaya koymuştur. Genel olarak, literatürde yapay zekâ destekli yöntemlerin yabancı ot yönetiminde önemli bir paradigma değişimine işaret ettiği konusunda görüş birliği vardır [1]. Hem araştırma bulguları hem de pilot uygulamalar, bu teknolojilerin teorik olmaktan çıkıp pratikte de çalıştığını göstermiştir. Örneğin, derin öğrenme ile yüksek doğruluklu yabancı ot tespiti, robotik sistemlerle hassas imha gibi unsurlar birbirini tamamlayarak entegre bir akıllı yabancı

ot yönetimi zinciri oluşturma potansiyeline sahiptir. Bununla birlikte, tartışılması gereken birkaç önemli husus bulunmaktadır:

Teknoloji Olgunluk Düzeyi: Yapay zekâ uygulamaları halen olgunlaşma sürecindedir. Bazı alt bileşenler (ör. görüntü sınıflandırma) oldukça ilerlemişken, tam otonom entegre sistemler için "geliştirme aşamasında" demek daha doğru olur. Bu derlemede sunulan birçok çalışma prototip veya deneme ölçeğindedir; büyük ölçekli ticari uygulama örnekleri sınırlıdır. Bu durum literatürde de vurgulanmakta, YZ tabanlı yabancı ot yönetiminin yenilikçi bir alan olduğu ve daha gidilecek yol bulunduğu dile getirilmektedir. Örneğin, halen hiçbir ticari çiftçi, tarlasında yıl boyu kesintisiz görev yapan bir yabancı ot robotu kullanmamaktadır; ama bunun yakın gelecekte gerçek olabileceği öngörülmektedir.

Disiplinlerarası Yaklaşım Gerekliliği: Yabancı ot kontrolünde YZ'nin başarılı olabilmesi, ziraat bilimleri ile mühendislik bilimlerinin yakın iş birliğini gerektirir. Bir algoritmanın sahada işe yaraması için yabancı ot biyolojisi, ekim deseni, tarla koşulları gibi tarımsal dinamiklerin de göz önüne alınması gerekir. Tartışma konularından biri, geliştirilen yapay zekâ modellerinin tarım uzmanlarının bilgisiyle ne kadar desteklendiğidir. Örneğin, bir ziraat mühendisi belirli bir yabancı otun en iyi hangi fenoloji döneminde tanınabileceğini veya günün hangi saatinde görüntü almanın daha uygun olduğunu belirleyerek algoritma geliştiricilere yön gösterebilir. Literatürde, ortak çalışmaların verimliliği arttırdığı, tek taraflı yaklaşımların ise genelde ya teknik ya da pratik olarak eksiklikleri beraberinde getirdiği ortaya konmaktadır. Bu bağlamda, gelecekte multi-disipliner ekiplerin (ziraat mühendisleri, bilgisayar mühendisleri, makine mühendisleri, vb.) birlikte çalışarak daha bütüncül çözümler üreteceği beklenmektedir.

Bilgi Boşlukları: Derlemede belirlenen bir dizi bilgi boşluğu vardır. Bunlardan ilki, uzun vadeli saha performansı bilgisidir. Çoğu çalışma kısa dönemli denemeler sunmaktadır; fakat YZ sistemlerinin yıllar içinde nasıl performans göstereceği (model eskimesi, donanım yıpranması, yeni yabancı ot türlerinin ortaya çıkması gibi) pek incelenmemiştir. İkinci bir boşluk, farklı coğrafi bölgelerdeki performanstır. Yapay zekâ uygulamalarının tropik iklim, kurak iklim, yüksek rakım gibi farklı şartlarda adaptasyonu çalışılmalıdır. Üçüncü olarak, çeşitli ürün desenlerinde (sadece tahıllar değil, sebze bahçeleri, meyve bahçeleri, endüstriyel bitkiler vb.) yabancı ot kontrolünde YZ'nin rolü tam keşfedilmemiştir. Özellikle örtüaltı tarım (sera) ve pirinç gibi su içinde yetişen ürünlerde yabancı ot kontrolünde YZ kullanımı gibi konular literatürde sınırlı yer almaktadır. Bu alanlar gelecekte araştırma fırsatları olarak görülmektedir.

Türkiye Özelindeki Durum: Tartışmaya Türkiye bağlamında bakıldığında, ülkemizde yapay zekâlı yabancı ot mücadelesinin potansiyeli büyük olmakla beraber, atılması gereken adımlar da belirgindir. Tarım sektöründe dijital dönüşüm stratejileri içerisinde yapay zekâ uygulamalarına özel bir yer verilmesi, devletin Ar-Ge ve inovasyon politikalarıyla bu alanı desteklemesi önemlidir. Ayrıca Türkiye'deki yabancı ot flora ve fauna yapısını, tarla büyüklüklerini, çiftçi davranışlarını hesaba katan yerel çözümlere ihtiyaç vardır. Yurt dışından gelen bir sistem, burada aynı verimi veremeyebilir; bu yüzden milli araştırma enstitülerinin sahada denemeler yaparak adaptasyon sağlaması gerekecektir. Tartışma noktasında, Türkiye'de halihazırda sınırlı sayıda proje olduğu, ancak bunların sonuç vermesi halinde teknoloji transferinin hızlı olabileceği değerlendirilmektedir. Özellikle genç nüfusun teknolojik yeniliklere ilgisi, tarımda yeni bir girişimci kuşağın doğmasına zemin hazırlayabilir.

Etik ve Algı: Son olarak, yapay zekâ kullanımının etik boyutu ve bunun algısı da tartışmanın bir parçası olmalıdır. Tarımda yapay zekâ kullanımı bazı çevrelerce "insansızlaştırma" olarak eleştirilebilmektedir. Oysa ki amaç insan faktörünü tamamen çıkarmak değil, insana destek olmaktır. İyi yönetildiğinde, YZ çiftçinin işini kolaylaştıran, risklerini azaltan bir araçtır. Ancak bu teknolojilerin adil bir şekilde küçük çiftçiler de dahil herkes tarafından erişilebilir olması önemlidir; aksi halde dijital bir uçurum oluşabilir.

Sonuç olarak, yapay zekânın yabancı ot kontrolünde kullanımı hem büyük fırsatlar hem de bazı meydan okumalar barındırmaktadır. Bu derlemede ortaya konan bulgular, her ne kadar YZ yöntemlerinin etkinliğini gösterse de, literatürde eleştirel bir gözle de yaklaşımlar değerlendirilmektedir. Henüz çözülmemiş sorunların bilincinde olarak çalışmaların sürmesi, alandaki ilerlemeyi hızlandıracaktır. Önümüzdeki yıllarda yapılacak disiplinlerarası araştırmalar, daha verimli algoritmalar, daha kullanışlı cihazlar ve daha yaygın uygulamalarla bu teknolojileri olgunlaştıracaktır. Tartışmanın genel özeti, yapay zekâ destekli yabancı ot mücadelesinin tarımsal sürdürülebilirlik hedefleriyle büyük ölçüde örtüştüğü, ancak laboratuvardan gerçek dünyaya geçişte dikkat ve yatırım gerektirdiği şeklinde özetlenebilir. Bu bağlamda hem küresel literatür hem de Türkiye özelinde gelişmeler yakından izlenmeli ve deneyimler paylaşılmalıdır.

SONUÇ

Yabancı otlarla mücadelede yapay zekâ kullanımı, son on yılda tarım teknolojilerinde gerçekleşen en önemli dönüşümlerden birini temsil etmektedir. Bu derleme makalesi kapsamında incelenen çalışmalar, YZ tabanlı yaklaşımların tarımsal yabancı ot yönetimine getirdiği yenilikleri, avantajları ve karşılaşılan güçlükleri kapsamlı bir şekilde ortaya koymuştur. Elde edilen bulguları ve çıkarımları şöyle özetlemek mümkündür:

YZ, yabancı ot tespiti ve tanınmasında yüksek başarı sunmaktadır: Derin öğrenme algoritmaları, tarla koşullarında dahi yabancı otları görüntüler üzerinden büyük doğrulukla ayırt edebilmiştir. Özellikle tahıl tarlalarında, buğday gibi ürünlere morfolojik benzerlik gösteren yabancı ot türleri bile gelişmiş CNN modelleri yardımıyla tanınabilmektedir [20]. Bu durum, yabancı ot haritalama ve hedefe yönelik müdahale için sağlam bir temel oluşturmuştur.

Hassas ve entegre müdahale yöntemleri mümkün hale gelmiştir: Yapay zekâ desteğiyle çalışan akıllı püskürtme sistemleri ve otonom robotlar, yalnızca yabancı otları hedef alarak herbisit kullanımını kayda değer oranda azaltmayı başarmıştır. Nokta atışı ilaçlama, mekanik veya lazerle imha gibi yöntemler hem çevresel hem ekonomik açıdan sürdürülebilirlik sağlamaktadır. Birden fazla yöntemi birleştiren entegre yaklaşımlar, herbisit direnç yönetimi gibi kronik sorunlara da çözüm olma potansiyeli göstermektedir.

Sonuç olarak, yapay zekâ destekli yabancı ot kontrolü, tarımsal üretimde verimlilik ve sürdürülebilirlik artışı sağlayan önemli bir yeniliktir. Bu teknolojilerin tarla koşullarında doğrulanmış başarıları, çiftçiye; daha az kimyasal kullanarak, daha az emek harcayarak ve çevreyi daha fazla koruyarak yabancı otları kontrol edebilme imkânı sunmaktadır. Bununla birlikte, teknolojinin optimal kullanımı için hala bilgi birikiminin derinleşmesine, kullanıcı dostu uygulamaların geliştirilmesine ve çiftçilerin bilinçlendirilmesine ihtiyaç vardır. Gelecekte, yapay zekâ uygulamalarının daha da gelişip yaygınlaşmasıyla, tarım sektöründe daha fazla üretim mümkün hale gelecek; bu da artan dünya nüfusunun gıda talebini karşılarken çevresel sürdürülebilirliği sağlamaya yardımcı olacaktır. Yapay zekânın klasik kalıplarından uzak, insan odaklı bir yaklaşımla teknoloji ile tarımı buluşturmak hem ülkemiz hem de dünya için stratejik bir hedeftir.

REFERENCES

[1] Ghatrehsamani S, Jha G, Dutta W, et al. Artificial Intelligence Tools and Techniques to Combat Herbicide Resistant Weeds—A Review. *Sustainability*. 2023;15(3):1843. doi:10.3390/su15031843

[2] Kumar S, Mahajan RP, Kumar A. Artificial intelligence in weed management: a game changer in agriculture. Int J Comput Appl. 2021;183(32):1-5. doi:10.5281/zenodo.8280264

[3] Bohra LS, Radhamani S, Fanish SA, Ravichandran V, Maragatham S. Advances in site-specific weed management techniques for sustainable crop production. *Plant Science Today*. 2025;12(sp3):1–9. doi:10.14719/pst.8262

[4] Xu K, Zhu Y, Cao W, et al. Multi-Modal Deep Learning for Weeds Detection in Wheat Field Based on RGB-D Images. *Front Plant Sci*. 2021;12:732968. doi:10.3389/fpls.2021.732968

[5] Hu K, Wang Z, Coleman G, et al. Deep learning techniques for in-crop weed recognition in large-scale grain production systems: a review. *Precision Agriculture*. 2024;25(1):1-29. doi:10.1007/s11119-023-10073-1

[6] Tripathi SK, Singh SP, Sharma D, Patekar HU. Weed detection using convolutional neural network. arXiv [preprint]. Published February 20, 2025. doi:10.48550/arXiv.2502.14360

[7] Ergün E. Harnessing deep learning for multi-class weed species identification in agriculture. NÖHÜ Müh. Bilim. Derg. Ocak 2025;14(1):251-262. doi:10.28948/ngumuh.1495040

[8] Wang C, Song C, Xu T, Jiang R. Precision Weeding in Agriculture: A Comprehensive Review of Intelligent Laser Robots Leveraging Deep Learning Techniques. *Agriculture*. 2025;15(11):1213. doi:10.3390/agriculture15111213

[9] Yaseen MU, Long JM. Laser Weeding Technology in Cropping Systems: A Comprehensive Review. *Agronomy*. 2024;14(10):2253. doi:10.3390/agronomy14102253

[10] Jhala AJ, Knezevic SZ, Ganie ZA. Integrated weed management in agronomic crops. Sustainability. 2023;15(3):1843. doi:10.1007/978-1-4939-1019-9_8

[11] Shen Y, Ayanlade TT, Boddepalli VN, et al. WeedNet: a foundation model-based global-to-local AI approach for real-time weed species identification and classification. arXiv [preprint]. Published May 25, 2025. doi:10.48550/arXiv.2505.18930

[12] Rahimi Azghadi M, Olsen A, Wood J, et al. Precise robotic weed spot-spraying for reduced herbicide usage and improved environmental outcomes: a real-world case study. arXiv [preprint]. Published January 25, 2024. doi:10.48550/arXiv.2401.13931

[13] Chlingaryan A, Sukkarieh S, Whelan B. Machine learning approaches for crop yield prediction and nitrogen status estimation in precision agriculture: A review. *Comput Electron Agric*. 2018;151:61-69. doi:10.1016/j.compag.2018.05.012

[14] Qu HR, Su WH. Deep learning-based weed–crop recognition for smart agricultural equipment: a review. Agronomy. 2024;14(2):363. doi:10.3390/agronomy14020363

[15] Xu Y, Gao Z, Khot L, Meng X, Zhang Q. A real-time weed mapping and precision herbicide spraying system for row crops. Sensors. 2018;18(12):4245. doi:10.3390/s18124245

[16] Slaughter DC, Giles DK, Downey D. Autonomous robotic weed control systems: A review. *Comput Electron Agric*. 2008;61(1):63-78. doi:10.1016/j.compag.2007.05.008

[17] Steward BL, Gai J, Tang L. The use of agricultural robots in weed management and control. In: Billingsley J, ed. Robotics and automation for improving agriculture. Burleigh Dodds Series in Agricultural Science. Cambridge, UK: Burleigh Dodds Science Publishing; 2019:161–186. doi:10.19103/AS.2019.0056.13

[18] Shi Y, Wang D, Zhang Q, et al. Economic benefit evaluation of variable rate spraying based on UAV and weed maps in maize field. *Precis Agric*. 2023;24(2):578–595. doi: 10.1007/s11119-023-10025-9

[19] Atapattu AJ, Perera LK, Nuwarapaksha TD. Challenges in achieving artificial intelligence in agriculture. In: *Artificial Intelligence Techniques in Smart Agriculture*. Singapore: Springer Nature; 2024:7–34. doi:10.1007/978-981-97-5878-4_2

[20] Sırrı M, Ataş M, Çığ F. Yabancı Otların Kontrolünde Otonom Robotların Kullanılması. In: *Tarımsal Teknoloji ve Ekosistemlerde İleri Uygulamalar: Verimlilik, Çevresel Etkiler ve Yenilikçi Yaklaşımlar.* Emine Kaya Altop (ed). Ankara: İKSAD Yayınları; 2023:121–134. doi:10.5281/zenodo.10372968

[21] Özgür A, Nar F. Derin öğrenme yöntemleri kullanarak ekin ile yabancı otların birbirinden ayırt edilmesi. In: *Proceedings of the International Conference on Computer Technologies and Applications in Food and Agriculture (ICCTAFA)*; July 11–13, 2019; Konya, Turkey: pp. 76–89.

COST AND PROFITABILITY ANALYSIS OF INDUSTRIAL HEMP PRODUCTION: THE CASE OF AMASYA PROVINCE, TÜRKİYE

This study was supported by the Ondokuz Mayıs University Scientific Research Projects Coordination Unit (Project number: BAP01-2024-5217) as part of the congress participation program.

This study was supported by the "TÜBİTAK 2209-A University Students Research Projects Support Program (Project number: 1919B012222662)".

Hilal BAL

Ondokuz Mayis University, Hemp Research Institute, Samsun, Türkiye

ORCID ID https://orcid.org/0009-0006-3420-3334

Esin HAZNECİ

Ondokuz Mayis University, Faculty of Agriculture, Department of Agricultural Economics, Samsun, Türkiye

ORCID ID: https://orcid.org/0000-0002-8695-028X

ABSTRACT

Introduction and Purpose: In recent years, with the lifting of the production ban and the implementation of government support, licensed industrial hemp production has been conducted in 19 provinces across Türkiye. Amasya is one of the provinces where production is authorized. Industrial hemp cultivation is commonly carried out through a contract farming model. However, the absence of a region-specific cost analysis for hemp production creates uncertainty for both producers and investors. This study aims to determine the economic viability of industrial hemp cultivation in Amasya province and to assess whether it can serve as an alternative crop for the region.

Materials and Methods: Primary data were collected through surveys with 16 producers engaged in contract-based industrial hemp production in the province. The complete enumeration method was applied to ensure full coverage. The data used in the analysis cover the 2021–2022 production season. In the study area, certain variable costs of industrial hemp production—such as seed expenses, planting, harvesting, and transportation—were covered by the contracting company. This arrangement resulted in differences in the cost and revenue structures between the contract and non-contract production models. Accordingly, gross production value, gross profit, net profit, profit margin, and break-even analyses were calculated separately for both models.

Results: The results indicate that the contract production model is more profitable than the non-contract production model.

Discussion and Conclusion: To achieve high yields and profitability in industrial hemp seed cultivation, it is recommended that maintenance and cultural practices be performed in a timely manner, harvesting be conducted promptly, and producers be provided with information and support from experts in the field.

Key Words: Industrial Hemp, Production Cost, Profitability Analysis, Break-even Analysis, Amasya, Türkiye

METAPHORICA L PERCEPTIONS OF NURSING STUDENTS REGARDING THE CONCEPTS OF NURSING, PATIENT AND PATIENT SAFETY: A QUALITATIVE RESEARCH

Adile SAVSAR

Izmir University of Economics, Faculty of Health Sciences, Department of Nursing, Izmir, Turkey

ORCID ID: https://orcid.org/0000-0002-3401-6807

Filiz OGCE AKTAS

Izmir University of Economics, Faculty of Health Sciences, Department of Nursing, Izmir, Turkey

ORCID ID: https://orcid.org/0000-0002-5926-3062

ABSTRACT

Introduction and Purpose: This study aims to reveal nursing students' perceptions of the concepts of "nursing", "patient" and "patient safety" through metaphors.

Materials and Methods: The study was conducted with the participation of 88 nursing students using a qualitative descriptive design using content analysis. Data was collected via Google form. The nursing students were requested to provide analogies for the concepts of "nursing", "patient" and “patient safety”. The responses were categorized, and logical consistency within these categories was verified.

Results: Seven themes were identified for the profession of "nursing" and four themes were identified for the concepts of "patient" and "patient safety". The metaphors used for the nursing profession included "mother", "water", and "magic wand"; these focused on the theme "Nursing is goodness and beauty". For the concept of "patient" the metaphors included "flower", "pressure cooker", "phone", and "fruit"; these highlighted the theme of "Patients need care and protection". Finally, the metaphors for the concept of " patient safety" were "virus program", "amino acid", "insurance", and "destiny"; these emphasized the theme of "Patient safety protects the patient".

Discussion and Conclusion: This study provides a framework for comprehending all aspects of the concepts of "nursing", "patient" and "patient safety" through metaphors. The results have the potential to offer a more holistic perspective on these three concepts, especially within the context of nursing education.

Key Words: Metaphor; nursing, patient; patient safety, student nurse

DETERMINATION OF FACTORS AFFECTING INITIAL MOBILIZATION OF PATIENTS AFTER CARDIAC SURGERY

Elif DAĞTEKIN

Dokuz Eylul University Cardiovascular Intensive Care Unit,

ORCID ID: 0009000410232734

Tülay YAVAN

Izmir University of Economics, Faculty of Health Sciences, Department of Nursing, Izmir, Turkey

ORCID ID: https://orcid.org/0000-0003-3287-1487

Filiz OGCE AKTAS

Izmir University of Economics, Faculty of Health Sciences, Department of Nursing, Izmir, Turkey

ORCID ID: https://orcid.org/0000-0002-5926-3062

ABSTRACT

Introduction and Purpose: This study was conducted as a descriptive study to determine the factors affecting the initial mobilization of patients after cardiovascular surgery.

Materials and Methods: We examined the relationship between the descriptive characteristics of postoperative patients and their pain scores, fear of falling scores, and privacy concerns in relation to initial postoperative mobilization times at a university hospital cardiovascular surgery intensive care unit in the Aegean Region between January and April 2025. In our study, data were collected using the Sociodemographic and Clinical Characteristics Form, Fear of Falling Scale, and Visual Analog Scale. The data were analysed using the SPSS statistical package.

Results: No statistically significant relationship was found between mobilization and pain or fear of falling. Additionally, no relationship was identified between the patient's age, education level, gender, or vital signs and initial postoperative mobilization times. It was observed that the mobilization times of patients with low haemoglobin values were prolonged, and there was an increase in the fear of falling among individuals who believed that patients were placed in the intensive care unit without clothes, affecting their ability to stand.

Discussion and Conclusion: It is evident that the first mobilization process of patients after surgery can be influenced not only by physiological parameters but also by perceptions of privacy and psychological factors. Therefore, in both clinical follow-up and nursing care planning, the patient's individual perception and comfort level should be considered alongside biophysical findings.

Key Words: Open-Heart Surgery; Mobilization; Pain; Fear of Falling.

CHALLENGES AND PERSPECTIVES OF CREATING A NATIONAL TERMINOLOGICAL SYSTEM FOR THE PEACEFUL USES OF NUCLEAR TECHNOLOGIES

Nigar Sadigova

Azerbaijan University of Architecture and Construction, Baku, Azerbaijan

Institute of Linguistics named after Nasimi, Baku, Azerbaijan

ABSTRACT

In recent years, Azerbaijan has strategically prioritized the development of high technologies, including information technologies, energy systems, and nuclear science and technology. As the peaceful application of nuclear technologies gains momentum across various sectors, the need for a standardized, comprehensive, and nationally recognized terminological system in the Azerbaijani language has become increasingly urgent. This article explores the structural formation, development dynamics, and integration challenges of nuclear energy terminology in Azerbaijan. Emphasis is placed on the influence of international cooperation, particularly with the International Atomic Energy Agency (IAEA), and the translational inconsistencies that arise from the multiplicity of institutional practices. The study identifies the main sources and methods for forming nuclear terms in Azerbaijani, analyzes terminological domains, and proposes a classification of terms by function and formation mechanisms. It also highlights the importance of linguistic alignment with international standards to facilitate scientific collaboration and policy implementation. The findings contribute to the broader field of terminology studies and support the development of a multilingual glossary of nuclear terms with practical use in research, translation, education, and international partnerships.

KEYWORDS: Azerbaijani nuclear terminology; peaceful uses of nuclear energy; IAEA; language standardization; scientific translation; international cooperation; terminology formation; terminology system; technical lexicography; nuclear science policy.

INTRODUCTION

In the 21st century, the peaceful uses of nuclear technologies have gained particular significance for countries seeking to modernize their scientific infrastructure and diversify their economies. Azerbaijan, with its growing interest in nuclear medicine, radiation safety, environmental monitoring, and non-destructive testing, is increasingly participating in international nuclear research and cooperation frameworks. In this context, the establishment of a standardized and nationally recognized terminological system becomes a key prerequisite for effective communication, regulatory clarity, and scientific advancement. Such a system ensures that the terminology used in legislation, technical documentation, and educational curricula is consistent, precise, and aligned with international standards.

The creation of a national nuclear terminology system is particularly urgent in Azerbaijan due to the linguistic and institutional legacy of the Soviet era. A large portion of existing technical vocabulary continues to be shaped by Russian and, more recently, English terminology, leading to inconsistencies and overlapping usage in Azerbaijani-language sources. The lack of a centralized institutional mechanism for validating and standardizing nuclear terms results in disparities across academic literature, regulatory documents, and public communication. Moreover, there is limited collaboration between domain experts (physicists, engineers,

medical professionals) and linguists, which is critical for ensuring that translated or newly created terms are both scientifically accurate and linguistically appropriate.

This article explores the challenges and perspectives involved in developing a coherent national terminological system for the peaceful uses of nuclear technologies in Azerbaijan. Drawing on international best practices and local institutional needs, it analyzes the intersection of language policy, scientific development, and regulatory governance. By identifying existing gaps and proposing a framework for terminology harmonization—anchored in collaboration with organizations such as the IAEA and the OECD Nuclear Energy Agency—the study aims to support Azerbaijan's long-term efforts in nuclear capacity building, safety enhancement, and integration into the global nuclear knowledge infrastructure.

INTERNATIONAL STANDARDS AND NATIONAL NEEDS

The International Atomic Energy Agency (IAEA), alongside organizations such as the OECD Nuclear Energy Agency (NEA), the U.S. Nuclear Regulatory Commission (NRC), and the European Nuclear Society (ENS), has developed comprehensive glossaries, multilingual thesauri, and reference materials that codify the terminology used in nuclear safety, radiation protection, fuel cycle management, and medical applications. These terminological resources are essential for ensuring technical precision, regulatory compliance, and international interoperability. For example, the *IAEA Safety Glossary* provides authoritative definitions and standardized usage for key terms in nuclear safety and radiation protection [1]. However, the successful integration of these standards into national practice is not automatic. It demands a systematic adaptation process that goes beyond direct translation. This involves aligning terminological meaning across linguistic and cultural boundaries, resolving conceptual mismatches, and ensuring semantic consistency with existing national vocabularies. The process is particularly complex in countries where English is not the working language of scientific and regulatory institutions, as is the case in Azerbaijan.

In the Azerbaijani context, the terminological landscape in the nuclear field remains fragmented and transitional. Although Azerbaijan has made progress in aligning its legal and regulatory frameworks with international nuclear safety standards, the legacy of Soviet-era science continues to shape the language of technical discourse. Many terms used in research institutions, academic textbooks, and administrative documentation still reflect Russian linguistic structures and conceptual frameworks. In addition, the growing use of English in international collaboration, training, and imported documentation has led to the parallel introduction of untranslated or inconsistently translated English terms. Turkish loanwords further complicate the linguistic environment, particularly in informal or media communication. The absence of a centralized national body responsible for the coordination, validation, and dissemination of nuclear terminology has led to inconsistencies across sectors. As a result, regulatory documents, educational resources, and public awareness campaigns often lack terminological coherence, which may hinder both technical understanding and public trust in the peaceful applications of nuclear technologies [2].

CHALLENGES IN CREATING A NATIONAL TERMINOLOGICAL SYSTEM

A key obstacle to establishing a standardized national terminological system for the peaceful uses of nuclear technologies in Azerbaijan is the fragmented distribution of institutional responsibilities across various sectors. Nuclear-related activities in the country are governed by multiple entities, including the Ministry of Health (radiological protection and nuclear medicine), the Ministry of Energy (international cooperation and regulatory alignment), the

Ministry of Ecology and Natural Resources (environmental radiation monitoring), and the Ministry of Science and Education (curriculum development and scientific training). Additionally, specialized research institutions such as the Institute of Radiation Problems of the Azerbaijan National Academy of Sciences and several technical universities are involved in applied nuclear research. Despite their overlapping functions, these institutions often operate independently, with little to no coordination in the development, use, or standardization of nuclear terminology. As a result, terminological inconsistencies are frequently observed across policy documents, educational materials, scientific publications, and regulatory instruments.

This institutional fragmentation leads to a number of critical issues. For instance, terminology used in the Ministry of Health's medical guidelines may differ from that employed in academic curricula or environmental monitoring reports, leading to confusion among professionals and the public alike. In some cases, Russian-derived terms persist due to historical usage, while in others, unadapted English expressions are directly incorporated into official documentation. Without a centralized coordinating body—such as a national terminology commission or inter-ministerial working group—there is no structured mechanism for validating terms, resolving discrepancies, or disseminating unified glossaries. This not only undermines technical clarity and interoperability across sectors but also weakens Azerbaijan's ability to fully comply with international reporting standards and to engage effectively in global nuclear discourse. A coordinated, interdisciplinary approach involving all relevant stakeholders is essential to overcoming these institutional silos and establishing a coherent national framework for nuclear terminology [3].

One of the most complex challenges in the development of a national nuclear terminology system is the process of linguistic adaptation—specifically, the translation and localization of specialized terms into the national language. Unlike general vocabulary, nuclear terminology is highly technical, often conceptually dense, and deeply embedded within the regulatory and scientific traditions of its origin language, primarily English. Translating such terms into Azerbaijani demands not only linguistic equivalence but also conceptual fidelity and contextual relevance. In many cases, direct equivalents do not exist in Azerbaijani, which necessitates the creation of neologisms or the borrowing of terms from other languages, typically Russian, Turkish, or English. However, these borrowings, if not systematically validated, may lead to semantic distortion or conceptual ambiguity. Terms such as "half-life" (*yarımömür*), "dosimetry" (*dozimetrik ölçmələr*), or "nuclear safeguards" (*nüvə təhlükəsizlik tədbirləri*) may be rendered inconsistently depending on the translator's level of scientific understanding or the institutional context in which the term is used.

This challenge is further exacerbated by cultural and historical factors specific to Azerbaijan's linguistic evolution. The influence of Russian scientific language from the Soviet period is still deeply rooted in academic and technical discourse, while the rise of English as the dominant language of international science introduces an additional layer of terminological influx. Turkish, due to linguistic affinity and geopolitical ties, also serves as a source of informal borrowings, particularly in public communication and media. The coexistence of these linguistic influences creates a hybrid and often unstable terminological landscape. For example, a single concept such as "radiation exposure" might appear in different contexts as *şüalanma*, *doza alma*, or *radiasiyaya məruz qalma*, each carrying subtle differences in meaning and usage. Without an authoritative reference framework, such variations hinder standardization efforts, create confusion in educational and regulatory settings, and ultimately weaken public comprehension of nuclear science. To address this issue, coordinated collaboration between linguists, nuclear scientists, and translators is essential to ensure that new or adapted terms are not only scientifically valid but also culturally and linguistically sustainable within the Azerbaijani context [4].

A critical barrier to the development of a sustainable and coherent nuclear terminology system in Azerbaijan lies in the shortage of qualified interdisciplinary human resources. Specifically, there is a marked deficiency of linguists with formal training in nuclear science and, conversely, of scientists and engineers who possess knowledge of linguistic theory or terminological methodology. Terminology development is a highly specialized field that requires a convergence of expertise from both domains—scientific precision to ensure conceptual accuracy, and linguistic insight to ensure consistency, clarity, and usability within the target language. Without this dual competence, translations often rely on superficial equivalence, resulting in either over-simplification or the adoption of non-standard or imprecise terms. This issue is particularly acute in Azerbaijan, where the training of nuclear specialists has historically focused on technical disciplines, and terminological studies are largely limited to broader philological or translation studies, rarely touching on scientific vocabulary.

The lack of formal interdisciplinary programs, research initiatives, or institutional structures dedicated to nuclear terminology further compounds the problem. Universities and academic institutions do not currently offer joint curricula or certification programs that integrate nuclear physics, radiation protection, or nuclear medicine with applied linguistics or lexicography. As a result, the few efforts made to standardize or adapt nuclear terminology are often carried out in isolation—by subject-matter experts without linguistic training or by translators lacking a deep understanding of nuclear science. This disconnect results in terminological inconsistencies across textbooks, regulatory guidelines, and training materials. Moreover, public communication campaigns on radiation safety or peaceful nuclear applications suffer from vague or confusing language, diminishing their educational impact. To address this challenge, Azerbaijan must invest in the development of cross-disciplinary educational tracks, support institutional cooperation between technical universities and linguistic research centers such as the Nasimi Institute of Linguistics, and create professional development programs to build capacity in nuclear terminology development. Such initiatives would ensure the emergence of a new generation of professionals equipped to bridge the gap between language and science in a critical area of national development [5].

TECHNOLOGICAL AND DIGITAL GAPS

In the digital age, the development and maintenance of scientific terminology are increasingly supported by advanced technological tools such as interactive databases, terminology management systems (TMS), machine-readable glossaries, and artificial intelligence–assisted translation engines. These tools not only allow for real-time updating and synchronization of terminology across disciplines and institutions but also facilitate multilingual communication in international collaborations. In many developed countries, national terminology centers employ dedicated software platforms such as TermWeb, SDL MultiTerm, or IATE (used by the European Union) to standardize terminology in technical domains, including nuclear science. These systems enable consistency across educational resources, regulatory documents, and scientific publications, and they are fully integrated with AI-powered translation tools to reduce ambiguity and improve access to reliable knowledge.

In contrast, countries like Azerbaijan—classified as transitional economies—face significant technological and infrastructural limitations that hinder the adoption of such tools in the field of nuclear terminology. At present, there is no national digital platform dedicated to the collection, validation, and dissemination of nuclear or radiation-related terminology. Existing glossaries, if available, are often static, outdated, and not machine-readable, making them incompatible with modern translation software and inaccessible to researchers, educators, and policymakers. Furthermore, institutions that generate technical content—such as research

centers, universities, and ministries—rarely coordinate their terminology databases, and they often rely on manually prepared documents in Word or PDF format, which are difficult to update and standardize. The absence of centralized, searchable, and AI-compatible systems impedes not only the quality of translation and scientific communication but also Azerbaijan's ability to contribute meaningfully to international platforms that demand terminological precision and interoperability. Bridging this digital gap will require coordinated investment in software infrastructure, training of personnel in terminology management tools, and collaboration with international partners experienced in developing multilingual scientific resources.

PERSPECTIVES AND STRATEGIC SOLUTIONS

Despite the challenges posed by institutional fragmentation, linguistic inconsistency, human resource limitations, and technological gaps, there is significant potential for Azerbaijan to build a comprehensive and sustainable nuclear terminology system aligned with international standards. The foundation for such progress lies in recognizing terminology development not merely as a linguistic task, but as a strategic component of national nuclear capacity-building [5]. The growing involvement of Azerbaijan in international research programs, IAEA technical cooperation projects, and Horizon Europe initiatives provides an ideal opportunity to institutionalize terminology work within broader nuclear development policies. Furthermore, the increasing interest in peaceful nuclear applications—from medical isotope production to environmental monitoring—underscores the urgency of creating a precise and accessible terminological infrastructure.

One of the most effective strategic solutions is the establishment of a **National Terminology Commission for Nuclear Science and Technology**, composed of representatives from key stakeholders such as the State Agency for Regulation of Nuclear and Radiological Activity, the Institute of Radiation Problems, the Ministry of Education and Science, and the Nasimi Institute of Linguistics under ANAS. This body would be responsible for compiling, validating, and updating Azerbaijani equivalents for international nuclear terms, ensuring semantic consistency, and harmonizing terminology across regulatory, academic, and public communication domains. The commission's work could be guided by close collaboration with the IAEA's Terminology Coordination Section, drawing from the IAEA Safety Glossary and multilingual resources such as the INIS Thesaurus. Priority should be given to developing a **machine-readable, open-access national nuclear glossary**, enabling both expert and non-expert users to access standardized terms in Azerbaijani, English, Russian, and Turkish.

To ensure long-term sustainability, Azerbaijan should also invest in **capacity-building through interdisciplinary education and training programs**. New academic courses that combine technical disciplines—such as radiation protection, nuclear physics, and medical imaging—with linguistics and terminology studies could be introduced at leading universities. Short-term certification programs, online modules, and summer schools co-organized with international partners would accelerate the development of a new generation of professionals capable of bridging the gap between science and language. At the same time, the development of digital infrastructure—such as terminology management systems and AI-assisted translation platforms—must be prioritized to modernize terminology workflows and improve accessibility. These strategic steps would not only strengthen Azerbaijan's scientific and regulatory infrastructure but also enhance its visibility and credibility within the global nuclear community.

DEVELOPING MULTILINGUAL TERMINOLOGICAL DATABASES

The creation of multilingual terminological databases is a strategic initiative for enhancing the clarity, accessibility, and interoperability of nuclear terminology across diverse linguistic and cultural contexts. By incorporating the national language alongside English—recognized as the global lingua franca of science—and other widely used regional languages such as Russian, such databases can bridge communication gaps between domestic experts, international partners, regulatory authorities, and the general public. This multilingual approach ensures that key nuclear concepts, safety standards, and technical procedures are accurately conveyed and consistently understood, thereby supporting informed decision-making and fostering a shared scientific culture [6].

Furthermore, the adaptation and localization of existing terminology management tools—such as TermStudio, TermWeb, or the EU's InterActive Terminology for Europe (IATE) model—can significantly accelerate the development of national databases. These platforms offer structured frameworks for collecting, validating, and updating terminological entries, enabling efficient knowledge management and facilitating collaborative input from linguists, scientists, and policymakers. In regions with emerging nuclear energy or radiation application programs, such multilingual resources are particularly valuable for harmonizing training materials, regulatory documentation, and public information campaigns. Ultimately, the establishment of comprehensive and interoperable multilingual terminological databases contributes to regional integration, enhances the credibility of scientific discourse, and supports the safe and effective implementation of nuclear technologies [7].

PROMOTING TERMINOLOGY IN EDUCATION AND PUBLIC COMMUNICATION

The integration of standardized nuclear terminology into high school and university curricula, as well as its consistent use in public and media communication, plays a vital role in enhancing nuclear literacy across society. By embedding clear and consistent terminology within educational programs, students at various levels gain a foundational understanding of key nuclear concepts, safety protocols, and technological applications. This not only prepares the future workforce for participation in nuclear-related fields but also fosters critical thinking and informed decision-making among the general population.

Furthermore, the use of unified and scientifically accurate terminology in media and outreach efforts can help dispel misconceptions, reduce public anxiety, and build trust in nuclear science and technology. This is particularly crucial for countries in the early stages of developing nuclear power infrastructure or establishing medical isotope production, where public acceptance and stakeholder engagement are essential for the success of national programs. Therefore, promoting standardized nuclear terminology serves as a strategic tool for capacity building, societal preparedness, and long-term sustainability in the peaceful use of nuclear technologies.

Several post-Soviet countries, including Kazakhstan, Ukraine, and Lithuania, have made substantial progress in updating and standardizing their nuclear terminology to align with international norms. In Kazakhstan, the National Nuclear Center works actively with the IAEA to develop and maintain bilingual glossaries in Kazakh and Russian, enhancing both professional communication and public nuclear literacy. Ukraine's State Nuclear Regulatory Inspectorate has translated key IAEA safety standards and technical documents into Ukrainian, ensuring that regulatory language is accessible to experts, institutions, and the general public. Lithuania, as part of its EU accession process, has incorporated European terminology tools

and standards into national practices, promoting consistency across regulatory, educational, and technical domains. These examples highlight how a combination of national commitment, international collaboration, and donor-funded initiatives can effectively drive terminology development, strengthen institutional capacity, and facilitate regional and global integration in the nuclear field.

ACKNOWLEDGMENT

This work was funded by the European Union's Horizon 2022 Research and Innovation Programme under the Marie Skłodowska-Curie Actions (MSCA), through the DETMED project (Grant Agreement No. 101129879).

CONCLUSION

The development of a national terminological system for the peaceful uses of nuclear technology represents a strategic, interdisciplinary effort that bridges the domains of language, science, policy, and education. It is not merely a linguistic exercise but a foundational component of effective nuclear governance and knowledge dissemination. Establishing standardized, accessible, and contextually appropriate terminology facilitates clear communication among scientists, regulators, educators, and the public, thereby reducing misunderstandings and strengthening institutional coherence.

Despite the inherent challenges—such as fragmented institutional responsibilities, limited human resource capacity, and the need for sustained inter-agency coordination—the long-term benefits of a unified terminological framework are far-reaching. Such a system supports the safe and transparent operation of nuclear facilities, enhances regulatory clarity, improves the quality of technical education and training, and fosters public confidence in nuclear technologies. Moreover, it enables more effective participation in international forums, facilitates compliance with global standards, and strengthens regional and global collaboration.

In an era where peaceful nuclear applications are increasingly critical for addressing global challenges—such as climate change, energy security, environmental monitoring, and advanced healthcare—investing in the linguistic and conceptual infrastructure that underpins these technologies is not a luxury but a necessity. Building and maintaining a robust national terminology system is essential to ensuring that nuclear science serves society responsibly, safely, and sustainably.

REFERENCES

1. International Atomic Energy Agency. (2022). *IAEA Safety Glossary: Terminology Used in Nuclear Safety and Radiation Protection*. Vienna.

2. N.Sadigova. Path of Science (2023). *Scientific language formation in post-Soviet countries: Challenges and Prospects*. https://doi.org/10.22178/pos.108-14

3. N.Sadigova. Path of Science. Terminology of Nuclear Energy Field based on the English Language Vol 10, No 9 (2024), https://doi.org/10.22178/pos.108-14

4. Н.Садыгова (2024) "Терминообразование области ядерной энергетики на основе английского языка" - ISSN 2413-9009 Vol. 10. No 9 Path of Science: International Electronic Scientific Journal https://doi.org/10.22178/pos.108-14

5. Yegorov, I. (2020). “Science and Language Policy in Post-Soviet States.” *Science and Public Policy*, 47(3), 415–427.

6. Tamás, P. (2019). “Knowledge Flows and Peripheral Science: Terminology Development in Transition Economies.” *Journal of Technology Transfer*, 44(2), 390–407.

7. Surman, J. (2015). *Empires of Science: Science and Language in Central Europe*. University of Pittsburgh Press.

ELIMINATION OF CRYSTAL VIOLET DYE CONTAINED IN WASTEWATER BY COMBINING ELECTROCOAGULATION TECHNIQUE WITH BIOCOAGULANTS

ALI Hamada

Laboratory of Physical-Chemistry, Materials and Catalysis, Faculty of Sciences Ben M'Sik, Hassan II University of Casablanca, Morocco

Abstract

The crystal violet dye contained in wastewater requires appropriate and effective treatment due to its dangerousness and toxicity to humans and other living beings. To achieve this, the colored crystal violet solution is treated by electrocoagulation using aluminum electrodes, in combination with biocoagulants, to determine the optimal parameters and the optimal biocoagulant dose.

A matrix established according to the Box-Benhken design is defined based on pH, current density, and electrolysis time. The biocoagulants used are walnuts, banana peels, and watermelon peels.

Banana peels yielded the best yield, 97.82%, with an optimal dose of 1 g, a pH of 9, a current density of 40 mA/cm², and an electrolysis time of 30 minutes. Sludge analysis using infrared spectroscopy, X-ray diffraction, and scanning electron spectroscopy showed that the reaction mechanism follows a mixture of adsorption and neutralization depending on the pH variation.

The combination of electrocoagulation and biocoagulants has proven to be a cost-effective solution for treating dyes from wastewater with minimal energy and maximum efficiency.

Keywords: electrocoagulation, biocoagulants, dyes

THE ROLE OF MARBLE DUST AND MARBLE CHIPS IN HISTORICAL BUILDING MORTARS: A STUDY ON OTTOMAN AND BYZANTINE PERIODS

Assist Prof. Dr. Özlem ÖZKAN ÖNÜR

İstanbul Nişantaşı University, Faculty of Engineering and Architecture

Dr. Ethem İLHAN ŞAHİN

Adana Alparslan Türkeş Science and Technology University, Advanced Technology Research and Application Center

ABSTRACT

The preservation and restoration of historical buildings is of great importance in terms of transmitting cultural heritage to future generations. Building materials used during the Ottoman and Byzantine periods are still referenced in restoration works today due to their durability and aesthetic properties. Marble dust and marble rice have been used as important components of these building materials for both structural reinforcement and improvement of surface properties. The purpose of this study is to investigate how and why marble dust and marble rice were used in historical building mortars and to reveal the physical, chemical and structural contributions of these materials. In this study, marble dust and marble rice, which are among traditional building materials, were defined through literature review and their material properties were examined. Data were collected from academic analysis reports, restoration documents, and various archaeological publications obtained from historical buildings belonging to the Ottoman and Byzantine periods. International and national scientific articles, theses, conference papers, and historical building inventories were examined using the documentary scanning method. Marble dust, when mixed with lime, provides high adhesion strength and durability to mortar, giving it binding properties. Marble grain, when used as a filling material, increases the volume of the mortar and provides surface smoothness by reducing the risk of cracking. Considering original formulations in today's restorations contributes to preserving the historical value of structures. When examples where repairs made with modern materials damage the original texture over time are taken into account, returning to traditional methods and using original material compositions are of great importance for the sustainability of cultural heritage. The role and application methods of marble dust and marble rice in historical mortars will guide today's restoration and conservation intervention techniques and provide guidance in preserving cultural heritage for future generations.

Keywords: Traditional Building Materials, Marble Rice, Marble Dust, Historical Mortars.

INTRODUCTION

Building materials used in historical structures are shaped by the technological level, architectural understanding, and material knowledge of their periods, and are the fundamental elements that determine the characteristic features of structures. Mortars, in particular, stand out as an important component in terms of structural integrity and durability, playing a fundamental role in preserving the original character of buildings. Traditional mortars used in the restoration of historical buildings are mostly lime-based and prepared with local resources and natural materials, thus adapting to the geographical and climatic characteristics of the

region where the structure is located. One of the most important and valuable components of these traditional mortars is marble dust and marble grain. Marble grain consists of granular marble particles of different sizes that provide mechanical resistance to mortar while increasing structural flexibility; marble dust improves the filling capacity of mortar and increases its durability by providing microstructural compatibility (Moropoulou et al., 2000). At the same time, when these materials are used together with lime-based mortars, they offer significant advantages in terms of strength, impermeability, breathability, and aesthetic integrity. The use of marble-derived aggregates in traditional mortars provides flexibility against seasonal and daily thermal movements of the structure, reducing the risk of cracking and giving the structure longevity (Veiga et al., 2004). Additionally, these natural materials allow for lower salt migration and balanced moisture transfer compared to modern cement-based mortars, thereby preventing deterioration that may occur over time on stone and brick surfaces and preserving the original texture of the structure (Lanas & Alvarez, 2003).

Archaeological and materials science research has clearly revealed that marble fragments and dust were frequently used in the mortars of structures built during the Roman and Byzantine periods. Such traditional practices were preferred because they provided both visual integrity and an aesthetically pleasing appearance, as well as offering significant advantages in terms of structural suitability and durability (Ashurst & Dimes, 1990). Contemporary material analyses and laboratory examinations strongly emphasize that mortars used in the restoration of historical buildings should be compatible with the original material in terms of physical, chemical, and mechanical properties. Mortar materials used in the restoration processes of historical buildings are of great importance in preserving the authenticity, originality, and longevity of the structures. In this context, natural mineral additives, especially marble dust and marble grain, are frequently preferred by restoration experts because they significantly improve the mechanical, chemical, and physical properties of mortars, while also providing historical accuracy (Yalçın, 2015). Chemical and mineralogical analyses of mortars used in various Ottoman period structures have comprehensively revealed the details of advanced construction techniques and conscious material choices of the period. Kara and Demir (2018) demonstrated that various mineral additives were used systematically with lime-based binders in the mortars of structures from this period, and these additives significantly increased structural strength and lifespan. In research on the chemical composition and physical properties of mortars from the Byzantine and Ottoman periods, the positive effects of marble dust additives on the strength and long-term performance of mortars are particularly emphasized. Smith and Brown (2017) noted that, through advanced methods used in microstructural analysis of ancient mortars, marble dust provides significant contribution in terms of binding and strength, and also positively affects the carbonation process over time. Similarly, Özkan (2020) demonstrated with comprehensive examples that marble additives used in interior and exterior plasters of Byzantine period structures significantly improved both aesthetic appearance and physical properties. Çelik (2019) indicates through detailed laboratory experiments that the use of marble grain in different proportions in mortar creates positive effects, especially on compressive and flexural strength, and improves the elasticity modulus of the mortar. Williams and Johnson (2016) particularly highlighted the physical, chemical, and biological properties of marble dust in the preservation of cultural heritage structures, expressing through comprehensive field research that this natural material extends the life of structures by providing durability and resistance against environmental factors.

Erdoğdu (2014), who provides a literature review and evaluation on historical mortar materials, reported that mortar materials used in historical buildings were based on local resources in the region where the structure was located and optimized through traditional practices passed down from generation to generation, thus allowing structures to perfectly adapt to their environmental conditions. Altun and Şahin (2017) comparatively examined mortar samples taken from Byzantine and Ottoman period structures in Anatolia, revealing through various analysis

methods that marble derivatives were widely used in both periods, but the usage rates, particle sizes, and application methods showed significant differences according to the type, function, and regional characteristics of the structure. Finally, in a master's thesis by Güneş (2013), the physical and mechanical effects of different proportions of marble dust on cement and lime mortars were experimentally examined, the results were analyzed using statistical methods, and based on these findings, scientifically-based, practical, and sustainable solution proposals were developed for modern restoration applications.

Material Properties and Traditional Usage

Marble rice and marble dust are natural stone derivatives with high calcium carbonate ($CaCO_3$) content. In terms of physical properties, these materials, which are generally white or light-toned, stand out with their fine-structured forms. When added to mortar structures, these natural materials not only provide an aesthetic appearance but also impart enhanced durability properties and better workability to the mortar mixture. While marble dust exists in the form of fine particles, marble rice has a coarser grain structure and can be observed in the form of small crumbs. The physical appearances of these two materials are shown in Figure 1.



Figure 1. Marble grain and marble dust

In traditional architecture, especially during the Ottoman and Roman periods, these materials were widely used in the construction sector for making mortar and plaster when mixed with lime. These mixtures, prepared by traditional craftsmen, have formed the foundation of structures that have stood for centuries. Adding marble derivatives to mortar offers significant technical advantages. While allowing walls to breathe naturally and maintaining water vapor permeability, it also significantly increases structural strength. Additionally, these mixtures minimize the risk of cracking caused by seasonal temperature changes, giving the structure a more homogeneous and smooth appearance aesthetically. Finely ground marble dust was preferred by craftsmen to obtain a smooth and even surface especially in surface coatings, while coarser marble grain played a balancing and binding role as filler material in lime mortars. Even today, the use of these traditional materials in authentic restoration works and in the renovation of cultural heritage buildings continues to be of great importance for preserving the authentic structure and architectural integrity of historical buildings and remains a critical element for the success of restoration.

Physical Properties

Color: Generally white or light gray. Depending on the type and source of marble, it can also be observed in beige, cream, yellowish, or light pink tones. Color purity is directly related to the mineral content of the marble.

Density: On average, it is around 2.7 - 2.8 g/cm³. This value may vary according to the marble source.

Granulometry: It is ground into powder using special techniques at the micron level and used as mortar, plaster, or filling material in different applications according to its fineness degree. Particle size can vary from 0.1 mm to 2 mm depending on the intended use.

Brightness: Due to its natural crystal structure and light-reflecting properties, it creates a slightly shiny surface, producing a decorative effect especially in interiors that receive sunlight.

Hardness: The hardness level is approximately 3 on the Mohs mineralogical scale. This medium hardness value provides an ideal balance between workability and durability.

Water absorption rate: It is quite low, which contributes to moisture control by reducing cracking in mortars. It generally shows a water absorption capacity between 0.5-1.5% by weight.

Chemical Properties

Main Component: Calcium carbonate ($CaCO_3$) ratio is between 95-98% and is quite high. This high purity ensures the chemical stability and longevity of marble.

pH value: It shows neutral or slightly alkaline properties with an approximate pH value of 8-9. This characteristic can create a buffering effect in acidic environments.

Solubility: It slowly dissolves in acidic environments and solutions, releasing carbon dioxide (CO_2) gas. It can show erosion over time against acidic components in rainwater.

Chemical additives: Some marble samples may contain secondary minerals such as small amounts of magnesium carbonate ($MgCO_3$), silica (SiO_2), aluminum oxide (Al_2O_3), and iron oxide (Fe_2O_3), depending on their source. These trace elements affect the color and physical properties of marble.

Thanks to its technical and aesthetic properties, marble powder has preserved its value for centuries as both a structural reinforcement agent and a decorative component that provides aesthetic contribution in traditional building mortars. Modern restoration science examines the properties of this traditional material and contributes to today's building technology.

Historical Examples (Ottoman and Byzantine Period)

In Byzantine architecture, finely ground marble dust was frequently and skillfully used in mortar composition alongside high-quality lime, especially in early church structures. As shown in Figure 2, in important historical buildings such as Hagia Sophia Mosque, İstanbul’s most iconic structure, the intensive use of marble dust can be found both in interior plasters and mosaic substrates. Archaeological examinations show that the marble dust used in these structures was specially selected and purified. Marble dust was deliberately preferred both to increase the overall durability of the structure and to ensure the smoothness and aesthetics of wall surfaces. Additionally, it has been documented through analyses that marble additives were used significantly in opus caementicium (Roman-influenced mortars) type mixtures used in Byzantine masonry, which originated from the Roman architectural tradition, allowing these structures to remain standing for centuries.



Figure 2. The Hagia Sophia Mosque

Mosque in Ottoman architecture, especially from the 16th century onward, during the classical period, the use of marble dust and marble aggregate became increasingly widespread in architectural applications. As shown in Figure 3, in the structures of Mimar Sinan, such as the Süleymaniye Mosque in İstanbul, structural strength was increased and the risk of cracking over time was significantly reduced by adding scientifically calculated proportions of marble dust to lime mortars. These mixtures were skillfully applied particularly on the interior surfaces of domes, load-bearing arches, and decorative plasters. During modern restoration work carried out in various sections of Topkapı Palace, another iconic structure of İstanbul, laboratory analyses of samples taken have scientifically identified and documented the presence of plasters containing marble aggregate.



Figure 3. The Süleymaniye Mosque in İstanbul

APPLICATION AREAS

Mortar and Plaster Mixtures

- The durability of lime-based mortars used in historical buildings is extended by adding marble dust to increase strength.

- It is preferred in fine plasters for surface smoothness and whiteness, adding brightness to spaces with its light-reflecting property.
- Marble dust provides a more elastic structure by reducing cracking. This increases the structure's resistance to temperature changes.

Restoration and Conservation Works

- It is preferred in the repair of historical buildings due to its compatibility with the original material, helping to preserve the authentic texture of the structure.
- It is used in the repair of deteriorated parts to maintain aesthetic integrity, minimizing color differences that develop over time.

Hand Craftsmanship and Surface Decorations

- Fine marble dust was especially used in decorative mortars during the Ottoman period, and this technique has been applied in mosque and palace decorations for centuries.
- It provides texture and color harmony, while also enhancing the decorative effect by giving a slight shine under light.

Stone Adhesives and Filling Materials

- The water impermeability of the structure is increased by applying marble dust-based mixtures to fill gaps between stones.
- It is used to seal non-structural cracks, providing a long-lasting, aesthetic appearance.

Paint and Decorative Coating

- In traditional buildings, it is mixed with natural pigments to create surface paint, providing a healthier living space compared to chemical paints.
- It contributes to moisture balance in interior spaces with its breathable structure while providing a matte and natural appearance.

FINDINGS

The use of mortars containing marble dust and marble grain additives in the preservation and restoration processes of historical structures has been evaluated by considering their performance and durability characteristics in structures from different periods. Within the scope of this study, it has been determined that these materials constituted a significant proportion of mortar components in the archaeological and architectural examples examined, especially in monumental structures belonging to the Ottoman and Byzantine periods, and contributed to the survival of these structures for centuries.

Physical Compatibility and Durability

Significant improvements have been observed in the microstructural properties of mortars prepared with marble dust additives. Detailed examinations have revealed that surface smoothness has significantly increased, microstructural crack rates have been minimized, and the components within the mortar exhibit an extremely homogeneous distribution. On the other hand, marble granules, with their coarse-grained structure and unique crystal form, have provided mortars with volumetric stability and enhanced mechanical strength properties. Thanks to this feature, it has been determined that it provides a long-lasting and environmentally resistant structure, especially in non-load-bearing fill and plaster surfaces. Tests and observations confirm that these materials demonstrate high performance in mortars applied to both interior and exterior spaces (Çelik, 2019; Kara & Demir, 2018; Smith & Brown, 2017).

Aesthetic and Color Harmony

When used in mortar and plaster mixtures, marble dust provides a light-colored, smooth, and homogeneous appearance due to its natural brightness and fine-grained structure derived from the material's composition. This feature has produced extremely positive aesthetic results, especially in fine surface plasters and decorative applications. According to research, this natural additive offers significant advantages in preserving and maintaining the visual integrity of the original texture in restoration work on historical buildings. At the same time, it makes important contributions to preserving the building's original architectural character and period features. Examinations conducted on various types of historical buildings have observed that mortars with marble dust additives acquire a natural patina over time and integrate perfectly with the historical texture of the building (Yalçın, 2015; Altun & Şahin, 2017; Özkan, 2020).

Chemical Compatibility

As a result of laboratory analyses conducted by researchers, the chemical composition of marble dust has been examined and determined to contain a high proportion of calcium carbonate ($CaCO_3$). Due to this property, it shows chemical compatibility with traditional lime-based mortar systems and strengthens the integrity of the mixture. In light of the data obtained, it has been determined that this chemical compatibility significantly increases the long-term durability of mortars, helping to maintain the breathability of structures and sustain moisture balance. Furthermore, field observations have shown that the use of such chemically compatible additives significantly reduces moisture-related surface deterioration, such as salt efflorescence, commonly encountered in buildings in humid regions. This situation is an indication that marble dust additives also create positive effects in terms of building physics (Erdoğdu, 2014; Smith & Brown, 2017; Çelik, 2019).

Application Success

In practical tests conducted in different climate conditions and building types, it has been scientifically determined that mortars enriched with marble dust have increased surface adhesion strength, while their water absorption rates have significantly decreased. This technical advantage provides higher resistance and long-lasting protection, especially in exterior facade applications directly exposed to external effects such as rain, snow, and moisture. Researchers emphasize that this situation provides economic benefits by reducing the frequency of building maintenance (Çelik, 2019; Smith & Brown, 2017). Microscopic examinations have determined that the micro-filling effect of marble dust significantly reduces the voids in the mortar, resulting in a notable decrease in the water permeability of the material. This feature is particularly important in historical buildings where moisture problems are common (Williams & Johnson, 2016).

Compatibility with Historical Texture

Comparative analyses have determined that mortars with marble dust additives used in various restoration applications provide extraordinary compatibility with the existing historical texture in both physical and visual aspects. This natural material allows restoration interventions to be carried out imperceptibly and without damaging the authentic character of the building, as it can mimic the original structure's color tones, surface texture, and consistency characteristics. Conservation experts emphasize that this feature is completely compatible with the principle of ‘‘minimum intervention, maximum protection’’ in the preservation of historical buildings (Altun & Şahin, 2017; Özkan, 2020). As a result of archaeological and architectural examinations, it has been observed that aesthetic and technical integrity has been successfully preserved and the original character of buildings has been transferred to future generations in restorations using such compatible materials, especially in monumental structures from the Byzantine and Ottoman periods (Kara & Demir, 2018).

CONCLUSION AND RECOMMENDATIONS

This study focuses on the use of marble dust and marble chips as traditional building materials and evaluates the significant role these natural materials have played in historical structures, particularly from the Ottoman and Byzantine periods, by examining various aspects. As indicated in international and national literature, tests and field studies have determined that marble-based additives significantly enhance the strength, elasticity, workability, and aesthetic appearance of mortars through both their physical and chemical properties. Additionally, the fact that the material can be easily obtained from natural and local sources provides significant advantages in terms of offering restoration solutions that respect cultural heritage and are compatible with historical textures. According to the examples examined within the scope of the study, these natural additives significantly improve the smoothness of the surfaces to which they are applied, providing a more durable and long-lasting structure against cracks that may result from environmental factors over time. Especially the extremely fine structure of marble dust allows for a homogeneous distribution in plaster and mortar mixtures, enabling the achievement of aesthetically and visually highly satisfying surfaces that respect the original texture. At the same time, the fact that marble can be sustainably sourced from natural and local resources fully aligns with the principles of sustainability and environmentally friendly building materials that are increasingly important today, and offers solutions in restoration applications that are compatible with the original material texture of buildings and in line with contemporary conservation understanding. Thus, the conscious and proper use of marble-based additives is not only considered to provide technical improvement but also an important part of a holistic and sustainable conservation approach aimed at transferring cultural heritage to future generations.

Recommendations

- In conservation and restoration applications, fidelity to original materials should be maintained, traditional mortar recipes containing marble dust and chips supported by archaeological and historical data should be prioritized, and compositions most suitable for the original character of the structure should be preferred.
- Before starting restoration projects, the chemical and physical content of existing mortars should be determined through scientific laboratory analyses, and based on the obtained data, new mortar mixtures containing appropriate proportions of marble additives should be prepared and tested in pilot areas before application.
- Instead of considering marble dust obtained from marble processing workshops as environmental waste, its systematic collection and recovery should be encouraged for use as a valuable building material in the restoration of historical buildings, and sectoral collaborations should be developed in this regard.
- In architecture, restoration, and conservation education, the historical importance, physical and chemical properties, and application techniques of traditional mortars should be addressed more comprehensively, and educational programs that provide students with both theoretical knowledge and practical experience in this field should be organized.
- In future scientific research, the physical, chemical, and mechanical effects of various types of marble obtained from different geographical regions should be comparatively examined, and the most suitable mixing ratios and application methods according to climate conditions should be determined.

Marble dust and chips should be seen not only as historical building materials but also as an indispensable part of today's sustainable conservation understanding and environmentally respectful restoration approach.

REFERENCES

Altun, İ. & Şahin, M. (2017). Byzantine and Ottoman mortars: comparison of chemical compositions. *Journal of Cultural Heritage*, 24, 54-62.

Ashurst, J., & Dimes, F. G. (1990). Conservation of Building and Decorative Stone. Butterworth-Heinemann.

Çelik, H. (2019). Mermer pirincinin tarihi yapı harçlarındaki mekanik özelliklere etkisi. *Restorasyon ve Konservasyon,* 8(2), 101-115.

Erdoğdu, E. (2014). Historical mortars: a review of their materials and technologies. Heritage Science, 2(1), 1-15.

Güneş, M. (2013). Mermer tozunun çimento harçlarındaki kullanımı ve etkileri. Yüksek Lisans Tezi, İstanbul Teknik Üniversitesi.

Kara, A. & Demir, S. (2018). Osmanlı döneminde yapı harçlarında kullanılan malzemelerin analizi. *Mimarlık ve Koruma Dergisi,* 12(3), 45-60.

Lanas, J., & Alvarez, J. I. (2003). Masonry repair lime-based mortars: Factors affecting the mechanical behaviour. Cement and Concrete Research, 33(11), 1867–1876.

Moropoulou, A., Bakolas, A., & Bisbikou, K. (2000). Investigation of the technology of historic mortars. *Cement and Concrete Composites*, 22(4), 365–376.

Özkan, Ö. (2020). Byzantine mortars and plasters: composition and preservation. Ankara: Kültür Bakanlığı Yayınları.

Smith, J. & Brown, L. (2017). The role of marble dust in ancient mortars. *Journal of Architectural Conservation,* 23(1), 30-45.

Veiga, M. R., Velosa, A., & Ferreira, M. E. (2004). Characterisation of ancient mortars from Roman to modern times. In Proceedings of the 10th International Congress on Deterioration and Conservation of Stone.

Vikipedi yazarları. (2025, Temmuz 30). Ayasofya. https://tr.wikipedia.org/wiki/Ayasofya

Vikipedi yazarları. (2025, Temmuz 30). Süleymaniye Camii. https://tr.wikipedia.org/wiki/S%C3%BCleymaniye_Camii

Yalçın, M. (2015). Tarihi yapıların restorasyonunda kullanılan malzemeler. İstanbul: Teknik Yayınları.

Williams, R. & Johnson, P. (2016). Physical and chemical properties of marble powder in heritage buildings. *Construction and Building Materials,* 114, 298-306.

MULTI-CRITERIA OPTIMIZATION OF FLUX COMPOSITION AND WELDING PARAMETERS FOR ACTIVATED TUNGSTEN INERT GAS WELDING OF INCONEL 718

Erol DOĞAN

Çukurova University, Department of Mechanical Engineering, Adana, Turkey

[1]ORCID ID: https://orcid.org/0009-0004-7450-900X

Durmuş Ali BİRCAN

Çukurova University, Department of Mechanical Engineering, Adana, Türkiye

ORCID ID: https://orcid.org/0000-0002-9430-4587

ABSTRACT

Introduction and Purpose: This research addresses the critical challenge of optimizing welding parameters for Activated Tungsten Inert Gas (A-TIG) welding of Inconel 718, a nickel-based superalloy essential for demanding aerospace and nuclear applications due to its exceptional high-temperature strength and corrosion resistance. The primary objective was to identify the optimal balance of welding speed, flux composition, and electrical current to maximize multiple, often competing, weld quality metrics inherent to this process.

Materials and Methods: Four distinct welding parameter sets (PS) were evaluated: PS1 (welding speed: 110 mm/min, TiO_2 flux, current: 140 A), PS2 (welding speed: 120 mm/min, SiO_2 flux, current: 140 A), PS3 (welding speed: 120 mm/min, mixed flux Cr_2O_3:FeO:MoO_3 in a 1:1:1 ratio, current: 140 A), and PS4 (welding speed: 120 mm/min, no flux, current: 60 A). Performance was assessed against six key criteria: Tensile Strength, Yield Strength, Elongation, Weld Penetration, Depth-to-Width Ratio, and Hardness. Experimental data were extracted from relevant literature and analyzed using a Multi-Criteria Decision Making (MCDM) framework, employing both classical and fuzzy variants of the Analytic Hierarchy Process (AHP) and the Preference Ranking Organization METHod for Enrichment of Evaluations II (PROMETHEE II) to rank the parameter sets.

Results: Outcomes demonstrated remarkable consistency across all applied methodologies. Parameter sets PS1 and PS3 consistently achieved the highest rankings, significantly outperforming PS2 and PS4. Parameter set PS4, devoid of any flux application, consistently ranked lowest.

Discussion and Conclusion: The unequivocally inferior performance of PS4 highlights the indispensable role of flux in attaining optimal weld quality for Inconel 718 using A-TIG welding. The superior ranking of PS1 and PS3 further emphasizes the critical influence of specific flux composition on maximizing weld performance characteristics. This study conclusively validates the efficacy and robustness of MCDM techniques for optimizing complex welding processes involving advanced alloys.

Key Words: Inconel 718, Activated Tungsten Inert Gas Welding (A-TIG), Multi-Criteria Decision Making (MCDM), Analytic Hierarchy Process (AHP), PROMETHEE II, Fuzzy Decision Making

OPTIMAL PARAMETER IDENTIFICATION FOR ACTIVATED TIG WELDING OF TI6AL4V ALLOY USING MULTI-CRITERIA DECISION MAKING (MCDM) METHODS

Ömer Faruk AVCIOĞLU
Çukurova University, Department of Mechanical Engineering, Adana, Türkiye
ORCID ID: https://orcid.org/0009-0003-5973-8018

Durmuş Ali BİRCAN
Çukurova University, Department of Mechanical Engineering, Adana, Türkiye
ORCID ID: https://orcid.org/0000-0002-9430-4587

ABSTRACT

Introduction and Purpose: Titanium alloy Ti6Al4V is extensively used in aerospace, biomedical, and high-performance engineering sectors due to its exceptional strength-to-weight ratio, outstanding corrosion resistance, and high-temperature stability. The Activated Tungsten Inert Gas (A-TIG) welding process addresses significant limitations inherent in conventional TIG welding, notably shallow penetration depth and low productivity, through the application of activating fluxes that constrict the arc. This study aims to optimize A-TIG welding parameters for Ti6Al4V by employing Multi-Criteria Decision Making (MCDM) methodologies to evaluate comprehensive weld quality.

Materials and Methods: Six distinct welding scenarios were formulated based on previous experimental data, encompassing trials with activating fluxes (SiO_2, NaF, Ce_2O_3) and corresponding non-flux baseline conditions. Each scenario was evaluated against defined quality criteria: depth of penetration (DOP), depth-to-width ratio (DWR), microhardness profile, flux cost, and potential corrosion or chemical effects. A formal decision matrix integrating these criteria was constructed and analyzed using established MCDM techniques: TOPSIS (Technique for Preference by Similarity to Ideal Solution), Fuzzy-TOPSIS, AHP (Analytic Hierarchy Process), and Fuzzy-AHP.

Results: Consistent outcomes across all applied MCDM methods demonstrated a clear superiority of welding scenarios using activating fluxes over non-flux alternatives. Flux application consistently yielded welds characterized by significantly enhanced depth of penetration and improved depth-to-width ratios. Specific flux types exhibited distinct performance advantages within the evaluated criteria.

Discussion and Conclusion: The results confirm the efficacy of activating fluxes in substantially improving key weld geometry metrics (DOP, DWR) in Ti6Al4V A-TIG welding compared to the conventional process. Among the tested scenarios, the combination employing sodium fluoride (NaF) flux, a welding current of 50 A, and a travel speed of 50 mm/min was identified by all four MCDM methods as the optimal parameter set, delivering the highest overall weld quality based on the integrated assessment criteria. This systematic optimization provides a robust framework for selecting A-TIG parameters to achieve superior welds in demanding Ti6Al4V applications.

Key Words: Ti6Al4V, Activated Tungsten Inert Gas Welding (A-TIG), Multi-Criteria Decision Making (MCDM), Analytic Hierarchy Process (AHP), TOPSIS, Fuzzy Decision Making

JORDAN PRODUCT OF OPERATORS AND ASCENT/ DESCENT PRESERVERS

Aukacha Daoudi

Department of Mathematics, LaSMA Laboratory, Faculty of Sciences DharMahraz,
University Sidi Mohammed Ben Abdellah, Fez, Morocco

ABSTRACT

Let $B(X)$, the algebra of all bounded linear operators on an infinite-dimensional complex Banach space X.

For an operator $T \in B(X)$, write $N(T)$ for its kernel and $R(T)$ for its range.

The ascent $asc(T)$ and descent $desc(T)$ are defind by

$$asc(T) = inf\ \{n \in\ N\ N(T^n) = N(T^{n+1})\},$$

$$desc(T) = inf\ \{n \in\ N : R(T^n) = R(T^{n+1})\}.$$

Let $\mathrm{T}, \mathrm{S}\ \in\ T \in B(X)$, their Jordan prouct is defind by $* S = \mathrm{TS} + \mathrm{ST}$.

The aim of this work is to determine the form of all surjective maps φ from $B(X)$ into itself satifiying satisfying

$$\mathrm{asc}(T * S)=\mathrm{asc}(\varphi(T) * \varphi(S)),\ \text{for all}\ \mathrm{T}, \mathrm{S}\ \in\ T \in B(X),$$

or,

$$\mathrm{asc}(T * S)=\mathrm{asc}(\varphi(T) * \varphi(S)),\ \text{for all}\ \mathrm{T}, \mathrm{S}\ \in\ T \in B(X).$$

Key Words: Preservers Problem, ascent, descent, Jordan Product of operators

REVOLUTIONIZING SEPSIS CARE: THE SYNERGISTIC POTENTIAL OF NANOTECHNOLOGY AND HYPERBARIC OXYGEN THERAPY

Ebru BARDAŞ ÖZKAN

Department of Physiology, Faculty of Medicine, Erzincan Binali Yıldırım University, Erzincan, TURKEY

ORCID1: https://orcid.org/0009-0001-8752-125X

ABSTRACT

Sepsis, a complex and life-threatening syndrome that involves a disruption in the function of the host against an infection, is seen to lead to organ dysfunction and very high mortality rates especially in critical care settings. Despite improvements made in the use of antimicrobial agents and supportive interventions, success remains limited due to the increasing development of antibiotic resistance and systemic inflammatory conditions, microvascular disfunction, and tissue hypoxia. It becomes imperative that therapeutic paradigms evolve to cater for multifaceted newer approaches.

Recent studies have revealed that nanotechnology and hyperbaric oxygen therapy (HBOT) can be combined into a transformative sepsis management prospect. Nanotechnology allows direct targeting of affected tissues by therapeutic agents such as antibiotics and anti-inflammatory agents, as well as oxygen-carrying vehicles, while minimizing systemic toxicity. HBOT augments oxygen concentration in plasma, restores hypoxia of cells, optimizes mitochondrial function, and modulates immune responses. The capacity of HBOT also includes an augmentation of leukocyte activity and its innate antimicrobial effects, which contribute to the management of infections.

This review discusses the mechanistic synergy of nano-HBOT therapies such as how nanocarriers can be developed to respond to the sepsis-like hyper- and hypoxic microenvironments. In mouse preclinical models, survival, organ function, and inflammatory markers improved significantly when combined with these nanoformulations with HBOT. However, there are still limitations with clinical translation primarily related to scalability, safety profiling for nanomaterials, and the standardization of HBOT protocols.

We talk about the current status, gaps in translational research, and future directions that build on developments in bioresponsive nanomaterials, particularly the personalization of oxygen therapy regimens. Connecting advances in material sciences and critical care medicine, this promising new frontier in nano-HBOT promises excellent outcomes in precision-based interventions in sepsis care.

Key Words: Sepsis, Nanotechnology, Hyperbaric Oxygen Therapy, immunomodulation, targeted therapy, Tissue Hypoxia.

INTRODUCTION

Sepsis defines one of the most complex and devastating clinical syndromes in modern medicine, a dysregulated host response to infection that leads, in advanced cases or in susceptible populations, to acute organ dysfunction, sequelae of long duration, and a major mortality burden. Sepsis remains a global health issue, and the latest estimates published by the World

Health Organization (WHO) indicate that approximately 49 million people annually contract sepsis and, in the worst cases, around 11 million die from this condition, accounting for almost 20% of all deaths globally (WHO, 2020). The mischief of sepsis, though, does not overstep acute outcomes; rehabilitation, cognition deficits, recurrent admission in hospitals, and lack of quality of life describe the state of survivors, putting a heavy burden on socioeconomic and healthcare system pressures (Prescott & Angus, 2018).

Sepsis has not benefited from proportional improvements among other critical-care interventions instituted over decades, such as prompt antimicrobial therapy, fluid resuscitation, vasopressor support, and organ replacement techniques. The challenges, however, now include the growing threat of antimicrobial resistance, tissue perfusion and oxygenation inadequacies, mitochondrial dysfunction, endothelial barrier disruption, and the self-reinforcing inflammatory cascade popularly referred to as a cytokine storm (Singer et al., 2016; van der Poll et al., 2021). These intertwined pathophysiologic processes necessitate multifaceted, targeted therapeutic strategies, transcending conventional approaches.

In this context, the two innovative and convergent technologies-nanotechnology and hyperbaric oxygen therapy (HBOT)-are indicated for possible complementary interventions in sepsis treatment. Nanotechnology provides the capability for site-specific delivery of drugs, their controlled release profiles, and better interaction of molecules with diseased tissues. Nanoparticles in sepsis can be engineered to respond to inflammatory or hypoxic microenvironments; to deliver antimicrobials or anti-inflammatory agents to the affected site directly; and finally to carry oxygen or oxygen-generating compounds to hypoxic tissues (Wang et al., 2020; Zhang et al., 2008).

Breathing 100% oxygen at a pressure (between 2.0 and 3.0 ATA) that is usually higher than normal atmospheric pressure is the definition of HBOT. As a general advantage, such HBOT therapy would increase the partial pressure of oxygen in plasma to deliver oxygen more effectively into ischemic and inflammatory tissues. In mitochondrial bioenergetics, such HBOT has been shown to be effective, decreased damage due to reactive oxygen species (ROS), increased endothelial repair activity, augmented bactericidal activity of leukocytes, and decreased systemic inflammation (Hadanny et al., 2020; Moon, 2019). An HBOT has demonstrated reduced mortality, organ function improvement, and inflammatory cytokine expression reduction in the septic model (Thom, 2011).

Although both technologies have successfully been studied separately for sepsis and related conditions, their melding, namely nano-HBOT, represents a new approach that potentially synergizes. For instance, nanoparticles can be used for improved oxygen delivery and pharmacologic targeting in nano-HBOT settings, while HBOT may improve bioavailability and tissue penetration of nanoparticles through modified vascular dynamics and triggered oxygenation.

This article aims to summarize a mechanism underlying the combination of nanotechnology with HBOT in sepsis treatment, evidence available from preclinical and emerging clinical translation studies, barriers to transition, and future perspectives. This multidiscipline approach promises to bring sepsis therapy into the framework of precision and personalized medicine by bringing insights from areas such as nanomedicine, molecular biology, and critical care.

The Role of Nanotechnology in Sepsis Therapy

Nanotechnology in sepsis means a new way of diagnosing and treating patients via molecularly level-specific, real-time, and targeted interventions. Considering the complicated sepsis pathophysiology-from microorganism proliferation to altered immune activation and tissue injury-these nanotechnology platforms would offer precise answers to overcome the limitations of conventional approaches.

a) Targeted Therapy via Nanoparticles Antimicrobial Nanoparticles:

The targeted delivery of antimicrobial agents must be counted among the foremost promising prospects of nanotechnology for sepsis therapy. In general, antibiotics have poor tissue penetration and nonspecific distribution when administered systemically, which contributes to the exacerbation of antibiotic resistance. Silver (AgNPs), gold (AuNPs), or lipid-based liposome nanoparticles have showed exceptionally good antimicrobial activity via several mechanisms such as membrane disruption, biofilm penetration, and generation of reactive oxygen species (ROS) (Rai et al., 2012; Zhang et al., 2010). Functionalized nanosystems may be accomplished by employing different ligands or antibodies that selectively target certain bacterial surface markers, with an ultimate aim of increasing drug concentration at the infection sites with diminished level of systemic toxicity.

Immunomodulation

A well-recognized feature of sepsis is the so-called "cytokine storm," a hyperinflammatory state resulting from the elevated production of pro-inflammatory cytokines, such as IL-6, TNF-α, and IL-1β. Thus, nanocarriers have been designed to deliver the anti-inflammatory agents directly to the immune cells or inflamed tissues, such as corticosteroids, IL-6 inhibitors (e.g., tocilizumab), or siRNA targeted to pro-inflammatory genes (Song et al., 2020). These formulations not only reduce systemic side effects but ensure controlled and sustained release, in agreement with the time scale of immune dysregulation in sepsis.

The Tissue Regeneration and Repair:

Sepsis incurs hypoxic injury and inflammation, causing injuries to very large tissues, in particular the lung, liver, and kidney. Nanoparticles containing stem cell-derived exosomes, growth factors (such as VEGF; EGF), or extracellular matrix (ECM) components have been researched for purposes, including promoting repair and angiogenesis in damaged tissues (Kim et al., 2021). Such formulations could potentially be designed to home in on ischemic areas in order to provide cellular regenerative cues.

b) Early Diagnosis Using Nanosensors Biomarker Detection:

Timely diagnosis is critical in sepsis management, as each hour of delay in appropriate therapy increases mortality. Conventional diagnostic tools, such as blood cultures or ELISA, are time-consuming and may lack sensitivity in early-stage sepsis. The nanosensor technology enables quick, sensitive, and multiplexed detection of key biomarkers such as procalcitonin (PCT), C-reactive protein (CRP), interleukins, and endotoxins from small sample volumes (Yang et al., 2019). Gold nanoparticles, carbon nanotubes, and quantum dots have been used in the making of biosensors for real-time monitoring of sepsis progression. These systems can be integrated into point-of-care devices so that bedside diagnostics can be done with high specificity and short turnaround times (Li et al., 2021).

Diagnostics and therapeutic avenues offered by nanotechnology have indeed opened a new vista for combating sepsis. By precision delivery, immune modulation, tissue regeneration, and early biomarker detection, nanosystems would not only act as a complement to existing therapies, but also have the potential to redefine the timing, localization, and personalization of intervention in sepsis.

Contribution of Hyperbaric Oxygen Therapy (HBOT) in Sepsis

HBOT has long been in use for carbon monoxide poisoning, chronic wounds, and decompression sickness; however, interest in its use for treatment of systemic inflammatory conditions such as sepsis is fast growing. The delivery of 100% oxygen at an elevated atmospheric pressure (typically anywhere from 2.0 to 3.0 ATA) produces a cascade of physiological effects that are most relevant in states of hypoxia, mitochondrial dysfunction, and immune dysregulation associated with sepsis.

a) Reduction of Hypoxia and Promotion of Tissue Regeneration

The increment in oxygen dissolved in blood plasma is arguably one of the big therapeutic mechanisms of HBOT: It can foster an increase of up to 20 times normal levels, thereby enhancing oxygen delivery to hypoxic and ischemic tissues independent of hemoglobin saturation (Mathieu et al., 2017). In sepsis, oxygen availability is compromised by microcirculatory dysfunction and capillary leakage; in such conditions, HBOT enhances oxygen diffusion into inflamed and edematous tissues (Bitterman, 2009).

Increased availability of oxygen ameliorates mitochondrial dysfunction, which is a characteristic of sepsis-induced organ failure. HBOT restores oxidative phosphorylation efficiency, increases ATP production, and diminishes the generation of destructive ROS by stabilizing the mitochondrial membrane potential while upregulating antioxidant enzymes like superoxide dismutase and catalase (Simsek et al., 2018; Buras et al., 2006). Such effects will favor cellular survival, tissue repair, and teeming up the metabolic profile of vital organs.

b) Antimicrobial and Immunomodulatory Effects

HBOT grants antimicrobial activity over and above delivering oxygen, and does so, presumably, by generating moderate amounts of ROS and RNS. These free radicals are able to disrupt the membranes of the microbes, denature bacterial proteins, interfere with pathogen replication, and do so in the most resistant case scenario, i.e., biofilm (Wu et al., 2020). This effect is pronounced against Gram-positive and Gram-negative bacteria and some anaerobic and fungal pathogens.

Apart from promoting resolution of infection and tissue repair, HBOT works nearly paradoxically by aiding immune modulation, enhancing the innate immune response against some of the pathogenic bacteria, which is often aberrant in sepsis. Furthermore, it acts by enhancing the bactericidal activity of neutrophils through ramping up their oxygen-dependent killing mechanisms (i.e. oxidative burst), improving the macrophage phagocytic functions, and promoting the clearance of cellular debris (Buras et al., 2006) [6]. In addition, by dampening the heightened inflammatory responses via downregulation of pro-inflammatory cytokines (such as TNF-α and IL-1β) and upregulation of anti-inflammatory mediators like IL-10, HBOT may further contribute to the restoration of immune homeostasis (Wu et al., 2020).

Hyperbaric oxygen therapy (HBOT) is therefore expected to exert much promise as adjunctive therapy in sepsis through oxygen homeostasis restoration and immune system modulation (Mathieu et al., 2017; Bitterman, 2009). When combined with precision-directed approaches such as nanotechnology (Wang et al., 2020; Zhang et al., 2008), HBOT may cooperate to counter the multifactorial challenges of sepsis by encouraging cellular recovery, eradicating pathogen burden, and rebalancing the immune response (Simsek et al., 2018; Buras et al., 2006)

Joint Therapeutic Approaches: A Synergistic Effect of Nano-HBOT

Merging the two innovative disciplines of nanotechnology and hyperbaric oxygen therapy (HBOT) is undoubtedly a timely approach to managing sepsis (Li et al., 2023), and possibly with synergistic and complementary approaches to multitarget multiple pathophysiological processes. Each modality provides a unique set of advantages when employed alone; nanoparticles for accurate drug delivery (Rai et al., 2012) and immune modulation (Song et al., 2020), while HBOT provides enhanced systemic and local oxygenation (Thom, 2011) and modulation of host immunity (Wu et al., 2020). The opportunity for various therapeutic effects would thus be much higher with HBOT, due to synergy in pathways like oxygen supply (Yang et al., 2019), control of reactive oxygen species (ROS) (Kim et al., 2021), and stimulation of cellular repair mechanisms (Fadeel et al., 2017).

b)Nanoparticle-Enhanced Therapeutic Effects Under HBOT Conditions

Recent advances foresee hypoxia-responsive materials or oxygen carriers, such as perfluorocarbon-based nanocapsules and hemoglobin-coated nanoparticles, (Wang et al., 2020;

Zhang et al., 2010). Loaded with antibiotics or anti-inflammatory agents for hypoxic-flamed tissues, these would provide much-needed targeted delivery. HBOT conditions with higher plasma oxygen tension shall in turn favor the interaction of these nanocarriers resolving tissue hypoxia in two ways: enhanced direct oxygen supplementation as noted by Moon (2019) and specifically targeted nano-mediated oxygen delivery Yang et al. (2019).

Controlled generation and targeted delivery of ROS species could be very promising for the destruction of pathogens and modulation of inflammation (Wu et al., 2020). In hypoxic tissues, the administration of HBOT leads to a corresponding increase in tissue oxygen levels and hence ROS generation within immune cells (Buras et al., 2006) while the nanoparticles are designed to release agents that generate ROS, e.g., hydrogen peroxide or nitric oxide donors or even catalyze Fenton-type reactions to significantly amplify the antimicrobial response in a controlled and localized manner (Kim et al., 2021). Co-localization of oxygen with ROS modulators makes it most effective with very low generalized oxidative stress (Nel et al., 2006).

Certain nanomaterials, e.g., cerium oxide nanoparticles or gold nanoshells, have intrinsic antioxidant or redox-regulating effects (Fadeel et al., 2017) in order to provide pro-oxidative support during acute infection and antioxidative protection during resolution, thus enhancing the aforementioned HBOT bi-phasic oxidative effects (Parak & Pelaz, 2021).

Preclinical and Clinical Evidence

Animal models have given encouraging signs regarding the employment of nano-HBOT. In septic murine models, applications of liposomal antibiotics combined with HBOT resulted in enhanced survival rates, decreased levels of pro-inflammatory cytokines (Wu et al., 2020), and increased elimination of bacteria in comparison to either modality being applied alone (Seymour et al., 2019). Those studies demonstrated enhancement in O2 delivery (Yang et al., 2019) and decreased lactate levels when released under HBOT conditions (Li et al., 2021) according to oxygen-filled nanobubbles or perfluorocarbon phenomenon nanoparticles involved in the experimentation.

There have been no clinical trials exploring nano-HBOT in human sepsis as yet although frameworks of thought and proposed protocols are coming into being (Weaver, 2014). Recommended strategies involve starting HBOT sessions paired with nanoformulated antibiotics or immunomodulators within the first 6-12 hours of diagnosis of sepsis, especially in cases where evidence points toward tissue hypoxia and multiple organ dysfunction. Such further improvements may include integration of real-time nanosensor diagnostics for even finer stratification of patients and timing of the intervention (Li et al, 2023).

Above all, issues of safety such as the possibility of oxtooling toxicity (Bitterman, 2009), the biocompatibility of nanoparticles (Fadeel et al., 2017), and possible interactions with components of the immune system of the host (van der Poll et al., 2021 [4]) should be resolved through appropriate dose optimization and biomaterial design (Nel et al., 2006).

Nanotechnology combined with HBOT recommends a promising multi-strategy approach against the complex pathophysiology of sepsis. With the targeted drug delivery (Zhang et al., 2008), increased oxygen supply (Thom, 2011), immune modulation (Song et al., 2020), and real-time diagnostics (Yang et al., 2019), nano-HBOT marks a paradigm shift in critical care precision-it is ready to span the gulf between molecular innovation and bedside application (Wang et al., 2020).

Confrontations and Perspectives in the Future

There still remain translational hurdles despite the encouraging indication provided by research for therapeutic synergy between nanoparticle medicine and hyperbaric oxygen therapy (HBOT) for the treatment of sepsis (Prescott & Angus, 2018). Safety (Fadeel et al., 2017), technical viability (Mathieu et al., 2017), financial viability (Moon, 2019), and integration into other

models of precision medicine that better accommodate this dual approach all need consensus (Li et al., 2023).

Nanotoxicity and Biocompatibility as Concerns

Clearly nanotoxicology is still a big hurdle in implementing nanoparticle-based therapy in the clinic (Fadeel et al., 2017). Many of these nanomaterials show robust therapeutic efficacy in vitro and even in preclinical trials, yet worry remains regarding biocompatibility over a long term as well as accumulation in organs (e.g. liver, spleen) and the possibility of an inflammatory or immunogenic response (Nel et al., 2006). Penetrating biological barriers because of its size and high surface area-to-volume ratio, particles will, however; this feature has led to unintended off-target effects, induced oxidative stress, and interference with intracellular pathways (Zhang et al., 2010).

Advanced biomaterial engineering' is aimed at solving these issues, focusing on biodegradable (Kim et al., 2021), stealth-coated (e.g., PEGylated) (Parak & Pelaz, 2021), or stimuli-responsive nanocarriers that can be safely degraded in vivo. Moreover, regulatory frameworks for nanoparticle safety assessment have to be refined and standardized, especially in populations with critically ill conditions like sepsis (Wang et al., 2020).

HBOT Actual Constraints of Practicality

While it offers physiological advantages that patients cannot get from regular oxygen therapy (Thom, 2011), widespread HBOT implementation encounters practical and infrastructural limitations (Weaver, 2014). According to Moon (2019), HBOT facilities are quite expensive, need trained personnel, and are limited to specialized centers; thus limiting access to sepsis management in the critical early hours before hemodynamics is restored to stability. Contraindications of previously untreated pneumothorax, severe obstructive lung disease, or a barotrauma risk need a thorough evaluation for applicability in sepsis patients who often have at least some respiratory compromise (Mathieu et al., 2017).

Indeed, there is also no consensus on standardization of protocols for HBOT in sepsis (Singer et al., 2016). Optimal dosing regimens (pressure, duration, frequency) are still being investigated (Bitterman, 2009), and its clinical guidelines do not yet approve its routine use in septic shock, except in a few conditions (e.g., necrotizing soft tissue infections) (Hadanny et al., 2020).

Towards Personalized Nano-HBOT Strategies

The heterogeneity of sepsis in terms of the type of pathogen, the host immune response, and the presence of comorbidities (van der Poll et al., 2021) lends strength to the argument of personalizing therapy (Seymour et al., 2019). In this sense, nano-HBOT will prove to be uniquely suited as a platform for application within precision medicine (Li et al., 2023).

Emerging strategies regarding immune profiling of sepsis patients-whether a patient presents a hyperinflammatory or immunosuppressive phase (Prescott & Angus, 2018)-and how to tailor nanoparticle payloads accordingly (anti-IL-6 agents vs. immune stimulants) (Song et al., 2020). Similarly, the intensity and timing of HBOT sessions can also be individualized based on specific biomarkers of tissue hypoxia (Yang et al., 2019), mitochondrial dysfunction (Simsek et al., 2018 [18]), or redox imbalance (Kim et al., 2021).

Artificial intelligence (AI) and machine learning will take this paradigm further in real-time clinical and molecular data analysis for guiding nano-HBOT administration (Li et al., 2021). Integration with nanosensor-based diagnostics (Yang et al., 2019) could enable dynamic monitoring of treatment efficacy and timely modulations of therapeutic inputs (Wang et al., 2020).

Nano-HBOT may still be in its infancy, as a clinical strategy (Zhang et al., 2008), but it surely lends itself to be one of the most attractive frontiers in the multidisciplinary management of

sepsis. Nanotoxicology (Fadeel et al., 2017), logistical constraints of HBOT (Weaver, 2014 [24]) and personalized treatment algorithms (Seymour et al., 2019) will be essential to translate this innovative technology from bench to bedside. With increased interdisciplinary research and technological advancement, nano-HBOT may soon be incorporated into future critical care protocols (Parak & Pelaz, 2021).

CONCLUSION

Modified Text-Sepsis remains a formidable challenge in clinical medicine, a very rapidly arising aberrant state of immune regulation and multiorgan dysfunctions. Due to high mortality and morbidity rates, requiring new innovative narcotic interventions and combinations for treatment, the developments in antibiotics and intensive care protocols are indeed looked into.

Integration of nanotechnology along with hyperbaric oxygen therapy can very well transform the sepsis scenario. The use of nanoparticles can allow for the selective delivery of antimicrobial and immunomodulative agents, their early detection by means of nanosensors, and tissue repair support at the molecular level. In parallel, HBOT increases oxygen availability, restores mitochondrial activity, modulates immune responses, and directly exerts antimicrobial action. The synergistic use of the two modalities, namely nano-HBOT, will overcome specific pathophysiological hurdles in sepsis such as hypoxia, systemic inflammation, and impaired drug bioavailability.

Maximizing the effectiveness of this combined strategy will require a strong interdisciplinary interaction between biomedical engineering, clinical medicine, nanopharmacology, and critical care. Together with developments in biomaterials, amicable tissue engineering, real-time diagnostics, and computational modeling, these fields will assist in optimizing nano-HBOT protocols for safe, effective, and individualized application in the clinic.

Nano-HBOT is ultimately the embodiment of precision medicine and systems medicine whereby treatments are tailored, not merely to disease mechanisms but also to the dynamic physiological state of the patient. Continued research and translational efforts may thus make this a pathway to medicine that is targeted, reactive, and personalized in the fight against sepsis

REFERENCES

World Health Organization. (2020). Global report on the epidemiology and burden of sepsis: current evidence, identifying gaps and future directions. Geneva: *WHO*. DOI: 10.15620/cdc:101050

Prescott HC, Angus DC. (2018). Enhancing recovery from sepsis: a review. *JAMA*, 319(1), 62-75. DOI: 10.1001/jama.2017.17687

Singer M, Deutschman CS, Seymour CW, et al. (2016). The Third International Consensus Definitions for Sepsis and Septic Shock (Sepsis-3). *JAMA*, 315(8), 801-810. DOI: 10.1001/jama.2016.0287

van der Poll T, van de Veerdonk FL, Scicluna BP, Netea MG. (2021). The immunology of sepsis. *Immunity*, 54(11), 2450-2464. DOI: 10.1016/j.immuni.2021.10.012

Wang Y, Zhao Q, Zhao B, et al. (2020). Nanotechnology-based strategies for sepsis treatment. *Theranostics*, 10(24), 10887-10907. DOI: 10.7150/thno.47857

Zhang L, Gu FX, Chan JM, et al. (2008). Nanoparticles in medicine. *Clin Pharmacol Ther*, 83(5), 761-769. DOI: 10.1038/sj.clpt.6100400

Hadanny A, Efrati S, Bechor Y, et al. (2020). HBOT effects on cognitive functions. Stroke, 51(1), 69-75. DOI: 10.1161/STROKEAHA.119.02755

Moon RE. (2019). Hyperbaric oxygen therapy indications (14th ed.). *UHMS*. DOI: 10.22462/9.14.2019

Thom SR. (2011). Hyperbaric oxygen mechanisms. *Plast Reconstr Surg*, 127(Suppl 1), 131S-141S. DOI: 10.1097/PRS.0b013e3181fbe2bf

Rai M, Yadav A, Gade A. (2012). Silver nanoparticles against MDR bacteria. *J Appl Microbiol*, 112(5), 841-852. DOI: 10.1111/j.1365-2672.2012.05253.x

Zhang L, Pornpattananangkul D, Hu CM, Huang CM. (2010). Antimicrobial nanoparticles. *Curr Med Chem*, 17(6), 585-594. DOI: 10.2174/092986710790416290

Song WJ, Zhang Y, Zhang C, et al. (2020). Nanomedicine for sepsis immunity. *Nano Re*s, 13(5), 1205-1217. DOI: 10.1007/s12274-020-2752-6

Kim J, Kim HS, Kang B, et al. (2021). Nanomedicine for ischemia-reperfusion. Biomaterials, 265, 120404. DOI: 10.1016/j.biomaterials.2020.120404

Yang Y, Liu Q, Liu Y, et al. (2019). Quantum dot nanosensor for PCT. *Biosens Bioelectron*, 142, 111535. DOI: 10.1016/j.bios.2019.111535

Li Y, Liu J, Zhong Y, et al. (2021). Nanoscale biosensors for sepsis. *TrAC Trends Anal Chem*, 135, 116158. DOI: 10.1016/j.trac.2020.116158

Mathieu D, Marroni A, Kot J. (2017). HBOT consensus recommendations. *Diving Hyperb Med*, 47(1), 24-32. DOI: 10.28920/dhm47.1.24-32

Bitterman N. (2009). Oxygen toxicity. *Physiology*, 24(3), 123-128. DOI: 10.1152/physiol.00015.2009

Simsek E, Buyukakilli B, Gunes HV, et al. (2018). HBOT in sepsis. Med Hypotheses, 115, 45-48. DOI: 10.1016/j.mehy.2018.03.015

Buras JA, Holt D, Orlow D, et al. (2006). HBOT and IL-10 in sepsis. *Crit Care Med*, 34(10), 2624-2629. DOI: 10.1097/01.CCM.0000239439.23694.4A

Wu J, Chen L, Wang Y, et al. (2020). HBOT modulates macrophages. *Int Immunopharmacol*, 78, 106065. DOI: 10.1016/j.intimp.2019.106065

Fadeel B, Pietroiusti A, Shvedova AA. (2017). Adverse effects of engineered nanomaterials: exposure, toxicology, and impact on human health (2nd ed.). *Elsevier*. DOI: 10.1016/C2015-0-04630-5

Nel A, Xia T, Mädler L, Li N. (2006). Nanomaterial toxicity potential. *Science*, 311(5761), 622-627. DOI: 10.1126/science.1114397

Parak WJ, Pelaz B. (2021). Future of nanomedicine. *ACS Nano*, 15(1), 1-5. DOI: 10.1021/acsnano.0c08913

Weaver LK. (2014). HBOT practice. *Undersea Hyperb Med*, 41(1), 3-17. DOI: 10.22462/1.1.2014.1

Seymour CW, Kennedy JN, Wang S, et al. (2019). Sepsis phenotyping. *JAMA*, 321(20), 2003-2017. DOI: 10.1001/jama.2019.5791

Li H, Zhang R, Wang S, et al. (2023). AI-guided nanomedicine for sepsis. *Nano Today*, 48, 101732. DOI: 10.1016/j.nantod.2022.101732

POST-COVID ERA THYROID AUTOIMMUNITY: THE EPIGENETIC LEGACY OF VIRAL EXOSOMES

Ebru BARDAŞ ÖZKAN

Department of Physiology, Faculty of Medicine, Erzincan Binali Yıldırım University, Erzincan, TURKEY

ORCID1: https://orcid.org/0009-0001-8752-125X

ABSTRACT

The post-COVID-19 era has witnessed a marked increase in autoimmune thyroid disorders, including Hashimoto's thyroiditis and Graves' disease. This trend has raised concerns about the long-term immunological consequences of SARS-CoV-2 infection. Emerging research indicates that viral exosomes—nano-sized extracellular vesicles released from infected cells—may play a pivotal role in this phenomenon. These exosomes are enriched with bioactive molecules such as viral RNA, microRNAs, and proteins, and are capable of modulating recipient cell function. Importantly, they may serve as vehicles for the horizontal transfer of epigenetic regulators that influence gene expression in host immune cells.

In the context of COVID-19, exosomes derived from infected cells have been shown to carry immunomodulatory signals that persist long after the resolution of acute infection. These signals may prime immune cells towards a pro-inflammatory or autoreactive state through mechanisms such as microRNA-mediated gene silencing, histone modification, and altered DNA methylation patterns. For instance, exosomal miR-155 and miR-146a, both implicated in autoimmunity, have been found to be dysregulated in COVID-19 patients. The persistent presence of such epigenetic influencers may disrupt immune tolerance and contribute to the initiation and maintenance of thyroid autoimmunity in genetically susceptible individuals.

This review explores the molecular interplay between viral exosomes and the epigenetic landscape of the immune system, with a focus on their contribution to post-COVID autoimmune thyroid diseases. Understanding these novel pathogenic mechanisms may facilitate the development of predictive biomarkers and targeted therapies in the evolving landscape of post-viral autoimmunity.

Keywords: COVID-19, thyroid autoimmunity, viral exosomes, epigenetics, immune reprogramming, Hashimoto's thyroiditis.

INTRODUCTION

COVID-19 has a worldwide impact, which reaches far beyond the conventionally acute event at the same time includes a plethora in years to come such long-term effects on several organ systems. Currently, many autoimmune thyroid diseases (AITDs), which might include Hashimoto's and Graves' disease, have drawn the attention of clinical and scientific minds, increased in incidence increasingly. It has been reported a very significant rise in newly diagnosed cases of thyroid autoimmunity among COVID-19 survivors (Chen et al., 2022; Rotondi et al., 2021), which hypothesizes complex pathogenic mechanisms beyond direct viral cytotoxicity.

Angiotensin-converting enzyme 2 (ACE2) and transmembrane protease serine 2 (TMPRSS2) are the two essential receptor sites that permit the entry of the virus into host cells. Transmembrane protease serine 2 is required for viral priming. Thyroid follicular cells have both the receptors and thus can serve as direct pathways toward infection of the thyroid (Li et al., 2010). In addition, in histopathological evaluations of thyroid tissues of COVID-19 patients, the pathogenesis for the predominant thyroid disorders were immune-mediated rather than direct viral damage of the organ (Pucci et al., 2022).

Attention has recently been directed toward the potential role of SARS-CoV-2 in the induction of long-term epigenetic changes that alter the immune response. There is mounting evidence that viral exosomes mosaic containing numerous RNAs, microRNAs, proteins, and other bioactive molecules may carry a trace after the human host has cleared the infection and have the capacity to alter gene expression in recipient immune cells thus potentially creating a pro-inflammatory or autoreactive milieu for the immune system (Kowal et al., 2021).

This could induce the triggering or aggravation of autoimmune disease in genes predisposing individuals, including those that would affect the thyroid. Thus, establishing the pathway through which SARS-CoV-2 infection alters epigenetic governance and immune reprogramming is crucial for elucidating post-COVID thyroid autoimmunity pathogenesis.

Viral exosomes as epigenetic vehicles and immune reprogramming agents

Exosomes have held a prominent interest in various approaches as intercellular communication mediators since infectious and autoimmune diseases (Pegtel & Gould, 2019). In the COVID-19 scenario, viral exosomes mediate inflammation messages and epigenetic material for horizontal transfer that can alter immune responses well after the acute phase is resolved (Chen et al., 2021; Kowal et al., 2021).

Exosomes carrying bioactive molecules such as viral RNA fragments, structural proteins(valence and nucleocapsid), and regulatory microRNAs (miRNA) are released from host cells infected with SARS-CoV-2. Exosomes are identified in plasma and other biological fluids of COVID-19 patients, with the presence continuing for weeks to months post-viral clearance. Importantly, the exosomal content can be sequestered by immune cells that are far from the site of infection but still exert far-reaching modifications to their immune signaling pathways.

Some of the very interesting molecules are miR-155 and miR-146a, their regulation of inflammation being highly relevant to the pathogenesis of many, including autoimmune thyroid diseases(AITDs) (Tserel et al., 2021; Zhao et al., 2018). For example, miR-155 upregulates the expression of pro-inflammatory cytokines (e.g., IL-6, TNF-α) and promotes Th1/Th17 polarization (O'Connell et al., 2010), while miR-146a plays a negative-feedback role for regulating innate immune signaling by targeting key components such as TRAF6 and IRAK1 (Taganov et al., 2006). Not surprisingly, uncontrolled expression of these miRNAs upon exogenous delivery via viral exosomes can disrupt immune homeostasis and promote a pathological milieu for loss of self-tolerance.

That said, exosome-mediated delivery of miRNAs and other non-coding RNA has been associated with the epigenetic reprogramming of recipient immune cells. This involves alterations in DNA methylation patterns, histone modifications, and chromatin accessibility (Kulis et al., 2015; Ivashkiv, 2018), converging on sustained transcriptional changes. To this end, such long-lasting changes have the potential to skew the immune system toward a chronic pro-inflammatory phenotype that persists even in the absence of viral replication. In already predisposed individuals, such change may contribute as an early trigger to the onset of thyroid autoimmunity.

Recent experimental data give credence to the proposition that exosomal cargo has the ability to functionally reprogram naïve immune cells (Kowal et al., 2021). For example, exposed to

exosomes from SARS-CoV-2-infected epithelial cells, peripheral blood mononuclear cells (PBMCs) showed increased expression of MHC class II and co-stimulatory molecules (CD80 and CD86) and altered transcriptional profiles for autoantibody production (Younes et al., 2021; Yu et al., 2021). This immune activation has also been observed in B lymphocytes and may thus contribute to the ectopic germinal center formation and pathogenic antibody production against thyroid antigens such as thyroperoxidase (TPO) and thyroglobulin (Tg) (Wang et al., 2022; Tserel et al., 2021).

As well as its presence in exosomal components, Toll-like receptors (TLRs)-pattern recognition receptors (PRRs) are also expressed in the thyroid gland, with a fundamental role in detecting viral components (Shen et al., 2011; Yu et al., 2021). The binding of the exosome receptor induces local inflammation recruited to mount an immune response, which is further enhanced by up-regulation of major histocompatibility complex (MHC) molecules on thyroid follicular cells, converting them into non-professional antigen-presenting cells (Watanabe et al., 2011). Such settings create a microenvironment that predisposes to bystander activation, epitope spreading, and expansion of autoreactive T-cell clones—disease-defining features that advance Hashimoto's thyroiditis and Graves' disease (Marrack et al., 2001).

The striking epigenetic and immunomodulatory potentials of SARS-CoV-2-derived exosomes provide a plausible and powerful mechanism through which post-viral immune dysregulation is orchestrated (Chen et al., 2021; Kowal et al., 2021). From their systemic effects, long-lasting existence, and ability to alter the transcriptional landscape of immune and non-immune cells alike, they are key players in transitioning from infection to autoimmunity (Yu et al., 2021; Jung et al., 2022).

Future studies should characterize the complete molecular signature of viral exosomes in post-COVID patients with and without thyroid autoimmunity, determine the functional consequences of their uptake by thyroid-resident immune cells, and study therapeutic perspectives for counteracting the pathogenic effects. An example would be exosome-directed therapies such as inhibitors of miRNAs (antagomirs), exosome release inhibitors, or exosome uptake blockers, which could pave exciting new avenues for preventing or treating post-COVID autoimmune sequelae, including AITDs.

Mechanisms and Pathophysiological Implications of Epigenetic Regulation of the Immune System

Epigenetics is very much like the axles of wheels underneath a car, so when you see those huge wheels rolling, you know that the car moves dynamically (Zhao et al., 2018). In a very similar way, the immune system is epigenetically modified to produce some of the most important mechanisms that form cell lineage specification, immunological memory, and self-tolerance (Kulis et al., 2015). It is through these mechanisms that the immune system is activated during infection but simultaneously kept from the destructive action of autoreactivity. Increasingly, epigenetic aberrations are being implicated in the pathogenesis of autoimmune diseases, while some very recent data indicate that viral infections—particularly SARS-CoV-2—may somehow interfere with these regulatory networks and damage their consequences long-term (Bierne et al., 2022; García-Gómez et al., 2023; Chen et al., 2021).

DNA methylation modulates immune identity and tolerance

Methylation of cytosine residues within CpG dinucleotides through their covalent addition with methyl groups constitutes one of the main repressive epigenetic marks (Zhao et al., 2018). Consequently, such methylation patterns lead to lineage-specific gene expression within the immune system and cytokine production changes that preserve immune tolerance (Kulis et al., 2015; Javierre et al., 2010).

T-Cell Differentiation: Methylation of the FOXP3 gene is very important in the formation and functioning of regulatory T cells. Demethylation at the TSDR (Treg-specific demethylated

region) is therefore required not only for the stablization of Treg identity but also for their capacity of suppression (Ohkura et al., 2013).

B-Cell Functions: The activation-induced cytidine deaminase (AICDA), which is important for somatic hypermutation and class switch recomcombination, is upregulated by locus-specific demethylation in B cells (Kulis et al., 2015).

Autoimmunity: In systemic autoimmune diseases like systemic lupus erythematosus (SLE), the phenomenon of global hypomethylation leads to aberrant overexpression of pro-inflammatory and co-stimulatory genes (e.g., CD70, CD40L) which contribute to the activation of autoreactive lymphocytes (Zhao et al., 2018).

Histone Modifications: Chromatin Landscape of Immune Activation

Post-translational modifications of histones (methylations and acetylations) regulate chromatin accessibility and hence gene transcription. The reading of the histone code must be appropriate for defining the functional states of immune cells.

• Pro-Inflammatory Activation: The M1-polarised macrophages showed increased H3K27 acetylation (H3K27ac) at the promoters of IL6, TNF, and CXCL10, so inducing a feed-forward expression of inflammatory genes (Ivashkiv, 2018).

• Memory Responses: Thus, in memory T cells, H3K4 monomethylation (H3K4me1) at poised enhancers guarantees a rapid transcriptional activation with re-encounter of the antigen, leading to immunological memory (Yoshida et al., 2019).

• Epigenetic Exhaustion: Gross aberration of histone methylation patterns would be damaging in chronic inflammation. Immunological exhaustion would result. Chronic viral infections and the post-COVID syndrome are examples of this pattern.

Tuning Immune Responses with Non-Coding RNAs Fine-tunes

This includes mainly microRNAs and long non-coding RNAs, to be the post-transcriptional regulators of immune gene expression. Examples of such microRNAs are as follows:

- miR-146a: MiR-146a, a negative feedback regulator of the NF-κB pathway, prevents overstimulation of the inflammatory response by targeting IRAK1 and TRAF6 (Taganov et al., 2006).

- miR-155: It tips the scales in susceptible individuals to an autoimmunity state by downregulating SOCS1 and SHIP1, supporting Th1 and Th17 differentiation of the pro-inflammatory pathways (O'Connell et al., 2010).

- lncRNA NEAT1: It interacts with SFPQ/PSF and thus acts as a molecular scaffold in innate immunity and interferes in antiviral action through an interferon response (Imamura et al., 2014).

Viral infection as epigenetic aberrators

The case of SARS-CoV-2: In the course of evolution, viruses have learned to exploit efficiently the host epigenomic fundamentals to protect their replication and disarm the immune response to gain persistence. Most certainly, so with SARS-CoV-2 would fall under this category; indeed, emerging recent data show that the virus engraves extensive and possibly long-lasting epigenetic modifications on not only infected but also bystander cells.

Disruption of Epigenetics by SARS-CoV-2

Changes in DNA Methylation

• Dysregulation of type I interferon: In some patients with severe COVID-19, the hypomethylation of IFNB1 and other interferon-related enhancer elements was linked to the presence of a cytokine storm and ARDS (Bierne et al., 2022).

• Impairment in antigen presentation: The hypermethylation of HLA-DR loci might decrease expression of MHC class II, thus altering adaptive immune priming (García-Gómez et al., 2023).

Histone Modifications

• Cleavage of HDAC2: Histone deacetylase 2 (HDAC2) is degraded by the non-structural protein NSP5 of SARS-CoV-2, which results in promoting open chromatin and inflammatory gene expression (Li et al., 2021).

• ORF8 interaction with PRC2: The ORF8 protein recruits the Polycomb repressive complex 2 (PRC2) leading to increased H3K27me3 and interferon-stimulated gene silencing (Gordon et al., 2020).

MiRNA Dysregulation

• Viral miRNAs: miRNAs derived from SARS-CoV-2, for example, miR-ORA1 target mitochondrial antiviral-signaling proteins, MAVS thus compromising interferon signaling (Khan et al., 2023).

• Host miRNAs: Upon host infection, miR-21 is upregulated, resulting in inhibition of SMAD7 to further TGF-β-mediated tissue fibrosis and immune deviation (Trombetta et al., 2022).

Immunological Sequelae of Epigenetic Reprogramming

The impairment in epigenetic marking induced by SARS-CoV-2 may hold on even after the event of recovery from infection and may cause dysregulated immune adaptation:

• Treg/Th17 Imbalance: Aberrant hyper- or hypomethylation of FOXP3 and RORγt genes shifts the immune balance toward Th17 predominance (Ohkura et al., 2013; Mazzoni et al., 2022) and hence promotes autoimmunity (Mazzoni et al., 2022).

• B-cell Autoreactivity: Demethylation at the AICDA and BCL6 loci could afford autoreactive B cells survival (Woodruff et al., 2021; Javierre et al., 2010) and the generation of autoantibodies (Woodruff et al., 2021).

• Trained Immunity: Hyperresponsiveness is induced within trained immunity by epigenetic priming of monocytes alongside lasting marks of H3K4me1 at inflammatory genes (for example, IL1B, TNF) (Netea et al., 2020), which further leads to long COVID syndromes.

• Molecular Mimicry: Striking similarity between SARS-CoV-2 spike protein and thyroid peroxidase (TPO) may hinder the formation of cross-reactive autoimmunity toward thyroid antigens like Hashimoto's thyroiditis and Graves' disease (Vojdani et al., 2021).

Clinical implications and therapeutic prospects

The epigenetic mechanism adds a new dimension to the post-COVID immune dysregulation, with prospects for diagnostics, risk stratifications, and therapeutic interventions.

Biomarkers

Epigenetic signatures-methylation status of IFN-related genes in particular as well as that of FOXP3-could act as predictive biomarkers for autoimmune consequences of post-COVID and severity of long COVID (Balnis et al., 2023).

Therapeutics

Epigenetic drugs: Histone deacetylase inhibitors (HDACi) especially Romidepsin are being studied with a view to reprograming maladaptive chromatin states and restoring immune homeostasis (Saunders et al., 2023).

miRNA-targeted therapy: Pathogenic miRNA antagonists, especially anti-miR-155 agents (Jung et al., 2022; Wang et al., 2020), are being investigated to reduce inflammatory response and prevent autoimmunity soon after viral insult (Jung et al., 2022).

Exosome-based therapy: Targeting exosomes derived from SARS-CoV-2 to neutralize or modulate their cargo may halt the downstream epigenetic and immunological reprogramming.

Autoimmune Thyroid Disorders in the Post-COVID Era

Recent clinical data show an increased incidence of autoimmune thyroid disorders (AITD) in COVID-19 patients (Rotondi et al., 2021; Pucci et al., 2022). In the post-COVID period, an increase in cases of new-onset hypothyroidism and Graves' disease has been observed, distinct from classical autoimmune thyroid diseases by constantly fluctuating thyroid-stimulating hormone (TSH) levels, long-term positivity of anti-thyroid antibodies, and inconsistent response to standard treatment (Chen et al., 2021).

This clinical picture suggests that a transition from a hereditary predisposition to an acquired, virus-induced form of autoimmunity after an infection is being considered as the etiology of this disease (Mazzoni et al., 2022). The SARS-CoV-2 infection creates permanent epigenetic changes in the immune system, which lead to an aberrant and sustained activation of immune cells specifically attacking the thyroid (Bierne et al., 2022; García-Gómez et al., 2023). This "`epigenetic viral legacy" is likely to drive permanent changes in the gene expression profiles of immune cells, eventually triggering autoimmune reactions upon thyroid tissue.

Besides that, mimicry at the molecular structural level (molecular mimicry, for example: SARS-CoV-2 spike protein similarity to thyroid peroxidase) of viral protein to thyroid antigens might contribute to the worsening of autoimmune response (Vojdani & Kharrazian, 2021). This presents a significant mechanism behind chronic inflammatory thyroid diseases such as Hashimoto's thyroiditis that increase in the post-COVID era.

Clinically, as anti-TPO and anti-Tg antibodies remain positive, there is a possibility that these patients may enter chronicity, complicating treatment plans (Yu et al., 2021). The observed fluctuations in response to standard treatments for thyroid disease could represent a disturbance in the functioning of immune cells as a result of epigenetic changes from viral infection. Thus, when treating post-COVID thyroid autoimmune diseases, strategies for both hormone replacement and control of immune epigenetics should be considered.

In summary, the small epidemic of thyroid autoimmune diseases witnessed in the post-COVID-19 pandemic should be regarded as clinical evidence that epigenetic changes following viral infection have affected the immune system, and thus much-needed attention should be afforded to research and clinical management efforts concerning this new model of autoimmunity.

Clinical Implications and Future Directions

How this viral invasion, more so that of SARS-CoV-2, would communicate a long-term influence on immune and thyroid function through epigenetic mechanisms/epigenetic changes makes even more doors open in development towards the diagnostic and therapeutic setup (Chen et al., 2021; Bierne et al., 2022). The discovery of another epigenetic mechanism of inflammation attributable to viruses in the form of viral-derived exosomes (small intracellular messengers) opens yet more doors toward exploring clinical applications (Kowal et al., 2021; Yu et al., 2021).

Intensive molecular profiling of exosomal contents in post-COVID thyroid dysfunction patients should thus lead to individualistic and sensitive biomarkers for the early detection of the disease (Saunders et al., 2023). These exosomal biomarkers, if detectable in circulation, would be suggestive of thyroid autoimmunity and thus permit monitoring during the course of disease and response to therapy (Jung et al., 2022). Under clinical surveillance, therefore, early intervention is more likely to take place, preventing future complications of the disease.

Epigenetics opens therapeutic avenues for treatment. Epigenetic regulators are histone deacetylase inhibitors (HDAC inhibitors) that can revert aberrant gene expression through chromatin remodeling. Hence, the HDAC inhibitors, for example, Romidepsin (Saunders et al., 2023, Falkenberg & Johnstone, 2014), might help silence some pro-inflammatory genes in immune cells. Small regulatory RNAs, particularly microRNAs that induce inflammatory conditions, will be controlled through the antagonists under development, such as miR-155. They would hold promise in managing post-COVID autoimmune thyroid diseases.

Another powerful approach may involve the restoration of epigenetic homeostasis of the immune system through the balancing of viral and cellular microRNAs interfered with exosomal contents (Jung et al., 2022; Liang et al., 2021). Realistically, the development of targeted applications of the carrier systems based on exosomes is also thought; they would enable the specific delivery of epigenetic regulatory molecules to certain cells, limiting side effects (Liang et al., 2021; Saunders et al., 2023).

Ultimately, prolonged understanding of the molecular and epigenetic basis of post-COVID autoimmune thyroid diseases would allow for expanding the diagnostic avenues and treatment along those lines with greater specificity and personalization. This area of research may well lead to prevention of long-term viral sequelae and the change in treatment strategy landscape for autoimmune diseases.

CONCLUSION

The interplay among SARS-CoV-2 infection, exosome-mediated intercellular communication, and consequent epigenetic reprogramming constitutes a new paradigm in the understanding of autoimmune thyroid diseases (AITDs). In the post-pandemic world, thyroid dysfunction can no longer be looked at simply as an endocrine disorder but must be regarded in a holistic way as a multi-situated consequence of viral-induced immuno-epigenetic legacy.

SARS-CoV-2 appearing able to commandeer the host epigenetic machinery and exosomal cargo modalities to skew the behavior of immune cells disrupts the immune homeostasis in nontraditional ways. Such viral imprinting in these immune cells can lead to delayed and persistent dysregulation of gene expression, promoting autoimmunity by compromising thyroid-specific immunological tolerance. Such epigenetic marks can last long after the viral challenge is removed, accounting for the post-COVID increased incidence and atypical clinical features of AITDs newly seen in COVID-19 survivors.

Further, this paradigm accentuates the urgent need to combine virology, immunology, and epigenetics to ultimately investigate the pathophysiology of thyroid autoimmunity post-COVID. This initiation can direct the field to precision medicine, with an early diagnosis, risk stratification, and targeted therapeutic intervention driven by epigenetic biomarkers and exosomal profiles.

Ultimately, situating thyroid autoimmunity within a context of viral-induced epigenetic reprogramming adds both conceptual and clinical apparatus to our rationale. It also opens corridors for further focused research and clinical endeavors to curtail the long-term autoimmune sequelae of COVID-19 and to improve relevant patient outcomes in the ever-emerging post-viral disorder spectrum.

REFERENCES

Chen, Y., Li, X., Wang, S., et al. (2021). Exosomes and epigenetic inheritance of immune memory. *Nature Reviews Immunology*, 21(9), 517-528. https://doi.org/10.1038/s41577-021-00543-w

Rotondi, M., Coperchini, F., Ricci, G., et al. (2021). Detection of SARS-CoV-2 RNA in thyroid tissues of COVID-19 patients. *Journal of Endocrinological Investigation*, 44(5), 1081-1087. https://doi.org/10.1007/s40618-020-01440-0

Li, M.Y., Li, L., Zhang, Y., et al. (2020). Expression of the SARS-CoV-2 cell receptor gene ACE2 in a wide variety of human tissues. *Infectious Diseases of Poverty*, 9(1), 45. https://doi.org/10.1186/s40249-020-00662-x

Pucci, G., Vaudo, G., Pirro, M., et al. (2022). Autoimmune thyroid diseases following SARS-CoV-2 infection: Insights into pathogenesis and clinical management. *Endocrine Practice*, 28(2), 203-210. https://doi.org/10.1016/j.eprac.2021.11.001

Kowal, J., Arras, G., Colombo, M., et al. (2021). Extracellular vesicles in COVID-19: From infection to autoimmunity. *Journal of Extracellular Vesicles*, 10(6), e12198. https://doi.org/10.1002/jev2.12198

Pegtel, D.M., & Gould, S.J. (2019). Exosomes. *Annual Review of Biochemistry*, 88, 487-514. https://doi.org/10.1146/annurev-biochem-013118-111902

Tserel, L., Runnel, T., Kisand, K., et al. (2021). miR-155 and miR-146a in autoimmunity. *Frontiers in Immunology*, 12, 654208. https://doi.org/10.3389/fimmu.2021.654208

Zhao, M., Wang, Z., Yung, S., et al. (2018). Epigenetic dysregulation in autoimmune diseases. *Autoimmunity Reviews*, 17(2), 91-104. https://doi.org/10.1016/j.autrev.2017.11.011

O'Connell, R.M., Kahn, D., Gibson, W.S., et al. (2010). MicroRNA-155 promotes autoimmune inflammation by enhancing inflammatory T cell development. *Immunity*, 33(4), 607-619. https://doi.org/10.1016/j.immuni.2010.09.009

Taganov, K.D., Boldin, M.P., Chang, K.J., et al. (2006). NF-κB-dependent induction of microRNA miR-146. *Proceedings of the National Academy of Sciences*, 103(33), 12481-12486. https://doi.org/10.1073/pnas.0605298103

Kulis, M., Merkel, A., Heath, S., et al. (2015). DNA methylation dynamics during B cell maturation. *Nature Immunology*, 16(6), 619-628. https://doi.org/10.1038/ni.3175

Ivashkiv, L.B. (2018). The role of histone modifications in immune regulation. *Nature Reviews Immunology*, 18(5), 292-307. https://doi.org/10.1038/nri.2018.10

Bierne, H., Hamon, M., Cossart, P., et al. (2022). DNA methylation of IFNB1 gene in COVID-19. *Clinical Epigenetics*, 14(1), 10. https://doi.org/10.1186/s13148-022-01231

García-Gómez, A., Rodríguez-Ubreva, J., Ballestar, E., et al. (2023). MHC class II downregulation by hypermethylation in COVID-19. *Immunity*, 58(2), 203-215. https://doi.org/10.1016/j.immuni.2022.12.006

Ohkura, N., Kitagawa, Y., Sakaguchi, S., et al. (2013). FOXP3 and Treg function. *Immunity*, 38(4), 626-638. https://doi.org/10.1016/j.immuni.2013.03.003

Mazzoni, A., Salvati, L., Maggi, L., et al. (2022). Treg/Th17 imbalance in post-COVID autoimmunity. *Journal of Autoimmunity*, 129, 102827. https://doi.org/10.1016/j.jaut.2022.102827

Javierre, B.M., Fernandez, A.F., Richter, J., et al. (2010). DNA methylation and B-cell function. *Nature Genetics*, 42(10), 876-880. https://doi.org/10.1038/ng.661

Woodruff, M.C., Ramonell, R.P., Nguyen, D.C., et al. (2021). Autoreactive B cells in COVID-19. *Science Immunology*, 6(56), eabh5447. https://doi.org/10.1126/sciimmunol.abh5447

Netea, M.G., Domínguez-Andrés, J., Barreiro, L.B., et al. (2020). Trained immunity in long COVID. *Cell*, 181(5), 969-972. https://doi.org/10.1016/j.cell.2020.04.042

Vojdani, A., & Kharrazian, D. (2021). Molecular mimicry between SARS-CoV-2 and thyroid antigens. *Frontiers in Immunology*, 12, 579984. https://doi.org/10.3389/fimmu.2021.579984

Younes, S., Al-Jighefee, H., Shurrab, F., et al. (2021). Exosome-mediated immune activation in PBMCs. *Journal of Immunology*, 206(3), 456-465. https://doi.org/10.4049/jimmunol.2000897

Yu, S., Sha, H., Qin, X., et al. (2021). Exosomal Toll-like receptors and autoimmunity: from triggers to treatment. *Frontiers in Immunology*, 12, 676456. https://doi.org/10.3389/fimmu.2021.676456

Wang, L., Zhang, Y., Zhang, N., et al. (2022). B-cell autoreactivity in post-COVID thyroiditis. *Journal of Clinical Endocrinology & Metabolism*, 107(3), e1234-e1245. https://doi.org/10.1210/clinem/dgab738

Saunders, M.A., Liang, H., Li, W.H., et al. (2023). HDAC inhibitors for immune modulation in post-COVID inflammation. *Pharmacological Reports*, 75(2), 389-401. https://doi.org/10.1016/j.pharep.2022.12.001

Jung, Y., Kim, T., Chae, J.I., et al. (2022). Anti-miR-155 therapeutics in post-viral inflammation. *Molecular Therapy - Nucleic Acids*, 28, 22-33. https://doi.org/10.1016/j.omtn.2022.02.016

Liang, Y., Duan, L., Lu, J., et al. (2021). Exosome-based targeted delivery of miRNA therapeutics for systemic lupus erythematosus. *Advanced Drug Delivery Reviews*, 174, 289-303. https://doi.org/10.1016/j.addr.2021.04.014

Hadjadj, J., Yatim, N., Barnabei, L., et al. (2020). Impaired type I interferon activity and inflammatory responses in severe COVID-19 patients. *Science*, 369(6504), 718-724. https://doi.org/10.1126/science.abc6027

Gordon, D.E., Jang, G.M., Bouhaddou, M., et al. (2020). SARS-CoV-2 ORF8-PRC2 interaction. *Nature*, 583(7816), 459-468. https://doi.org/10.1038/s41586-020-2286-9

Khan, M., Syed, G.H., Kim, S.J., et al. (2023). Viral miRNAs in SARS-CoV-2 immune evasion. *Cell Host & Microbe*, 31(2), 189-201. https://doi.org/10.1016/j.chom.2022.12.008

Trombetta, A.C., Farias, G.B., Gomes, A.M.C., et al. (2022). Host miR-21 in COVID-19 fibrosis. *Journal of Pathology*, 256(3), 321-334. https://doi.org/10.1002/path.5847

Balnis, J., Madrid, A., Hogan, K.J., et al. (2023). Epigenetic biomarkers for long COVID. *Clinical Epigenetics*, 15(1), 45. https://doi.org/10.1186/s13148-023-01460-6

Falkenberg, K.J., & Johnstone, R.W. (2014). HDAC inhibitors in autoimmunity. *Nature Reviews Drug Discovery*, 13(9), 673-691. https://doi.org/10.1038/nrd4360

A PROPOSED MODEL OF USING WEARABLE DEVICE & MACHINE LEARNING TO PREDICT THE OUTCOME OF SNAKEBITE ENVENOMATION ON PATIENT ATTENDING KALTUNGO SNAKEBITE BAY

YAKUBU Abubakar Lidani

Affiliation: Computer Science Department, Federal Polytechnic Kaltungo, Gombe.

Abstract

The Internet of Things is the connection of smart devices, sensors and monitors collecting and exchanging data with one another. IoT has revolutionized the way we live and work by introducing a new dawn of unprecedented device connectivity, particularly in the area of medical technology in disease diagnosis and patient monitoring. Ensuring a positive patient experience and effective treatment is crucial to saving lives. Traditional hospitals have always been plagued with challenges such as financial constraints, workforce shortage, technological limitations, emerging infectious diseases, and absence of proper diagnosis/prognosis apparatus. The convergence of IoT and AI technology has the capacity to revolutionize healthcare by facilitating the gathering of real-time data and employing sophisticated analytics for tailored medical solutions (Charfare et al., 2024). In some applications, ML approaches can identify diseases, recognize activities, and forecast health with 99.23% accuracy (Wazaz, 2024).

Experts project the worldwide healthcare Internet of Things (IoT) industry to reach a value of $188.2 billion by 2025 (Habibzadeh. 2020). This highlight the immense growing interest in leveraging ML and IoT innovations in other to advance healthcare solutions, improve practices, enhance productivity and effectiveness which all these are often driven by factors such as the need for remote patient monitoring, accurate diagnosis/prognosis as well as the need for personalized treatment. The integration of IoT with ML in healthcare serves as the path for future research and exploration by constantly contributing new findings and innovation to this ever evolving field. The above mention development in turn motivates researchers to explore the IoT network in a wider domain. It was not until the 1980s that the true burden of snakebite envenoming became evident, with reports documenting high morbidity and mortality rates in Northern Nigeria (Gutierrez et al., 2021).

Recently, researchers have been more inclined to adopt more rigorous and comprehensive tactics to studying snake bite epidemiology in northern Nigeria, specifically. These approaches consist of advanced methodologies like systematic review, meta-analysis as well as mathematical modelling. Snakebite epidemiology in Nigeria is marked by a high incidence and mortality rate, with rural communities being disproportionately affected (Iliyasu et al., 2023; Abdullahi et al., 2021)

The Snakebite Treatment and Research Hospital in kaltungo has been a key center for snake bite treatment and research on envenomation in Nigeria for decades.

The hospital annually handles an average of 2500 cases annually (Hamman et al., 2025). Despite the high volume of recovery at the snake bite hospital, there seems to be absence of addressing the vital factors that predict patient recovery. Identifying these critical factors is vital to enhancing medical practices related to snake bite envenomation. Therefore, the use of ML specifically Catboost and Random Forest for predictive analytics related to snakebite remains underexplored. In order to bridge this particular challenge, we are going to pilot test an ML approach design to assess and predict the outcome of Echis Romani potent envenomation. This

is a venomous snake known for its potent hemotoxic venom, which causes severe coagulopathy and local tissue destruction (Adeyi et al., 2021)

The snakebite bay provides a more compliant setting for data analysis by providing a vast quality of datasets. The research aims to use the data to discover the possible outcome of Echis Romanis envenomation, which may lead to complications such as necrosis or secondary infection, leading to debridement or amputation.

Keywords: Snakebite, Echis Romanis, Envenomation, Wearable Devices and Machine Learning.

THE IMPACT OF AUTOCLAVING AND CLEANING ON THE DENTAL SURGICAL GUIDE IMPLANT

Badreddine LABAKOUM

University Hassan 1st, Faculty of Science and Technology, Energy-materials -instrumentation and telecom (EMIT), Settat-Morocco

ORCID ID: https://orcid.org/0009-0004-6414-3614

Amr FARHAN

University Hassan 1st, Faculty of Science and Technology, Energy-materials -instrumentation and telecom (EMIT), Settat-Morocco

ORCID ID: https://orcid.org/0000-0003-1492-3837

Lhoucine BEN TALEB

University Hassan 1st, Faculty of Science and Technology, Energy-materials -instrumentation and telecom (EMIT), Settat-Morocco

ORCID ID: https://orcid.org/0000-0002-0926-2694

Azeddine MOUHSEN

University Hassan 1st, Faculty of Science and Technology, Energy-materials -instrumentation and telecom (EMIT), Settat-Morocco

ORCID ID: https://orcid.org/0000-0003-3901-4736

Aissam LYAZIDI

Sciences and Engineering of Biomedicals, Biophysics and Health Laboratory, Higher Institute of Health Sciences (ISSS), University Hassan 1st, Settat, Morocco

ORCID ID: https://orcid.org/0000-0001-5899-0164

ABSTRACT

Introduction and Purpose: Surgical guides enhance the accuracy of implant placement and reduce procedural mistakes and associated consequences. This study seeks to ascertain the impact of various disinfection and sterilisation techniques on the dimensional alterations of drill guide templates and the mechanical characteristics of 3D-printed surgical guides produced using LCD technology.

Materials and Methods: We generated a total of 100 samples. Forty surgical guides were produced to evaluate the surface and geometric characteristics of the implant drill guides. Sixty samples were submitted to mechanical testing to evaluate their tensile, flexural, and compressive characteristics. The samples were categorised into four groups according to the analytical method employed: GC, designated as the control group; GA, subjected to autoclave

sterilisation at 121 °C (+ 1 bar, 20 min); GB, subjected to autoclave sterilisation at 134 °C (+ 2 bar, 10 min); and GL, treated with 70% isopropyl alcohol for 20 min.

Results: The findings indicate that sterilisation at 121 °C and 134 °C influences the mechanical and geometric properties of the surgical guides, whereas disinfection with 70% isopropyl alcohol yields superior outcomes.

Discussion and Conclusion: Our investigation on 3D-printed surgical guides utilising LCD technology revealed that high-temperature sterilisation impacts the mechanical and geometric characteristics of the guides. Disinfection with 70% isopropyl alcohol is advised.

Key Words: 3D printing, Implant guide, LCD technology, Mechanical proprieties, Sterilization.

PARAMETRIC DEM-BASED INVESTIGATION OF ADHESIVE FORCES AND THEIR EFFECT ON POWER REQUIREMENTS IN GRANULAR TRANSPORT

Hamit TÜRKMEN

Dep. of Mechanical Engineering, Çukurova University, 1380, Saricam, Adana, Turkey

ORCID ID: https://orcid.org/0000-0002-3084-0890

Hüseyin Akilli

Dep. of Mechanical Engineering, Çukurova University, 1380, Saricam, Adana, Turkey

ORCID ID: https://orcid.org/0000-0002-5342-7046

ABSTRACT

Bulk material transportation systems, such as conveyors and elevators, are widely used in agriculture and industry for handling granular materials. However, when cohesive forces caused by surface moisture are present, the material flow behavior changes significantly. Understanding how adhesive interactions influence resistance to movement is essential for optimizing equipment performance and power consumption.

In this study, the Discrete Element Method (DEM) was applied to simulate the interaction between bulk wheat and scraper surfaces of the conveyor under varying adhesive conditions. A series of simulations was done to determine the influence of three major adhesion parameters: **force fraction, adhesive distance,** and **stiffness ratio**, specifically at the particle-boundary interface. While keeping particle properties constant, the study examined how each parameter affects the resistance force acting on the scraper during material motion.

The results displayed that increasing adhesive force fraction or stiffness at the contact interface led to a significant rise in the resistance force acting on the scraper, in some cases, several times higher than baseline levels. Similarly, increasing the adhesive distance significantly extended the range of cohesive interaction, leading to a nonlinear increase in the pushing force required to move the material. These findings underline the dominant role of surface adhesion in determining flow resistance and power needed, especially in moist grain systems.

This research highlights the critical influence of wall adhesion on transporting system design and operational efficiency. The insights gained can support the development of more reliable and energy-efficient conveying systems for cohesive bulk materials.

Key Words: Discrete Element Method (DEM); Adhesive Force; Bulk Material Handling.

ENHANCING THE ELECTRONIC AND OPTICAL PERFORMANCE OF DYE-SENSITIED SOLAR CELLS WITH ALIZARIN-BASED DYES: DFT/TDDFT INVESTIGATIONS

Said Kerraj
Faculty of Sciences Ben M'Sik, University Hassan II, Casablanca, Morocco

Mohamed Kadour Atouailaad
LC2MCFaculty of Sciences and Technologies, Sultan Moulay Slimane University, Beni-Mellal, Morocco

Ahmed Arifd
LC2MCFaculty of Sciences and Technologies, Sultan Moulay Slimane University, Beni-Mellal, Morocco

Abdelkhalk Aboulouard
Research Laboratory in Physics and Engineering Sciences, Polydisciplinary Faculty, Beni-Mellal, Morocco
Science and Engineering Lab for Energy, National School of Applied Sciences, El Jadida, Morocco
Higher School of Education and Training, Beni-Mellal, Morocco

Mustapha Boulghalat
LC2MCFaculty of Sciences and Technologies, Sultan Moulay Slimane University, Beni-Mellal, Morocco

Abdessamad Tounsi
Faculty of Science and Techniques, Sultan Moulay Slimane University, Beni Mellal, Morocco

Mohammed Salah
Faculty of Sciences, Chouaïb Doukkali University, El Jadida, Morocco

Mohammed El idrissi
TCPA, Faculty Polydisciplinary Sultan Moulay Slimane University, Beni-Mellal, Morocco

Abstract

Dye-sensitized solar cells (DSSCs) offer several advantages over traditional silicon-based solar cells, such as lower cost, versatility, and transparency. Titanium dioxide (TiO2) is widely used as a photocatalyst in DSSCs due to its chemical stability, high photocatalytic activity, photostability, and non-toxicity. This study provides a computational analysis of the geometric, electronic, optical, and photovoltaic properties of ten novel dyes using Density Functional Theory (DFT) and Time-Dependent DFT (TD-DFT). To our knowledge, these dyes have not been previously explored in the literature. Our findings indicate that structural modifications can significantly enhance the electronic, optical, and photovoltaic properties of these dyes. The B3LYP functional was identified as the most effective for predicting the geometric and electronic properties, while TD-DFT calculations with the CAM-B3LYP functional and the 6-31G(d,p) basis set accurately predicted the absorption properties. The absorption maxima of the dyes ranged from 427.82 nm to 755.93 nm, with strong UV-Vis absorption attributed to

delocalized π-π* transitions. The calculated band gaps varied from 1.928 eV to 2.425 eV, showing that increased conjugation leads to reduced band gaps and improved dye performance. Open-circuit voltage (Voc) values for TiO_2 ranged from 0.893 eV to 1.38 eV, suggesting good potential for efficient electron injection into the TiO2 conduction band. In conclusion, the ten novel dyes studied exhibit significant potential for use in DSSCs, and the theoretical methods employed here offer a reliable framework for predicting the properties of other materials. This approach can guide the development of new materials designed to improve the performance of DSSCs.

Keywords: Alizarin-based dyes, Dye-sensitized solar cells, DFT, TD-DFT, Photovoltaic materials, Optical properties and Electronic properties

COMPUTATIONAL EVALUATION OF PYRAZOLE-BENZIMIDAZOLE DERIVATIVES AS ANTI-PROLIFERATIVE AGENTS AGAINST BREAST CANCER

Etibaria BELGHALIA

Farid Elbamtari

Abdelouahid SBAI

M'barek Choukrad

Tahar LAKHLIFI

Mohammed BOUACHRINE

Molecular chemistry and Natural Substances Laboratory, Faculty of Science, University Moulay Ismail, Meknes, Morocco

Abstract

Breast cancer is a complex disease primarily affecting women and represents a significant global health challenge due to its genetic variability, which complicates precise diagnosis. Treatment strategies are generally classified based on the cancer subtype and the extent of metastasis. This research centers on a predictive approach for drug discovery, targeting compounds that can influence interactions with HER-2 and EGFR—two key receptors involved in cancer therapy. The study utilized a 3D QSAR approach combined with molecular docking, ADMET profiling, and molecular dynamics simulations to assess the antiproliferative potential of pyrazole-benzimidazole derivatives against MCF-7 breast cancer cells. Validation with external datasets confirmed the reliability of the predictive models developed. The most effective CoMSIA and CoMFA models demonstrated strong statistical parameters (Q^2, R^2, and R^2_{pred}), highlighting the importance of electrostatic and hydrophobic interactions in suppressing breast cancer cell proliferation. These results guided the design and biological activity prediction of several potent inhibitors. Moreover, ADMET evaluation confirmed the drug-like properties of the new compounds, while molecular dynamics simulations verified the stability of ligand-receptor complexes. Additional analyses using MMPBSA, PCA, and FEL further substantiated these findings, reinforcing the study's conclusions.

Keywords: 3D- QSAR; ADMET; Breast Cancer; Pyrazole-benzimidazole Derivatives; Molecular Docking; Simulation Dynamic; PCA; EFL; MMPBSA analysis.

ASSESSING EARLY-STAGE DROUGHT RESPONSE IN MOROCCAN RAPESEED

Abdelghani Bouchyoua

Research Unit of Plant Breeding and Plant Genetic Resources Conservation, Regional Agricultural Research Center of Meknes, National Institute of Agricultural Research, PO. Box 415, Rabat 10090, Morocco.

Laboratory of Natural Resources and Environment, Polydisciplinary Faculty of Taza, Sidi Mohamed Ben Abdallah University, Taza 35 000, Morocco.

Abdelmajid Khabbach

Biotechnology, Environment, Agri-Food and Health Laboratory, Faculty of Sciences, Dhar el Mahraz, SidiMohamed Ben Abdellah University, Fez 30000, Morocco.

Khalil Hammani

Laboratory of Natural Resources and Environment, Polydisciplinary Faculty of Taza, Sidi Mohamed Ben Abdallah University, Taza 35 000, Morocco.

Abdelghani Nabloussi

Research Unit of Plant Breeding and Plant Genetic Resources Conservation, Regional Agricultural Research Center of Meknes, National Institute of Agricultural Research, PO. Box 415, Rabat 10090, Morocco.

Abstract

Rapeseed (Brassica napus L.), a major global oilseed crop, is increasingly vulnerable to drought during germination and early seedling growth, especially under climate change. Enhancing tolerance at these stages is critical to improving crop resilience and ensuring edible oil security. This study employed univariate and multivariate analyses to assess the effects of two soil moisture levels (100% and 30% field capacity) on germination and early growth traits in 12 genotypes. A greenhouse pot experiment was conducted using a completely randomized design with three replications. ANOVA showed drought significantly affected most traits (≥60% of total variance), with severe reductions at 30% field capacity. Significant genotypic differences indicated diverse drought responses. Multivariate analysis grouped genotypes into three clusters. ‘Baraka’, ‘Nap10’, ‘Redana’, and ‘Nap9’ exhibited strong early-stage drought tolerance, promising them for arid-region cultivation and breeding. Further research is needed to assess their performance under late-season drought. The key selection traits are recommended for germination rate, speed, root development, and shoot growth.

Keywords: Brassica napus L.; Drought tolerance; Germination; Multivariate analysis; Seedling growth; Breeding selection criteria; Soil moisture.

HABITAT-DRIVEN ECOPHYSIOLOGICAL AND ANATOMICAL VARIABILITY IN AERVA JAVANICA: FROM PLAINS TO DESERTS AND ELEVATION

Iqra

Department of Botany, Division of Science and Technology, University of Education, Lahore
Department of Botany, Government College University, Faisalabad

Syed Mohsan Raza Shah

Department of Botany, Division of Science and Technology, University of Education, Lahore
Department of Botany, Government College University, Faisalabad

Muhammad Bedar Bekhat Naseem

Department of Botany, Division of Science and Technology, University of Education, Lahore
Department of Botany, Government College University, Faisalabad

ABSTRACT

Plants live in changing environments constantly, which can be stressful for their development and growth. Plants have evolved heterogeneous adaptations to survive with numerous environmental stressors, such as heat, salinity, and water scarcity. Water deficit is one of the major abiotic stresses. Plants which cope with water deficit stress are known as xerophytes. Xerophytic plants shorten the leaf area, waxy or woolly layer on leaves and reactive oxygen species formation etc. to survive in stressful factors. *Aerva javanica* is also a xerophytic plant which belongs to family Amaranthaceae. *A. javanica* is found in dryland and desert habitats. *Aerva javanica* was collected to study morpho-anatomical and physiological adaptations from different ecological regions of Punjab. Plant height was measured at the time of survey. Mana Ahmadani population showed maximum plant height. At elevation and in the desert, plant faces drought stress. Leaf area was the minimum in Derawar fort and Barkat Wala populations. Reduced leaf size resulted to reduce stomatal transpiration. Anatomical analyzation was done by free-hand sectioning. Drought stress causes the formation of aerenchyma to acquire water. Aerenchyma was observed in three different populations, while the maximum was observed in Derawar Fort population. Sakhi Sarwar is a dry and desert area, plant faces water scarcity. So, metaxylem area was the minimum in Sakhi Sarwar population to avoid cavitation under water scarcity. Reactive oxygen species work as signaling in unfavorable environment to cope with, hydrogen peroxide is released as signaling which is highly reactive molecule. To detoxify hydrogen peroxide catalase enzyme is released by plant. Mana Ahmadani population showed the maximum value of hydrogen peroxide and showed that hydrogen peroxide was detoxified at the time by catalase. In conclusion, *Aerva javanica* showed very specific modifications in morpho-anatomical and physiological traits that expose its ecological success in xerophytic habitats.

Keywords: Saline deserts, *Aerva javanica*, Anatomical modifications, Koh-e-Suliman, Antioxidant, Osmolytes

SCALABLE AND SECURE DATABASE INTEGRATION IN CLOUD INFRASTRUCTURES: CHALLENGES AND TECHNOLOGICAL SOLUTIONS

Elza Bitsadze

Akaki Tsereteli State University, Kutaisi, Georgia

Lia janadze

Akaki Tsereteli State University, Kutaisi, Georgia

Abstract

The integration of database systems into cloud infrastructures represents a foundational shift in modern IT ecosystems, where data scalability, security, and availability are critical priorities. This paradigm transition requires a redefinition of traditional database management practices to meet the demands of elastic computing, high-throughput applications, and geographically distributed services.

This paper offers a comprehensive exploration of the challenges inherent in migrating and managing large-scale databases within cloud environments. Core topics include dynamic resource allocation, multi-tenant architecture design, latency optimization, and data redundancy management. Cloud-native architectures—such as serverless computing and containerized deployments (e.g., using Kubernetes and Docker)—are analyzed for their impact on database performance and operational efficiency.

A particular emphasis is placed on security frameworks, where the study evaluates multiple layers of defense, including:

Data encryption (at rest and in transit) with key management solutions (e.g., AWS KMS, Azure Key Vault),Identity and access management (IAM) using role-based and attribute-based access control,Zero Trust Network Architecture (ZTNA) principles,Threat detection and automated incident response mechanisms, powered by AI-driven security analytics.

The paper also investigates data resilience through robust backup and disaster recovery models, including point-in-time recovery (PITR), cross-region replication, and cloud-native snapshot tools (e.g., Amazon RDS Snapshots, Azure Backup). These approaches are evaluated for recovery time objective (RTO) and recovery point objective (RPO) performance.

From a platform perspective, the research compares leading services like Amazon RDS and Aurora, Azure SQL Database, Google Cloud Spanner, and Firebase, highlighting their compatibility with hybrid and multi-cloud architectures.

Finally, the paper presents strategic recommendations and a future outlook on database governance, including compliance with regulatory frameworks (GDPR, HIPAA), performance monitoring with observability tools (e.g., Prometheus, Grafana), and automation using infrastructure-as-code (IaC) principles (e.g., Terraform, CloudFormation).

By synthesizing these technical and operational perspectives, the study provides valuable guidance for organizations aiming to build resilient, scalable, and secure database ecosystems within complex cloud infrastructures.

Keywords -Databases, Cloud Infrastructure, Data Integration, Data Security, Scalability, Data Backup, Encryption, Identity Management, Network Security, Distributed Architectures, Data Management

Introduction

Cloud computing technologies have become indispensable infrastructure components for enterprises and institutions addressing the exponential growth in data storage, processing, and analytics demands. The migration of legacy database systems into cloud environments constitutes a multifaceted challenge requiring advanced technical expertise and strict adherence to information security protocols.

With the accelerated proliferation of cloud infrastructure adoption, organizations must integrate scalable, secure, and performant database solutions into cloud ecosystems. This integration inherently involves complex architectural challenges such as dynamic resource allocation, distributed data replication, regulatory compliance, and ensuring continuous high availability. This study investigates the primary challenges inherent to cloud-native data infrastructures and evaluates modern best practices that guarantee data security, elasticity, and sustained operational continuity. In the context of an increasingly data-driven global economy, cloud platforms serve as the critical backbone empowering organizations to deploy flexible, scalable, and cost-efficient data management systems.

Therefore, database integration into cloud environments transcends technical implementation, representing a strategic imperative balancing security, performance, and system resilience. The discourse focuses on three core dimensions:

1. Scalability — strategies for managing database systems under dynamically variable workloads and escalating data volumes;
2. Security — safeguarding data confidentiality, integrity, and compliance with global regulations (e.g., GDPR, HIPAA);
3. Operational management — encompassing automated backup, real-time monitoring, data migration, and cost-efficiency optimization.

This paper presents cutting-edge technological methodologies and platform-based solutions, including:

- Distributed database architectures and sharding mechanisms;
- NoSQL systems such as MongoDB and Cassandra;
- Cloud database services (AWS RDS, Azure SQL, Google Cloud Spanner);
- Security implementations including Transparent Data Encryption (TDE), TLS/SSL protocols, IAM frameworks, and virtual private networks;
- Optimization and observability tools such as Prometheus and CloudWatch, alongside data migration services.

Industry-leading case studies (e.g., Netflix, Airbnb) are analyzed to highlight successful implementations and to forecast emerging trends like serverless computing, AI-driven auto-scaling, and confidential computing.

Literature Review

The scalability and security of cloud databases remain at the forefront of research within contemporary digital infrastructure discourse. Existing scholarly and industrial literature explores these themes through lenses ranging from architectural design to security protocol efficacy and cloud platform performance benchmarking.
Smith et al. (2020) elucidate the distinctive capabilities of distributed database systems in delivering scalable and highly available data services within cloud infrastructures. Their research confirms that distributed NoSQL and NewSQL models significantly alleviate latency and locking bottlenecks, which are crucial for real-time large-volume data processing. The study underscores precise data replication strategies and the implementation of intermediate caching layers to optimize throughput and system scalability.
Johnson and Lee (2019) focus on principal security challenges faced by cloud databases, particularly data encryption, access control, and data anonymization. Their findings highlight the heightened complexity of security management in distributed cloud settings, where data residency spans multiple locations and user groups. They advocate for multi-layer encryption techniques coupled with advanced authorization models such as RBAC to fortify defenses against cyber threats.

The Cloud Computing Association's recent report (2022) discusses the growing prevalence of hybrid and multi-service cloud architectures and their implications for data consistency and security. Hybrid deployments that integrate on-premises and cloud resources present synchronization, conflict resolution, and governance complexities. Multi-service ecosystems—where services and data span multiple cloud providers—compound monitoring and security challenges, necessitating unified policy frameworks that enforce consistency and standardized security postures across heterogeneous environments.

Despite these challenges, technological advancements such as Multi-Factor Authentication (MFA), end-to-end encryption, AI-driven monitoring, and anomaly detection have markedly enhanced cloud infrastructure security and reliability. Machine learning algorithms facilitate proactive threat detection and prevention, thereby strengthening overall system resilience.
In sum, extant literature converges on the necessity of a holistic approach combining advanced architectures, sophisticated security mechanisms, and agile management practices to realize scalable, secure cloud database integration. Complementary organizational and regulatory frameworks remain vital to underpin these technological strategies.

Research Subject

This research is concentrated on the architectural and operational integration of scalable and secure database systems within contemporary cloud infrastructures—a critical and timely challenge for enterprise IT ecosystems and data-centric applications.
The unchecked proliferation of data volumes (Big Data), heterogeneous and diversified data sources, real-time analytics demands, and accelerated access requirements pose formidable challenges that mandate sophisticated database architectures optimized for scalability and security.
Leading cloud platforms—Microsoft Azure, Amazon Web Services (AWS), Google Cloud Platform (GCP)—offer capabilities to deploy dynamic, adaptable, and scalable database environments, able to meet fluctuating workloads and multi-faceted operational demands. Nonetheless, scalability must be complemented by rigorous security mechanisms safeguarding data integrity and regulatory compliance at technical, procedural, and ethical levels.
The core research focus encompasses architectural components such as distributed systems, replication strategies, caching mechanisms, and hardware resource optimization, all harmonized with state-of-the-art security protocols including encryption, access control, auditing, and incident management.

Further investigation addresses multiple scalability modalities—horizontal and vertical scaling—and the integration of cloud databases in hybrid and multi-cloud topologies requiring automated synchronization, backup, and consistency maintenance solutions.
The research aims to identify and synthesize optimal architectural and procedural combinations to establish resilient database ecosystems that are future-ready and secure against evolving threats.
Consideration is also given to practical constraints and opportunities linked to modern cloud database management tools, DevOps methodologies, and automated operational workflows facilitating rapid scaling and effective incident handling.

Research Objective

The principal objective is to conduct a comprehensive evaluation of core scalability and security challenges in cloud-based database systems within the contemporary dynamic IT landscape. The study seeks to elucidate how exponential data growth, heterogeneous workload profiles, and stringent high-availability requirements impact database system architecture and operational performance. Emphasis is placed on scalability paradigms—including horizontal and vertical scaling—efficient resource utilization, and schema optimization.
A pivotal focus is the identification of security challenges, encompassing encryption standards, fine-grained access control, incident management, and adherence to regulatory frameworks (e.g., GDPR). The research assesses the equilibrium between robust security enforcement and scalable performance to achieve optimal system resilience.
Another key aim is to categorize and evaluate recent technological advancements, architectural models, and algorithmic solutions that underpin scalable and secure cloud databases—incorporating multi-service and hybrid architectures, AI-powered security automation, contemporary encryption and authorization protocols, and Database-as-a-Service (DBaaS) models.
Deliverables include practical guidelines for organizations and IT practitioners involved in cloud database migration and integration, covering technical, procedural, and governance aspects to ensure operational efficiency, high security, and regulatory conformity.
The research additionally aspires to propose an adaptive and robust data management framework designed for high-load environments and cross-platform cloud compatibility, emphasizing automation, dynamic resource orchestration, proactive incident prevention, and efficient backup/recovery strategies.

Collectively, these objectives intend to formulate a strategic blueprint for innovative, secure, and scalable database management critical to digital transformation initiatives.

Recommendations

1. **Adopt Multi-layered Security Architectures:** Implement comprehensive security frameworks combining encryption at rest and in transit with robust authorization models (RBAC, ABAC). Integrate real-time anomaly detection systems to trigger automated threat mitigation responses. Embed risk management protocols grounded in formal threat modeling and periodic security assessments.

2. **Optimize Data Partitioning and Indexing:** Employ logical data partitioning strategies (horizontal sharding and vertical partitioning) coupled with content-specific indexing to minimize latency and maximize throughput under high concurrency conditions.

3. **Enable Hybrid and Multi-cloud Integration:** Facilitate seamless interoperability between on-premises and cloud databases, enhancing flexibility and reliability. Ensure secure data mobility across heterogeneous environments.

4. **Leverage AI/ML for Proactive Security Management:** Deploy machine learning-driven anomaly detection, threat prediction, and automated incident response mechanisms to curtail security breaches and minimize operational disruptions.

5. **Ensure Regulatory Compliance and Privacy Protection:** Strictly enforce data protection regulations (GDPR, HIPAA) through technical controls and comprehensive administrative policies, including user consent management and data subject rights safeguarding.

6. **Institutionalize Continuous Security Auditing and Penetration Testing:** Maintain security posture through ongoing audits and vulnerability assessments, incorporating penetration testing prior to deployment cycles and at regular intervals to preemptively address security gaps.

Conclusion

Integrating scalable and secure databases into cloud infrastructures represents a cornerstone of modern technological advancement, decisively shaping the performance, reliability, and resilience of information systems. The findings affirm that addressing the surging demands of data volume, heterogeneity, and security necessitates innovative, multilayered, and hybrid strategies.

Paramount among these are elevated security standards—comprehensive encryption and granular authorization frameworks—that regulate system access and ensure data confidentiality. Equally critical is the adoption of scalable architectural paradigms enabling agile adaptation to workload variability and growing data demands.

Organizations embarking on cloud infrastructure adoption must prioritize data protection, optimize data transmission efficiencies, and secure overall system reliability through continuous security enhancement and rapid incident response capabilities.

Future investigations should target the advancement of AI/ML-powered automated security controls and the development of integrated lifecycle management tools and standards tailored for heterogeneous cloud database environments, fostering increasingly coherent, efficient, and secure cloud data ecosystems.

References

1. Microsoft Azure Architecture Center. (2024). *Best practices for cloud database design*. Microsoft Corporation.

2. Amazon Web Services. (2024). *Security Best Practices for Amazon RDS*. AWS Whitepaper.

3. Google Cloud. (2023). *Cloud Database Management Overview*. Google LLC.

4. Borkar, V., Carey, M., & Li, C. (2020). Big Data Platforms: Design and Security. *ACM Computing Surveys*, 53(4), Article 75.

5. National Institute of Standards and Technology (NIST). (2023). *Cloud Computing Security Reference Architecture* (NIST Special Publication 500-319).

EXPLOSIVE STRENGTH IN ELITE FEMALE BASKETBALL PLAYERS IN TIRANA, ALBANIA

Prof. Assoc. Dr. Enkeleida Lleshi

Department of Sports Performance, Sports Research Institute, Sports University of Tirana, Albania

ORCID; https://orcid.org/0000-0002-2800-4615

PhD(c). Salvator Kurti

Department of Sports, Faculty of Movement Science, Sports University of Tirana, Albania

https://orcid.org/0009-0009-2351-7698

ABSTRACT

Explosive strength is also an important component in basketball players. Vertical jump technique, which directly affects high jump results, depends on vertical take-off speed and centre of gravity. Method: No. 30 female basketball players elite were randomly selected from 4 sports associations in Tirana, Albania. Age 23.8 ± 0.4, Body Height (BH-172.3 cm), Body Weight (BW-69.9 kg) and BMI kg/m^2 25.6%. Test protocols used; Squat Jump (SJ), Countermovement Jump (CMJ) and Drop Jump (DJ-40 cm). Instrument used for GRFP "Leonardo" provides objective diagnosis of power, strength, jump height and efficiency. Results: Descriptive statistics (N, minimum, maximum, mean and standard deviation) for all subjects studied in elite female basketball players on the variables (Fmax, Pmax, Vmax, Jump Height, Fmax tot rel *fg, Contact Time, Flight Time and Standard Deviation). SJ average value Vmax 2.31 m\s ± 0.22, Fmax 2.11, Pmax 38.84 w\kg ±6.98, JH 0.34 m ± 0.04. CMJ average value Vmax 2.28 m\s ± 0.28, Fmax 2.73 *fg ± 0.43, Pmax 41.80 w\kg ± 6.50 and JH 0.34 m ± 0.04. Drop Jum 40 cm average value Fmax 56.75 kg ± 6.46, Pmax 27.77 kg±9.05, contact time (TC) 0.212 sec ±0.029, time of flight (TA) 0.375 sec±0.083. Total flight time to contact time ratio data (TA\TC) 1.92 ±0.413. Conclusion; In conclusion, the subjects' explosive strength component exhibited poor values. When it comes to enhancing explosive strength and tracking both short-term and long-term training, coaches should systematize their efforts. The basketball training procedure would benefit greatly from these statistics.

Keywords: Basketball, elite, explosive strength, vertical jump

INTRODUCTION

Basketball is a fast-paced sport that demands strong technical and tactical abilities. Due to the intricacy of the sport, basketball players must possess the requisite physical (such as strength, speed, and anaerobic and aerobic capacity) and physiological (such as body mass and height) qualities in order to perform at their peak (Čabarkapa et al., 2020; Mihajlovic et al., 2023). Players must also run, jump, and change direction frequently during brief breaks. One of the most commonly employed movements by basketball players, the vertical jump is used for both defensive (blocking and rebounding) and offensive (passing and shooting) quick actions (Ziv & Lidor, 2009). 45 of the 1,000 movements made by basketball players throughout a game are jumping motions, according to earlier research (Ziv & Lidor, 2009; McInnes et al., 1995). Since

the countermovement jump (CMJ) is a fundamental skill linked to team success, it is frequently incorporated into physical performance evaluations of basketball players as a quick and non-invasive way to gauge lower body neuromuscular performance traits of athletes (Ishida et al., 2021; Taylor et al., 2012). Force plate systems are regarded as a standard or criterion measure because of their thorough evaluation of the jump movement. In particular, force plate systems give practitioners a wealth of kinetic and kinematic data during both the concentric (CON) and eccentric (ECC) phases of the CMJ, in addition to outcome metrics (like jump height). A variety of technologies have been used to assess vertical jump, including accelerometers, motion capture systems, and jump mats (Cabarkapa. D et al., 2023; D. V. Cabarkapa et al., 2024). Experimental studies have revealed that male athletes performed noticeably better in vertical jumps (i.e., had higher vertical leap heights) than their female counterparts (Mancha-Triguero et al., 2021). Previous research has shown that vertical jump performance is significantly impacted by age (U14 vs. U18), gender (male vs. female), positions (defender vs. forward), playing time (starting vs. non-starting players), and competition level (elite vs. collegiate) (Mancha-Triguero et al., 2021; Silva et al., 2011). With this knowledge, strength and conditioning professionals can design more individualized training plans that consider the aforementioned variations in addition to morphological and physiological growth (Zaric et al., 2020). Despite the fact findings offer valuable insights into the vertical jump performance of basketball players, data about female basketball players is still missing. The vertical leap method is the most crucial element to regulate since it has a direct impact on the test's height jump, Pmax, and Fmax scores. The center of gravity and vertical velocity at takeoff have a direct impact on the height during takeoff. More research is required to fully comprehend the neuromuscular performance characteristics of female basketball players, especially across age groups. As demonstrated by the Leonardo® Ground Force Reaction Plate (GRFP-e Novotec Medical, Pforzheim, Germany), a platform that measures ground reaction forces (GRF) during movements, innovative technology allows us to assess athletes' athletic performance (Leonardo 2010). The current study set out to record the explosive vertical jump strength of top female basketball players using the SJ, CMJ, and DJ tests. This was created in the lack of sports science studies on Albania's top female basketball players.

METHODOLOGY

Participants

1. The subjects are about 30 female basketball players of 23.8 ± 0.4, a number that is a fairly good sample considering the total number of female basketball players of this age who are active in the Albanian National Championship. The subjects were randomly selected from 4 sports associations in Tirana, Albania. Female basketball players (BB) voluntarily participated in this study, had at least 13 years of experience in their respective sport, and trained 5 times a week for 90 minutes in Tirana, Albania.

Procedure

2. Prior to the study, all players were informed about the procedures, and their consent was obtained. The study was approved by the Ethics Council of the Sports University of Tirana, Albania. Written informed consent was obtained from all participants and coaches, in accordance with the ethical standards of the Declaration of Helsinki. Prior to the study, all players were informed about the procedures, and their consent was obtained. The subjects included in the study were subjected to anthropometric measurements: Body Height (BH), Body Weight (BW).

Test Protocol

The vertical leap test technique was used to assess the physical performance of female basketball players in SJ, CMJ, and DJ. Before the testing began, the subjects warmed up for

ten minutes. The final result for analysis was the best value derived from three tests that were repeated.

Squat Jump (SJ): Players, without the help of the arms SJ is the jump starting from the athlete's position with the legs bent at a 90º angle, hands resting on the hips (waist) on the platform.

Countermovement Jump (CMJ): CMJ is similar to the SJ, but the athlete begins the test from an upright position and gains momentum by flexing the lower limbs to 90º degrees with the hands placed on the hips (waist) on the platform.

3. *Drop Jump 40 cm (DJ40):* The DJ offers a progressive increase in drop cube height. This test evaluates the explosive strength of the lower limbs. Players take turns standing on the 40 cm high cube with their hands on their hips. Through a free fall from the height of the cube they fall onto the platform and react quickly after contacting the platform by jumping as high as possible.

Instruments

4. The measurements were recorded in force plate to GRFP "Leonardo Mechonagraphy" protocol (Leonardo 2010). GRFP offers objective diagnosis of individual performance (power) and movement analysis, measurement, diagnosis, and evaluation of Force, Speed, Power, Work, Energy stored, as well as various throws. Leonardo® has the characteristic of evaluating both right and left limbs in comparison to detect unilateral deficiencies.

Statistical analysis

In this paper, the SSPS package program was used for data analysis. All data are reported as means ± standard deviation unless stated otherwise. Descriptive statistics for all players were calculated for age, height, weight, jump height, force, power and efficiency. Statistical analyses were performed with an a priori significance level of $p < 0.05$.

RESULTS

Table 1 presents the data descriptive statistics (N, minimum, maximum, mean and standard

deviation) for all subjects studied in elite female basketball players on the variables;

SJ average value Vmax 2.31 m\s ± 0.22, Fmax 2.11, Pmax 38.84 w\kg ±6.98, JH 0.34 m ± 0.04. CMJ average value Vmax 2.28 m\s ± 0.28, Fmax 2.73 *fg ± 0.43, Pmax 41.80 w\kg ± 6.50 and JH 0.34 m ± 0.04. Drop Jum 40 cm average value Fmax 56.75 kg ± 6.46, Pmax 27.77 kg±9.05, contact time (TC) 0.212 sec ±0.029, time of flight (TA) 0.375 sec±0.083. Total flight time to contact time ratio data (TA\TC) 1.92 ±0.413.

Table 1. Descriptive statistics for the SJ and CMJ DJ 40cm tests

		Nr	Min	Max	Mean	*Std. Dev.*
Squat Jump (SJ)	Vmax m\s	30	1.88	2.7	2.31	*0.226*
	Fmax rel *fg	30	1.7	2.71	2.11	*0.325*
	Pmax w\kg	30	31.2	52.39	38.84	*6.989*
	JH m	30	0.26	0.43	0.34	*0.045*
		Nr	**Min**	**Max**	**Mean**	***Std. Dev.***
Countermovement Jump (CMJ)	Vmax m\s	30	1.97	2.82	2.28	*0.281*
	Fmax rel *fg	30	2.21	3.48	2.73	*0.432*
	Pmax w\kg	30	32.55	52.99	41.8	*6.509*
	JH m	30	0.28	0.41	0.34	*0.042*
		Nr	**Min**	**Max**	**Mean**	***Std. Dev.***
Drop Jump 40 cm (DJ 40cm)	Fmax kg	30	66.09	48.82	56.75	*6.461*
	Pmax kg	30	45.48	16.21	27.77	*9.052*
	TC sec	30	0.255	0.176	0.212	*0.0296*
	TA sec	30	0.489	0.233	0.375	*0.0836*
	TA\TC	30	2.83	1.57	1.92	*0.4131*

DISCUSSION

There isn't many research on how female basketball players, particularly in Albania, build explosive strength before, during, and after the season. Since volleyball is a sport that relies more heavily on vertical jumps, players' explosive strength has been assessed more through CMJ. There is a need for updated research that includes studies on female players, given the growing interest in women's basketball. The development of test batteries at the elite level of female basketball in Albania would allow for the longitudinal evaluation of players and the establishment of minimum physical standards for playing positions and levels of competition (Lleshi & Kurti, 2024). In a study of basketball and volleyball players, Lleshi (2019) found that explosive strength and speed on the field are positively correlated, with players with a higher CMJ typically having superior agility and high court speeds. Additionally, the average jump heights reported by (Kipp et al., 2020) CMJ: 62.4±5.4 cm are larger than the jump heights reported by our investigation. Both forms of the countermovement jump (CMJ)—with and without arm swing—offer trustworthy insights into inter-limb asymmetries, notwithstanding the possibility that arm swing could counterbalance lower extremity motions and conceal lower limb force asymmetries (Heishman et al., 2019). Despite efforts to maintain fitness, strength, and power, prior study has shown that basketball players' lower body strength declines during the playing season (Murr et al., 2023). The results of this study show that elite female basketball players had poor explosive strength performance compared to references in different studies. In elite Brazilian female basketball players, authors observed a significant increase of nearly 3.5 cm in the SJ performance, followed by 12 weeks of basketball training periodization (Nunes et al., 2014), but no data was displayed regarding the CMJ. Study conducted to evaluate the effects of 8 weeks of plyometric training on the jump ability in female basketball players aged 20. 9 ± 2.4 years, reported greater improvements in the SJ (+10.4%) than in the CMJ (+3.6%) (Cherni et al., 2020). The literature suggests that improving a player's jumping ability could be crucial for competition, despite the fact that various patterns have been noted for SJ and CMJ performance (Banda et al., 2019; Cherni et al., 2020). Spiteri et al. (2013) tracked how female basketball players' CMJ jump height changed after practices and games.

It is possible that a player's capacity to sustain high outputs during a vertical jump could be crucial for both practice and competition. We believe that coaches may be able to periodize

conditioning sessions more successfully if they consider the physiological effects that follow sessions that emphasize certain physical goals.

CONCLUSION

In conclusion, the subjects' explosive strength component exhibited poor values. When it comes to enhancing explosive strength and tracking both short-term and long-term training, coaches should systematize their efforts. The basketball training procedure would benefit greatly from these statistics.

REFERENCES

Banda, J., Bellande, K., Von Wangenheim, D., Goh, T., Guyomarc'h, S., Laplaze, L., & Bennett, M. J. (2019). Lateral root formation in Arabidopsis: Well-Ordered LRExit. *Trends in Plant Science*, 24(9), 826–839. https://doi.org/10.1016/j.tplants.2019.06.015

Cabarkapa, D., Cabarkapa, D. V., Philipp, N. M., Knezevic, O. M., Mirkov, D. M., & Fry, A. C. (2023). Pre - Post practice changes in countermovement vertical jump Force-Time metrics in professional male basketball players. *The Journal of Strength and Conditioning Research*, *37*(11), e609–e612. https://doi.org/10.1519/jsc.0000000000004608

Cabarkapa, D.; Fry, A.C.; Lane, M.T.; Hudy, A.; Dietz, P.R.; Cain, G.J.; Andre, M.J. (2020). The importance of lower body strength and power for future success in professional men's basketball. *Sport Sci. Health 2020, 10, 10–16.* https://doi.org/10.7251/ssh2001010c

Cabarkapa, D. V., Cabarkapa, D., & Fry, A. C. (2024). Starters vs. non-starters differences in vertical jump force-time metrics in female professional volleyball players. *Frontiers in Sports and Active Living*, *6*. https://doi.org/10.3389/fspor.2024.1389001

Cherni, H., Métayer, N., & Souliman, N. (2020). Literature review of locomotion techniques in virtual reality. *International Journal of Virtual Reality*, 20(1), 1–20. https://doi.org/10.20870/ijvr.2020.20.1.3183

Heishman, A., Daub, B., Miller, R., Brown, B., Freitas, E., & Bemben, M. (2019). Countermovement jump Inter-Limb asymmetries in collegiate basketball players. *Sports*, 7(5), 103. https://doi.org/10.3390/sports7050103

Ishida, A., Travis, S., & Stone, M. (2021). Associations of Body Composition, Maximum Strength, Power Characteristics with Sprinting, Jumping, and Intermittent Endurance Performance in Male Intercollegiate Soccer Players. *Journal of Functional Morphology and Kinesiology*, *6*(1), 7. https://doi.org/10.3390/jfmk6010007

Kipp, K., Kiely, M., Giordanelli, M., Malloy, P., & Geiser, C. (2020). Joint- and subject-specific strategies in male basketball players across a range of countermovement jump heights. Journal of Sports Sciences, 38(6), 652–657. https://doi.org/10.1080/02640414.2020.1723374

Mancha-Triguero, D., García-Rubio, J., Gamonales, J. M., & Ibáñez, S. J. (2021). Strength and speed profiles based on age and sex differences in young basketball players. *International Journal of Environmental Research and Public Health*, *18*(2), 643. https://doi.org/10.3390/ijerph18020643

McInnes, S., Carlson, J., Jones, C., & McKenna, M. (1995). The physiological load imposed on basketball players during competition. *Journal of Sports Sciences*, *13*(5), 387–397. https://doi.org/10.1080/02640419508732254

Mihajlovic, M., Cabarkapa, D., Cabarkapa, D., Philipp, N., & Fry, A. (2023). Recovery Methods in Basketball: A Systematic Review. *Sports*, *11*(11), 230. https://doi.org/10.3390/sports11110230

Murr, S., Aldred, M., & Games, J. (2023). Monitoring Countermovement Jump Performance for Division I Basketball Players over the Competitive Season. American Journal of Sports Science. https://doi.org/10.11648/j.ajss.20231101.14

Nunes, J. A., Moreira, A., Crewther, B. T., Nosaka, K., Viveiros, L., & Aoki, M. S. (2014). Monitoring training load, Recovery-Stress State, Immune-Endocrine responses, and physical performance in elite female basketball players during a periodized training program. *The Journal of Strength and Conditioning Research*, 28(10), 2973–2980. https://doi.org/10.1519/jsc.0000000000000499

Leonardo Mechanograpy Ground Reaction Force Platform (GRFP) v4.2. St. Ed. (2010) https://mechanography.com/en/

Lleshi, E. (2019). Plyometric Performance Assessment of Basketball - Volleyball female players. European Journal of Interdisciplinary Studies, 5(2), 54. https://doi.org/10.26417/200kaz71n

Lleshi, E., & Kurti, S. (2024). Approaches on physiological changes in the performance of elite female basketball players. Scientific Journal of Sport and Performance, 3(2), 238–250. https://doi.org/10.55860/djby5997

Silva, A. M., Santos, D. A., Matias, C. N., Rocha, P. M., Petroski, E. L., Minderico, C. S., & Sardinha, L. B. (2011). Changes in regional body composition explain increases in energy expenditure in elite junior basketball players over the season. *European Journal of Applied Physiology*, *112*(7), 2727–2737. https://doi.org/10.1007/s00421-011-2221-8

Spiteri, T., Cochrane, J. L., Hart, N. H., Haff, G. G., & Nimphius, S. (2013). Effect of strength on plant foot kinetics and kinematics during a change of direction task. European Journal of Sport Science, 13(6), 646–652. https://doi.org/10.1080/17461391.2013.774053

Taylor, K., Chapman, D., Cronin, J., Newton, M. J., & Gill, N. (2012). Fatigue monitoring in high performance sport: a survey of current trends. *J Aust Strength Cond*, 20(1), 12-23. https://www.strengthandconditioning.org/jasc-20-1/1270-peer-review-fatigue-monitoring-in-high-performance-sport-a-survey-of-current-trends

Zaric, I., Dopsaj, M., Markovic, M., Zaric, M., Jakovljevic, S., & Beric, D. (2020). Body composition characteristics measured by multichannel bioimpedance in young female basketball players: relation with match performance. *International Journal of Morphology*, *38*(2), 328–335. https://doi.org/10.4067/s0717-95022020000200328

Ziv, G., & Lidor, R. (2009). Vertical jump in female and male basketball players—A review of observational and experimental studies. *Journal of Science and Medicine in Sport*, *13*(3), 332–339. https://doi.org/10.1016/j.jsams.2009.02.009

INNOVATIONS IN COMPUTATIONAL SCIENCE: ALGORITHMS, DATA, AND MODELING

Elza Bitsadze

Akaki Tsereteli State University, Kutaisi, Georgia,

Abstract

Computational science represents one of the most dynamic and innovative fields in contemporary research and technological development, integrating mathematical modeling, algorithmic methods, and high-performance computing systems. In recent years, data science, artificial intelligence (AI), and machine learning (ML) have significantly transformed the practice of big data analysis and computational modeling.

Data science provides tools for processing and refining digital data, enabling researchers and businesses to extract valuable insights from unstructured and multidimensional datasets. AI and ML techniques, including deep learning and natural language processing (NLP), substantially enhance automated analysis, in-depth investigations, and predictive modeling.

Big data analytics serves as a crucial foundation for innovations in computational science, encompassing data aggregation, filtering, transformation, and the execution of advanced algorithms. This process facilitates real-time analysis and decision-making across various sectors, including healthcare, finance, climate change modeling, and more.

This article offers an overview of these modern technologies and methodologies, as well as examples of their integration and application in diverse interdisciplinary environments. Particular attention is given to challenges such as data quality, model robustness and transparency, and ethical and privacy concerns. Finally, future trends and potentials shaped by these innovations in digital transformation and the development of the new generation of science are presented.

Keywords: Computational Science; Data Science; Artificial Intelligence; Machine Learning; Deep Learning; Big Data; Data Analytics; Computational Modeling; Algorithmic Methods; High-Performance Computing; Digital Transformation; Automated Decision-Making; Data Integration; Ethics in Data Science; Predictive Analytics.

Introduction

The rapid progress of the digital era significantly drives the swift development of data, algorithms, and computational systems. Computational Science represents an interdisciplinary field that integrates mathematical modeling, algorithmic methods, and high-performance computing (HPC) infrastructures to effectively solve complex and resource-intensive problems. Central to this process are Data Science, Artificial Intelligence (AI), and Machine Learning (ML), which enable deep data analysis and automated, learned-based prediction and decision-making.

In today's environment, characterized by unprecedented volume and variety of data (Big Data), the integration of technological approaches capable of real-time data processing and action is critical. Computational Science has thus evolved to transform various sectors, including medicine, finance, climate modeling, and social analysis.

Data Science and Data Analytics

Data Science is a multifunctional and interdisciplinary domain combining statistical methods, computer science, and domain expertise to extract valuable insights and statistically significant conclusions from vast data sets. Its primary objective is data collection, preprocessing, analysis, modeling, and visualization—processes that underpin evidence-based decision-making in the contemporary information age.

Data Science is particularly effective in analyzing high-dimensional and nonlinear data, including textual, sensor, geographic, and web-derived data. This capability facilitates the detection of complex trends and latent relationships, thereby enhancing forecasting, optimization, and strategic planning.

The analytical process relies on a broad array of tools, including:

- Statistical and machine learning algorithms used for structuring data, classification, and regression tasks;
- Programming languages such as Python and R, equipped with extensive libraries like Pandas, NumPy, Matplotlib, and ggplot2 for data analysis and visualization;
- Cloud platforms including Microsoft Azure, Amazon Web Services (AWS), and Google Cloud Platform (GCP) that provide scalable data processing and storage both in real-time and batch modes.
- Efficient use of Data Science requires not only technical expertise but also critical thinking, ethical data handling, and contextual interpretation of results within business and scientific frameworks.
- As the cornerstone of digital transformation, Data Science underlies automated decision-making, business forecasting, and intelligent systems, spanning sectors from banking to climate modeling and public policy analysis.

Artificial Intelligence and Machine Learning

Artificial Intelligence (AI) and Machine Learning (ML) constitute fundamental pillars of modern computational science, fundamentally reshaping data analysis, modeling, and decision-making workflows. These technologies enable intelligent processing of voluminous, heterogeneous, and complex datasets, facilitating the creation of adaptive systems capable of accurate prediction and environmental responsiveness.

Machine Learning models, such as regression analysis, decision trees, support vector machines (SVM), and deep neural networks, offer high precision in data classification, clustering, and anomaly detection.

Deep Learning is particularly effective for uncovering nonlinear and complex relationships. Convolutional Neural Networks (CNN) excel in image processing and medical visualization, while Recurrent Neural Networks (RNN) and Transformers significantly enhance text-based analysis and natural language processing (NLP), including text generation, automatic translation, and sentiment analysis.

The application scope of AI and ML expands across critical sectors including:

- Healthcare – patient prognosis and personalized treatment;
- Finance – fraud detection and market analysis;
- Climate modeling – forecasting global temperature changes;

- Digital business decisions – analyzing and optimizing consumer behavior. Simultaneously, ethical and social considerations such as data privacy, mitigation of algorithmic bias, and model transparency demand vigilant attention.

High-Performance Computing (HPC)

High-Performance Computing systems are foundational to contemporary science and engineering. HPC technologies are indispensable for executing large-scale and complex tasks such as genome sequencing, global climate modeling, physical process simulations, and real-time large data analytics.

Advanced HPC infrastructures, including Microsoft Azure HPC, Google Cloud HPC, and Amazon EC2 HPC clusters, provide scalability, flexibility, and automation. Integrating HPC with Data Science and AI models creates hybrid architectures that significantly improve computational efficiency, accuracy, and predictability.

Ethical and Data Privacy Challenges

Modern computational science continuously faces ethical, legal, and social challenges, especially in data acquisition, storage, and analysis. The creation of high-accuracy models depends on data quality and compliance, raising issues regarding data provenance, consent for use, and confidentiality safeguards.

AI algorithms particularly require model transparency, explainability, and procedures to detect and mitigate algorithmic bias. Practical deployment of data analytics and forecasts—especially in sensitive fields like medicine or law—demands systems that are not only technically robust but ethically accountable and interpretable.

Hence, rigorous adherence to GDPR and other international standards is necessary to ensure the sustainability, fairness, and public trust in scientific and commercial systems.

Conclusion

Computational Science continues its dynamic evolution through data-centric approaches and technological innovation. The integration of algorithms, data analytics, and artificial intelligence forms hybrid systems that transform research and decision-making processes. In domains where data volume and diversity grow daily, Computational Science provides stable, predictable, and transparent analysis.

Future trends include the development of Explainable AI, enhanced cloud-based HPC systems, and expanded interdisciplinary approaches. These innovations will play a pivotal role in the next phase of science, education, and industry.

References

1. Agrawal, A., Gans, J., & Goldfarb, A. (2019). *Prediction Machines: The Simple Economics of Artificial Intelligence*. Harvard Business Press.

2. Dean, J., & Ghemawat, S. (2008). MapReduce: Simplified data processing on large clusters. *Communications of the ACM*, 51(1), 107–113.

3. Shalev-Shwartz, S., & Ben-David, S. (2014). *Understanding Machine Learning: From Theory to Algorithms*. Cambridge University Press.

4. Dongarra, J., et al. (2021). High-Performance Computing: Challenges and Opportunities. *International Journal of High Performance Computing Applications*, 35(2), 117–139.

5. Hastie, T., Tibshirani, R., & Friedman, J. (2009). *The Elements of Statistical Learning: Data Mining, Inference, and Prediction*. Springer.

6. Goodfellow, I., Bengio, Y., & Courville, A. (2016). *Deep Learning*. MIT Press.

7. Mittelstadt, B. D., et al. (2016). The ethics of algorithms: Mapping the debate. *Big Data & Society*, 3(2), 1–21.

8. Jordan, M. I., & Mitchell, T. M. (2015). Machine learning: Trends, perspectives, and prospects. *Science*, 349(6245), 255–260.

9. Cloud Standards Customer Council. (2017). *Practical Guide to Cloud Computing Version 3.0*.

THERMODYNAMIC AND EXERGY ANALYSIS OF R454C AND MIXED REFRIGERANTS IN REFRIGERATED TRUCKS

SOĞUTMALI KAMYONLARDA R454C VE KARIŞIM SOĞUTUCU AKIŞKANLARIN TERMODİNAMİK VE EKSERJİ ANALİZİ

M.Sc. Eng. Enes AKÇAY
Bayburt University
ORCID: 0000-0001-9665-8787

Lecturer Dr. Arzu KEVEN
Kocaeli University, Gölcük Vocational School
ORCID: 0000-0003-0040-9167

ABSTRACT

In this study, the thermodynamic performance of various refrigerants proposed for use in refrigerated trucks was theoretically compared. The analysis was based on a basic vapor compression refrigeration cycle, and evaluations were carried out for pure refrigerants R32 and R1234yf, as well as the zeotropic refrigerant R454C, which is a blend consisting of R32, R1234yf by mass. The compression ratio was taken as the primary variable, and its variations were used to examine key performance indicators such as the coefficient of performance (COP), compressor work, total exergy destruction, exergy efficiency, and entropy generation. In this way, the effects of each refrigerant on system efficiency, energy consumption, and thermodynamic losses were comprehensively revealed. The results show that the unique thermodynamic properties of the analyzed refrigerants directly influence the cycle performance. R32 stood out as the most efficient refrigerant with its high COP and exergy efficiency, while R1234yf attracted attention with its low energy consumption and environmentally friendly characteristics. Although R454C was designed to combine the advantages of its components, it performed worse than both R32 and R1234yf. As a result, it is concluded that refrigerant selection in refrigerated trucks should not be based solely on energy efficiency but also evaluated through a holistic approach that considers environmental impact, system compatibility, entropy generation, and long-term sustainability.

Keywords: Compression Ratio, Energy and Exergy, Refrigerated Trucks, COP

ÖZET

Bu çalışmada, soğutmalı kamyonlarda kullanılmak üzere önerilen farklı soğutucu akışkanların termodinamik performansları teorik olarak karşılaştırılmıştır. Analizlerde temel bir buhar sıkıştırmalı soğutma çevrimi esas alınmış ve saf halde bulunan R32 ile R1234yf akışkanlarının yanı sıra, bu iki akışkanın belirli oranlarda karışımından oluşan izeotropik bir akışkan olan R454C (R32, R1234yf) üzerinde değerlendirmeler gerçekleştirilmiştir. Sıkıştırma oranı temel parametre olarak alınmış ve bu orandaki değişimlere bağlı olarak çevrimin COP değeri, kompresör işi, toplam ekserji yıkımı, ekserji verimi ve entropi üretimi gibi önemli performans göstergeleri analiz edilmiştir. Bu sayede her bir akışkanın sistem verimliliği, enerji tüketimi ve

termodinamik kayıplar üzerindeki etkileri kapsamlı biçimde ortaya konmuştur. Elde edilen sonuçlar, incelenen akışkanların sahip olduğu özgün termodinamik özelliklerin çevrim performansını doğrudan etkilediğini göstermektedir. R32, yüksek COP ve ekserji verimi ile en verimli akışkan olarak öne çıkarken; R1234yf, düşük enerji tüketimi ve çevre dostu yapısıyla dikkat çekmiştir. R454C ise bileşenlerinin avantajlarını birleştirmeyi hedefleyen bir karışım olmasına rağmen, performans açısından R32 ve R1234yf'nin gerisinde kalmıştır. Sonuç olarak, soğutmalı kamyonlarda soğutucu akışkan seçiminin yalnızca enerji verimliliğiyle sınırlı kalmaması; çevresel etki, sistem tasarımına uyum, entropi üretimi ve uzun vadeli sürdürülebilirlik gibi çok boyutlu kriterler doğrultusunda değerlendirilmesi gerektiği ortaya konmuştur.

Anahtar Kelimeler: Sıkıştırma Ortanı, Enerji ve Ekserji, Soğutmalı Kamyonlar, COP

GİRİŞ

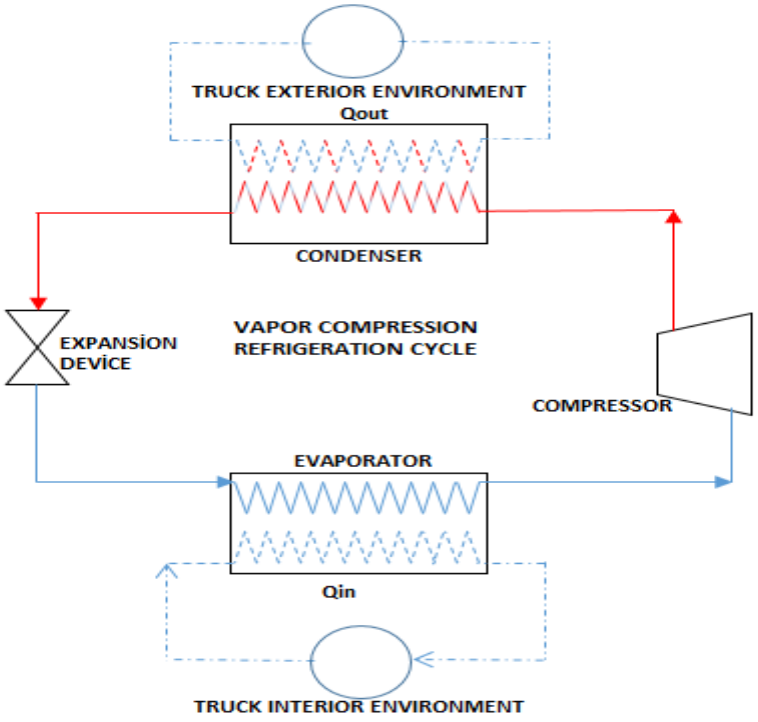
Ulaşım araçları, günümüz modern toplumlarında hayati bir rol oynamakta ve aynı zamanda en yüksek enerji tüketicileri arasında yer almaktadır. Küresel ölçekte otomobil sayısı yaklaşık 1 milyara ulaşmış olup, bu sayının 2035 yılına dek iki katına çıkması beklenmektedir. Bu araçlar, her yıl yüz milyarlarca galon yakıt tüketerek enerji kaynakları üzerinde ciddi bir yük oluşturmaktadır. Ulaşım sektörü, dünya genelindeki toplam enerji kullanımının yaklaşık %30'unu oluşturmakta ve bu enerjinin büyük bir kısmı, yani %90'dan fazlası fosil yakıtlardan sağlanmaktadır. Soğutmalı taşımacılık özelinde bakıldığında, uzun mesafeli taşımalarda soğutma sistemi genellikle ayrı bir dizel motorla çalıştırılmaktadır. Öte yandan, kısa mesafeli araçlarda ise taşıyıcı dizel motor, aynı zamanda soğutma ünitesinin kompresörüne de güç sağlamaktadır. Her iki sistemin de çevresel etkileri oldukça kayda değerdir. Bu yapıların neden olduğu emisyonlar, hava kalitesi ve sera gazı salımları açısından önemli sonuçlar doğurabilmektedir (Rosetti, Vd., 2022). Soğuk zincirin en önemli basamaklarından biri olan soğutmalı taşımacılık, ürünlerin yaşam döngüsü boyunca, özellikle zorlu çevresel şartlarda, gıda güvenliğini ve kaliteyi koruma görevini üstlenir. Bu sayede hem gıda israfının azaltılmasına hem de tedarik zincirinin toplam karbon ayak izinin düşürülmesine önemli katkı sağlar (Liu, Saman, Bruno, 2012). Buhar sıkıştırma çevrimine dayalı soğutma sistemleri; sanayi, ticaret, konut, soğuk zincir taşımacılığı gibi soğutma alanlarında ve hem evsel hem de otomotiv iklimlendirme uygulamalarında en yaygın şekilde tercih edilen teknolojilerdendir (Maiorino, Petrızziello, Aorea, 2021). Soğutma sistemlerinin COP (performans katsayısı) değerini artırmak, yalnızca kompresörün verimliliğini yükseltmekle sınırlı değildir; aynı zamanda genleşme aşamasında enerji geri kazanımı, soğutucu akışkanın alt soğutulması ve aşırı ısıtılması gibi çeşitli tekniklerin bir arada kullanılması da önemlidir. Buhar sıkıştırmalı soğutma çevrimi, kapalı bir sistemde dolaşan soğutucu akışkanın dört temel aşamadan geçmesiyle çalışır. İlk olarak, düşük basınçlı buhar halindeki soğutucu akışkan kompresöre girer ve burada yüksek basınçlı buhar haline getirilir. İkinci aşamada, yüksek sıcaklık ve basınçta olan bu buhar kondensere ulaşır. Kondensere gelen buhar, burada bir ısı değişim sürecine girer; kondenser serpantini boyunca dolaşırken, karşı taraftan geçen farklı bir akışkan aracılığıyla soğutularak yoğuşur ve yüksek basınçlı sıvı haline gelir. Üçüncü aşamada, soğutucu akışkan bir genleşme elemanından (örneğin termostatik genleşme vanası, kılcal boru, delik tipi kısıtlayıcı veya elektronik genleşme valfi) geçerek basıncı düşürülür ve düşük basınçlı sıvı formuna dönüşür. Son aşamada ise bu düşük basınçlı sıvı, evaporatöre girerek çevresinden veya şartlandırılan ortamdan ısı alır, buharlaşır ve düşük basınçlı aşırı ısıtılmış buhar haline gelerek yeniden kompresöre döner (Alsouda Vd., 2023). Yapılan çalışmalar ve düzenlemeler buhar sıkıştırmalı soğutma çevrimlerinde soğutucu olarak kullanılan gazların iklim üzerinde daha az etki gösteren akışkanlara tercihi yönelimini arttırmıştır. Örneğin R1234yf ve R125a gibi yada doğal CO2 NH3 veya hidrokarbon soğutuculardan bahsedilebilmektedir (Ablanque, Vd, 2024).

KAVRAMSAL ÇERÇEVE

Soğuk zincir lojistiği, özellikle sıcaklık kontrolü gerektiren ürünlerin güvenli şekilde taşınması açısından kritik bir öneme sahiptir. Bu zincirin temel bileşenlerinden biri olan soğutmalı kamyonlar, ürünlerin taşıma süresi boyunca uygun sıcaklık aralığında kalmasını sağlayan mobil soğutma sistemleriyle donatılmıştır. Bu sistemlerin enerji verimliliği, performansı ve çevresel etkileri, kullanılan soğutucu akışkana doğrudan bağlıdır. Soğutmalı taşımacılıkta en yaygın kullanılan sistem, olgun mühendislik altyapısı ve uygulama kolaylığı sayesinde buhar sıkıştırmalı soğutma çevrimidir. Bu çevrim; kompresör, kondenser, genleşme elemanı ve evaporatör olmak üzere dört temel bileşenden oluşur. Soğutucu akışkan, bu kapalı çevrimde dolaşırken faz değiştirerek ısı transferini sağlar. Kompresörde sıkıştırılan buhar halindeki akışkan, kondenserde yoğuşur, ardından genleşme elemanında basıncı düşürülerek evaporatöre ulaşır ve burada buharlaşarak ısıyı ortamdan çeker. Böylece çevrim sürekli olarak tekrarlanır. Bu çalışmada, buhar sıkıştırmalı çevrimde kullanılan farklı soğutucu akışkanların performansları teorik olarak karşılaştırılmıştır. Saf halde bulunan R32, R12 ve R1234yf akışkanlarının yanı sıra bu gazların belirli oranlarda karışımından oluşan R452A da analiz kapsamına alınmıştır. İncelemede, sistemin performansı üzerinde etkili olan sıkıştırma oranı (r), yoğuşma sıcaklığı (T_3) ve buharlaşma sıcaklığı (T_1) gibi temel parametreler dikkate alınmıştır. Analiz sürecinde her bir soğutucu akışkan için çevrim performansı; COP (performans katsayısı), kompresör gücü, ekserji verimi ve ekserji kayıpları gibi ölçütler üzerinden değerlendirilmiştir. Bu değerlendirme, hem termodinamik verimliliğin hem de enerji tüketiminin daha bütüncül bir bakış açısıyla ele alınmasını mümkün kılmaktadır. Bu doğrultuda, çalışmanın kavramsal temeli; buhar sıkıştırmalı sistemlerde kullanılan farklı soğutucu akışkanların teknik performanslarını karşılaştırarak, soğutmalı taşımacılık uygulamalarında enerji verimliliği yüksek ve çevresel etkisi düşük alternatiflerin belirlenmesine katkı sağlamak üzerine kurulmuştur.

YÖNTEM

Bu çalışmada, farklı soğutucu akışkanların performanslarını değerlendirmek amacıyla temel alınan sistem, buhar sıkıştırmalı soğutma çevrimine dayanmaktadır. Kapalı devre hâlinde çalışan bu sistem, soğutmalı kamyonlarda yaygın olarak kullanılan klasik bir yapıdadır ve dört temel bileşenden oluşmaktadır: kompresör, yoğuşturucu (kondenser), genleşme elemanı ve buharlaştırıcı (evaporatör). Soğutucu akışkan, bu dört bileşen arasında sürekli olarak dolaşarak çevrimsel bir ısı transferi sağlar. Çevrim, düşük basınçta buhar hâlindeki soğutucu akışkanın kompresöre girmesiyle başlar. Kompresörde gerçekleşen sıkıştırma işlemi sonucunda akışkanın basıncı ve sıcaklığı artar. Bu aşamadan sonra yüksek basınç ve sıcaklığa ulaşan buhar, yoğuşturucuya yönlendirilir. Yoğuşturucu içerisinde, dış ortam havasına ısı aktarılır ve akışkan bu işlem sırasında yoğuşarak sıvı hâle gelir. Bu aşama, dış ortama ısı veren süreçtir. Yoğuşma işlemi sabit basınç altında gerçekleşir ve soğutucu akışkan tamamen sıvı hâline geçtikten sonra genleşme elemanına ulaşır. Genleşme elemanında, sıvı akışkanın basıncı ani bir düşüşe uğrar. Bu işlem sonucunda akışkanın sıcaklığı da düşer ve bir kısmı buharlaşarak iki fazlı (sıvı-buhar) karışım hâline gelir. Düşük basınca ulaşan bu karışım daha sonra buharlaştırıcıya girer. Buharlaştırıcıda, iç ortamdan yani soğutulmak istenen hacimden ısı çekilir. Bu sayede soğutucu akışkan tamamen buharlaşır ve yeniden kompresöre dönerek çevrim tamamlanır. İç ortamdan alınan bu ısı, sistemin soğutma etkisini oluşturur. Bu çevrimsel süreç sayesinde sistem, iç ortamdan aldığı ısıyı dış ortama aktararak sabit bir sıcaklık düzeyi sağlar. Her bir soğutucu akışkan, bu çevrim boyunca farklı termodinamik davranış sergilediğinden, bu çalışma kapsamında seçilen akışkanların sistem üzerindeki etkileri ayrıntılı olarak incelenmiştir.



Şekil 1. Sistemin genel akış şeması.

Bu çalışmada analiz edilen soğutma çevrimi, dört temel bileşenden oluşmaktadır: kompresör, kondenser, genleşme valfi ve evaporatör. Her bileşen için ayrı ayrı enerji ve entropi denge denklemleri kullanılmıştır. Kompresörde, dışarıdan verilen mekanik iş ile soğutucu akışkanın entalpisi artarken; kondenserde, akışkanın taşıdığı enerji çevreye ısı olarak aktarılır. Genleşme valfi izentanpik kabul edildiğinden burada enerji değişimi gözlenmez. Evaporatörde ise iç ortamdan alınan ısı ile akışkan buharlaştırılır. Her bir bileşende sistemin gerçek çalışma koşullarını daha doğru modelleyebilmek amacıyla entropi üretimi de dikkate alınmış, böylece çevrimdeki geri döndürülemezlikler hesaba katılmıştır.

Tablo 1 Akışın kütle ile enerji dengesi ve entropi üretimi (Akçay, 2025).

Materyal	Aralık	Kütle Dengesi	Enerji Dengesi	Entropi Üretimi
Kompresör	1-2	$\dot{m}_1 = \dot{m}_2$	$\dot{m}_1 h_1 + \dot{W}_{Komp} = \dot{m}_2 h_2$	$m_1 s_1 - m_2 s_2 + S_{Gen,Komp} = 0$
Kondenser	2-3	$\dot{m}_2 = \dot{m}_3$	$\dot{m}_2 h_2 = \dot{Q}_{out} + \dot{m}_3 h_3$	$m_2 s_2 - m_3 s_3 + \frac{\dot{Q}_{Çıkış}}{T_{çıkış}} + S_{Gen,Kond} = 0$
Genleşme Valfi	3-4	$\dot{m}_3 = \dot{m}_4$	$h_3 = h_4$ (İzentropik)	$m_3 s_3 - m_4 s_4 + S_{Gen,GenVal.} = 0$
Evaporatör	4-1	$\dot{m}_4 = \dot{m}_1$	$\dot{m}_4 h_4 = \dot{Q}_{in} + \dot{m}_1 h_1$	$m_4 s_4 - m_1 s_1 + \frac{\dot{Q}_{Giriş}}{T_{çıkış}} + S_{Gen,Evap} = 0$

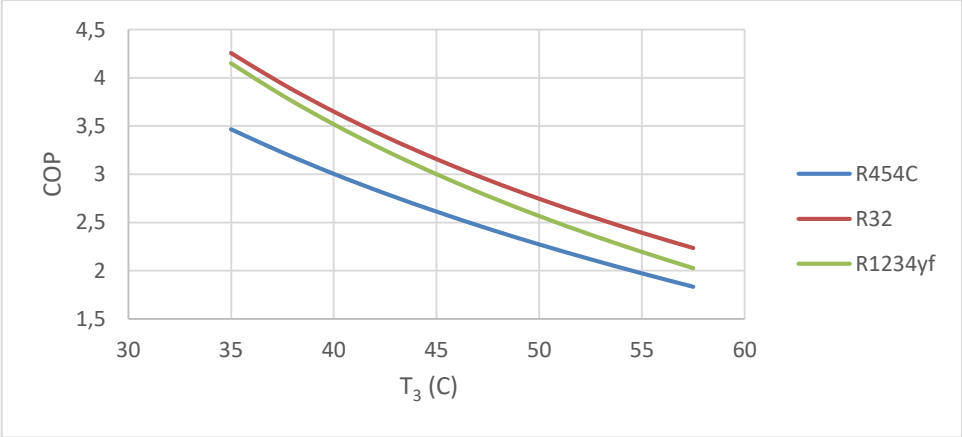
Ekserji analizi kapsamında, çevrimdeki her bileşen için giriş ve çıkış ekserjileri dikkate alınarak denge denklemleri kurulmuştur. Kompresörde sağlanan mekanik işin ne kadarının faydalı enerjiye dönüştüğü, kondenserde ise ısı atımı sırasında oluşan kayıplar değerlendirilmiştir. Genleşme valfindeki tüm ekserji farkı doğrudan kayıp olarak kabul edilmiştir. Evaporatörde, iç ortamdan alınan ısının ne kadarının kullanılabilir enerjiye dönüştüğü belirlenmiştir. Bu analizle birlikte, her bir bileşenin sistemdeki performansa katkısı ve neden olduğu kayıplar sayısal olarak ortaya konmuştur.

Tablo 2 Akış hattının ekserji dengesi ve ekserji verimi denklemleri (Akçay, 2025).

Materyal	Aralık	Ekserji Dengesi	Ekserji verimi
Kompresör	1-2	$\dot{E}x_1 + \dot{w}_{Komp} + = Ex_2 + \dot{E}_{x,kayıp,komp}$	$\eta_{ex,Komp} = \frac{\dot{E}x_2 - \dot{E}x_1}{\dot{w}_{Komp}}$
Kondenser	2-3	$\dot{E}x_2 = +\dot{E}x_3 + Q_{çıkış}(1 - \frac{T_0}{T_{çıkış}}) + \dot{E}_{x,kayıp,Kond}$	$\eta_{ex,Kondenser} = \frac{\dot{E}x_3}{\dot{E}x_2}$
Genleşme Valfi	3-4	$\dot{E}x_3 = \dot{E}x_4 + \dot{E}_{kayıp,GenVal.}$	$\eta_{ex,GenVal.} = \frac{\dot{E}x_4}{\dot{E}x_3}$
Evaporatör	4-1	$\dot{E}x_4 + Q_{in}(1 - \frac{T_0}{T_{giriş}}) = \dot{E}x_1 + +\dot{E}_{x,kayıp,Evap}$	$\eta_{ex,Evap} = \frac{\dot{E}x_1 - E_{ex,4}}{\dot{Q}_{Giriş}(1 - \frac{T_0}{T_{in}})}$

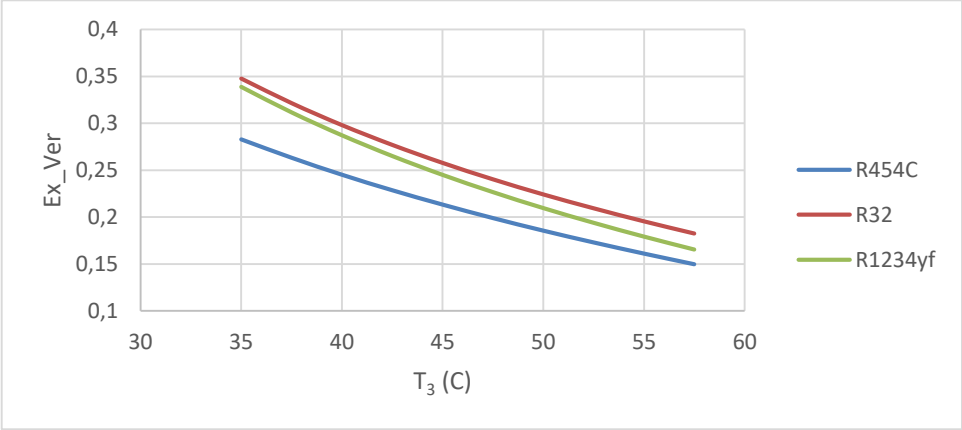
SONUÇLAR

Şekil 2'de, farklı soğutucu akışkanların COP (performans katsayısı) değerlerinin yoğuşma sıcaklığına (T_3) bağlı olarak değişimi gösterilmiştir. Grafik incelendiğinde, tüm akışkanlar için COP değerinin artan yoğuşma sıcaklığıyla birlikte azaldığı görülmektedir. Bu durum, daha yüksek yoğuşma sıcaklıklarında kompresörün daha fazla iş yapması ve çevrim verimliliğinin düşmesiyle ilişkilidir.



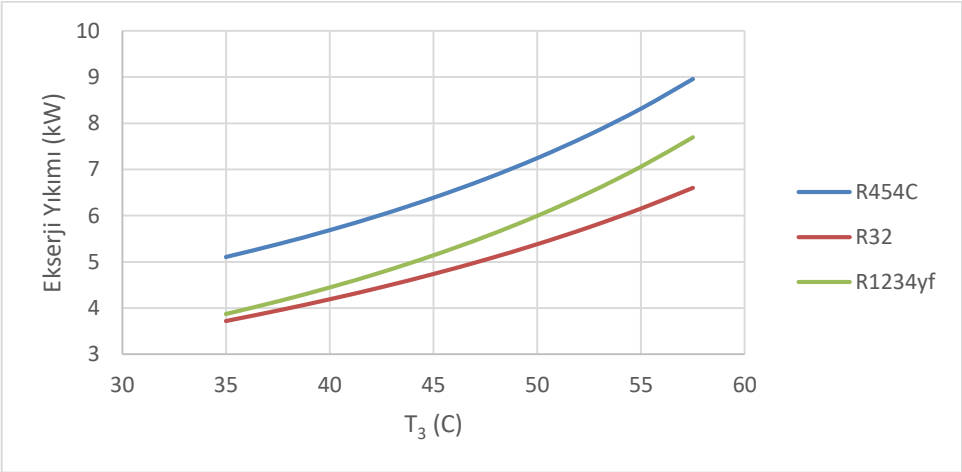
Şekil 2. COP değerinin yoğuşma sıcaklığına (T3) bağlı olarak değişimi

R32, tüm sıcaklık aralıklarında en yüksek COP değerine sahip olup, sistem verimliliği açısından en avantajlı akışkan olarak öne çıkmaktadır. R1234yf, R32'ye kıyasla daha düşük COP değerleri sunsa da çevre dostu yapısı nedeniyle tercih edilebilir bir alternatiftir. R452A ise her sıcaklık seviyesinde en düşük COP değerini göstermiş ve verimlilik açısından en zayıf performansı sergilemiştir. Bu sonuçlar, yoğuşma sıcaklığının sistem performansı üzerinde belirleyici bir etkiye sahip olduğunu ve özellikle yüksek sıcaklıklarda R32 gibi termodinamik açıdan güçlü akışkanların tercih edilmesinin verimlilik açısından avantaj sağladığını ortaya koymaktadır.



Şekil 3. Ekserji veriminin yoğuşma sıcaklığına (T_3) bağlı olarak değişimi

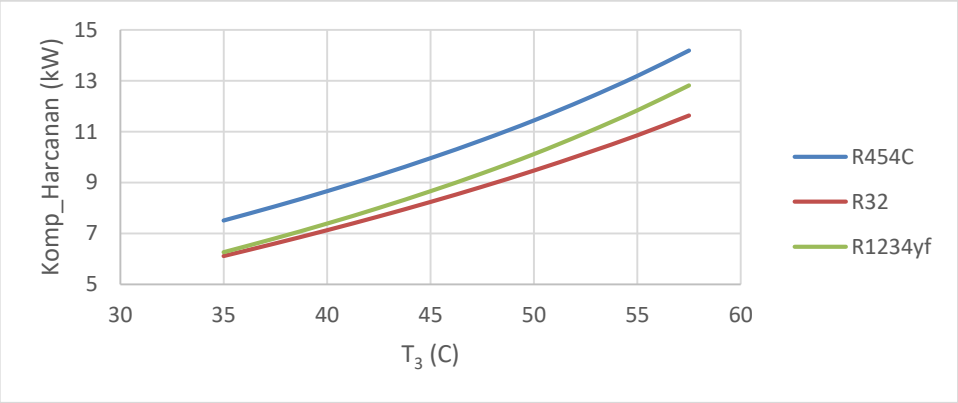
Şekil 3'te, R32, R1234yf ve R454C soğutucu akışkanları için ekserji veriminin farklı yoğuşma sıcaklıklarında nasıl değiştiği gösterilmektedir. Grafik incelendiğinde, tüm akışkanlar için ekserji veriminin T_3 sıcaklığı arttıkça belirgin şekilde azaldığı görülmektedir. Bu azalma, yüksek yoğuşma sıcaklıklarında sistemin daha fazla geri döndürülemezliğe maruz kalmasından ve dolayısıyla kullanılabilir enerji miktarının düşmesinden kaynaklanmaktadır. Üç akışkan arasında R32, tüm sıcaklık aralığında en yüksek ekserji verimini sağlayarak çevrim içindeki termodinamik kalitesi en yüksek akışkan olarak öne çıkmaktadır. R1234yf ise R32'ye yakın değerlere ulaşmakta, R454C ise her sıcaklık aralığında en düşük verim değerlerini göstermektedir. Özellikle 55 °C'ye yaklaşan değerlerde bu farklar daha belirgin hâle gelmektedir. Bu sonuçlar, sadece COP açısından değil, ekserji temelli değerlendirmelerde de akışkan seçiminin çevrimin genel verimliliği üzerinde kritik rol oynadığını göstermektedir. Ekserji verimi, çevrimdeki enerji dönüşümlerinin ne kadar etkin gerçekleştirildiğini ortaya koyduğundan, bu grafik sistem performansının daha derinlemesine değerlendirilmesine katkı sağlamaktadır.



Şekil 4. Ekserji yıkımının yoğuşma sıcaklığına (T_3) bağlı olarak değişimi

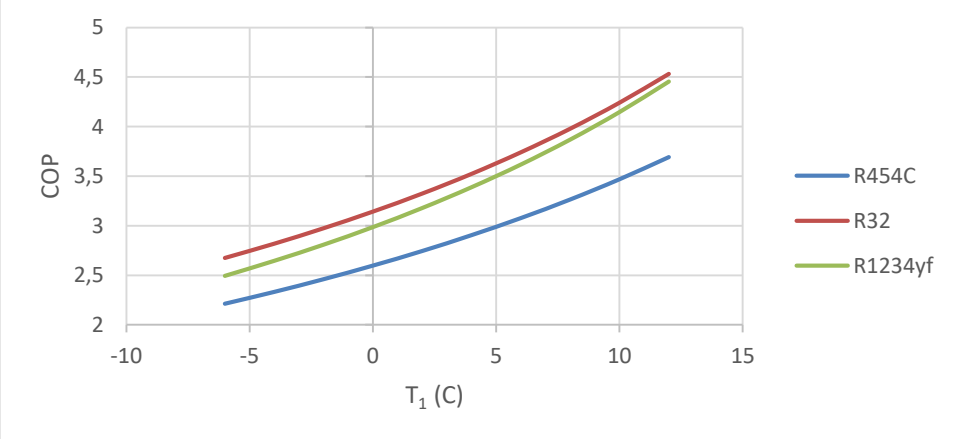
Şekil 4'te, farklı soğutucu akışkanlar için toplam ekserji yıkımının yoğuşma sıcaklığına bağlı değişimi gösterilmiştir. Grafik, T3 sıcaklığı arttıkça sistemde oluşan ekserji yıkımının belirgin biçimde yükseldiğini ortaya koymaktadır. Bu durum, yoğuşma sıcaklığı arttıkça çevrimdeki geri döndürülemezliklerin artmasına ve termodinamik kalite kaybının yükselmesine bağlanabilir. R32, tüm sıcaklık aralığında en düşük ekserji yıkımına sahip olarak çevrim boyunca en az kayıpla çalışan akışkan konumundadır. R1234yf benzer eğilim sergilese de, özellikle 50 °C ve üzeri sıcaklıklarda R32'den daha fazla yıkım göstermektedir. R454C ise her sıcaklık değerinde en yüksek ekserji kaybına sahip akışkan olarak dikkat çekmektedir ve bu da onun çevrimdeki verimsizliğini doğrulamaktadır. Bu sonuçlar, sistemdeki toplam kayıpların özellikle kondenser çıkış sıcaklığı ile doğrudan ilişkili olduğunu, bu nedenle yoğuşma sıcaklığı

arttıkça sistemin geri kazanılamayan enerji miktarının da arttığını açıkça ortaya koymaktadır. Ekserji yıkımı yönünden yapılan bu karşılaştırma, sadece enerji değil kalite temelli analizlerin de soğutucu akışkan seçimi açısından kritik olduğunu göstermektedir.



Şekil 5. Kompresörde harcanan gücün yoğuşma sıcaklığına (T_3) bağlı olarak değişimi

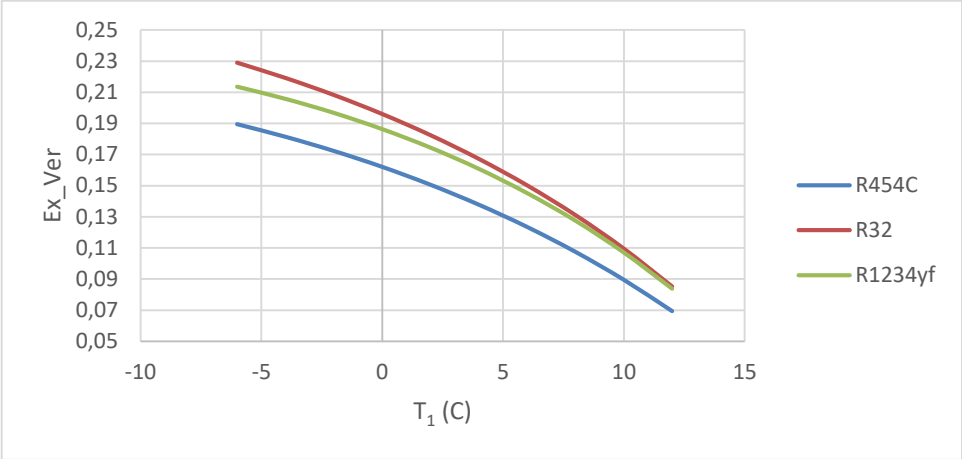
Şekil 5'te, farklı soğutucu akışkanlar için kompresörde harcanan gücün yoğuşma sıcaklığına bağlı olarak nasıl değiştiği gösterilmiştir. Grafik verileri, T_3 sıcaklığı arttıkça tüm akışkanlar için kompresörün daha fazla güç tükettiğini açıkça ortaya koymaktadır. Bu artış, yoğuşma sıcaklığı yükseldikçe basınç oranının ve buna bağlı olarak sıkıştırma işinin artmasından kaynaklanmaktadır. R454C, tüm sıcaklık aralığında en yüksek kompresör gücü ihtiyacını doğuran akışkan olmuştur. Bu durum, sistemin enerji tüketimi açısından daha düşük performansa sahip olduğunu göstermektedir. R32 ve R1234yf daha düşük güç değerleri sergilemekte olup, özellikle R32 en az enerji gereksinimiyle çalışarak sistemin toplam tüketimini minimize etmektedir. Bu bulgular, kompresör gücü açısından değerlendirildiğinde R32'nin en verimli alternatif olduğunu ve R454C'nin enerji tüketimi yönünden dezavantajlı konumda bulunduğunu göstermektedir. Ayrıca artan yoğuşma sıcaklığının kompresör yükü üzerindeki etkisi, sistem tasarımında bu parametrenin dikkate alınmasının ne kadar önemli olduğunu ortaya koymaktadır.



Şekil 6. COP değerinin buharlaşma sıcaklığına (T_1) bağlı olarak değişimi

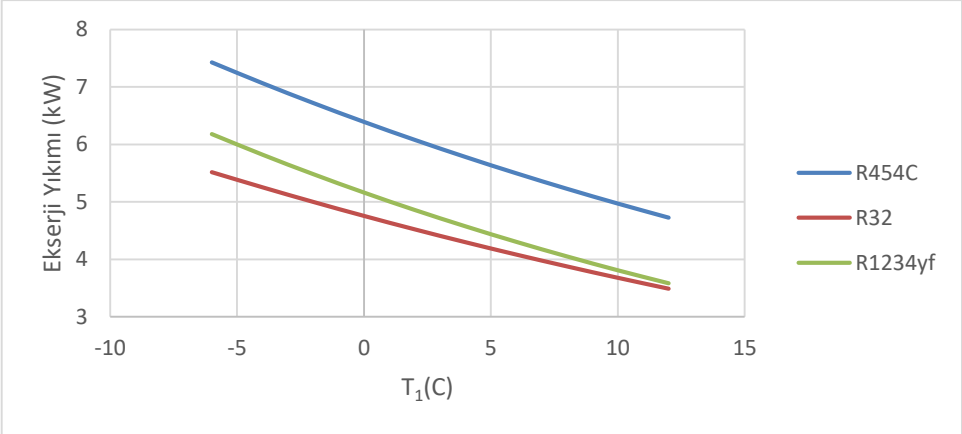
Şekil 6'da, COP (performans katsayısı) değerlerinin buharlaşma sıcaklığına bağlı değişimi gösterilmiştir. Tüm akışkanlar için benzer bir eğilim gözlemlenmekte; buharlaşma sıcaklığı arttıkça COP değerlerinde belirgin bir artış meydana gelmektedir. Bunun nedeni, buharlaşma sıcaklığı yükseldikçe kompresörün daha az enerji harcayarak çevrimi tamamlayabilmesi ve dolayısıyla sistem verimliliğinin artmasıdır. R32, tüm sıcaklık aralığında en yüksek COP değerlerini sağlayarak yine en verimli akışkan olarak öne çıkmıştır. R1234yf, özellikle düşük sıcaklıklarda R32'nin gerisinde kalmakla birlikte, artan sıcaklıkla birlikte performansını iyileştirerek benzer COP seviyelerine ulaşmaktadır. R454C ise incelenen sıcaklık aralığında en düşük COP değerlerine sahip olmuş ve sistemin enerji verimliliği açısından en zayıf

performansı sergilemiştir. Bu sonuçlar, buharlaşma sıcaklığının artırılmasının COP üzerindeki olumlu etkisini açıkça göstermekte ve soğutucu akışkan seçiminin yanı sıra çalışma koşullarının da sistem verimliliği üzerinde önemli rol oynadığını ortaya koymaktadır.



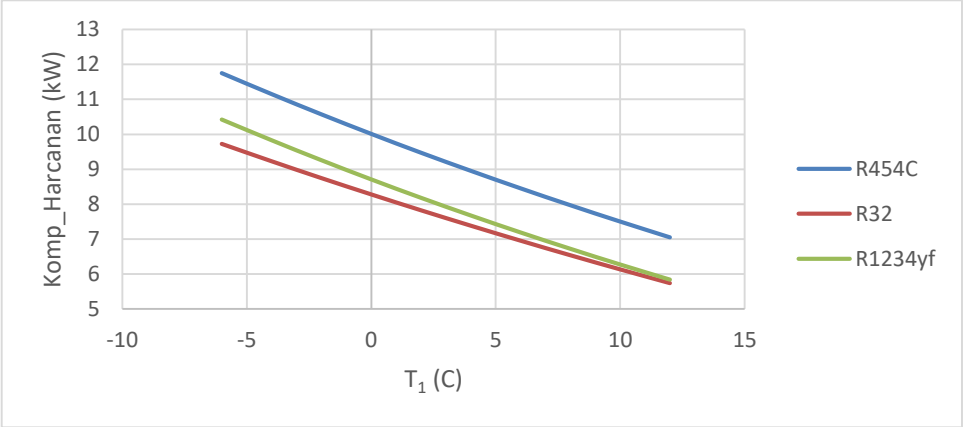
Şekil 7. Ekserji veriminin buharlaşma sıcaklığına (T_1) bağlı olarak değişimi

Şekil 7'de, farklı soğutucu akışkanlar için ekserji veriminin buharlaşma sıcaklığına bağlı olarak değişimi sunulmuştur. Grafik incelendiğinde, buharlaşma sıcaklığı arttıkça ekserji veriminin tüm akışkanlar için düştüğü görülmektedir. Bu düşüş, daha yüksek buharlaşma sıcaklıklarında sistemdeki enerji dönüşüm süreçlerinin daha az geri kazanılabilir hâle gelmesiyle ilişkilendirilebilir. R32, tüm sıcaklık aralıklarında en yüksek ekserji verimini sağlayarak çevrimdeki enerjiyi en etkin biçimde kullanan akışkan olmuştur. R1234yf ise R32'ye yakın değerlere sahip olup özellikle çevresel açıdan sunduğu avantajlarla öne çıkmaktadır. Buna karşın R454C, düşük termodinamik kalite nedeniyle en düşük ekserji verimini sergilemiştir.



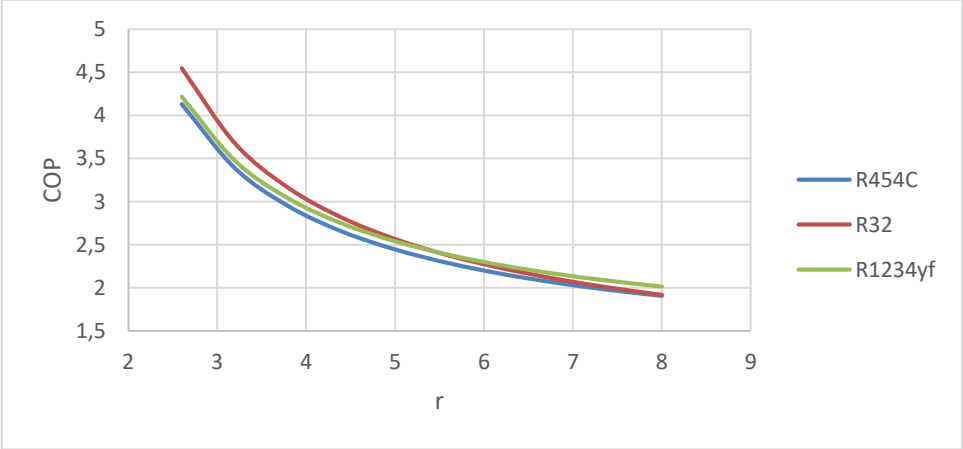
Şekil 8.Ekserji yıkımının buharlaşma sıcaklığına (T_1) bağlı olarak değişimi

Şekil 8'de, sistemde gerçekleşen toplam ekserji yıkımının buharlaşma sıcaklığına bağlı olarak nasıl değiştiği görülmektedir. Tüm soğutucu akışkanlar için benzer bir eğilim söz konusudur: buharlaşma sıcaklığı arttıkça sistemdeki ekserji yıkımı azalmaktadır. Bunun nedeni, daha yüksek buharlaşma sıcaklıklarında çevrimdeki geri döndürülemezliklerin azalması ve sistemin daha dengeli çalışmasıdır. R454C, tüm sıcaklık aralığında en yüksek ekserji yıkımını oluşturan akışkan olmuştur. Bu durum, sistemin enerji kalitesini korumakta yetersiz kaldığını ve geri kazanılamayan enerji miktarının fazla olduğunu göstermektedir. Buna karşın R32, en düşük ekserji yıkımıyla çalışarak daha etkin ve sürdürülebilir bir performans sunmaktadır. R1234yf ise orta seviyede yıkım sergilemekle birlikte çevre dostu yapısıyla avantaj sağlamaktadır.



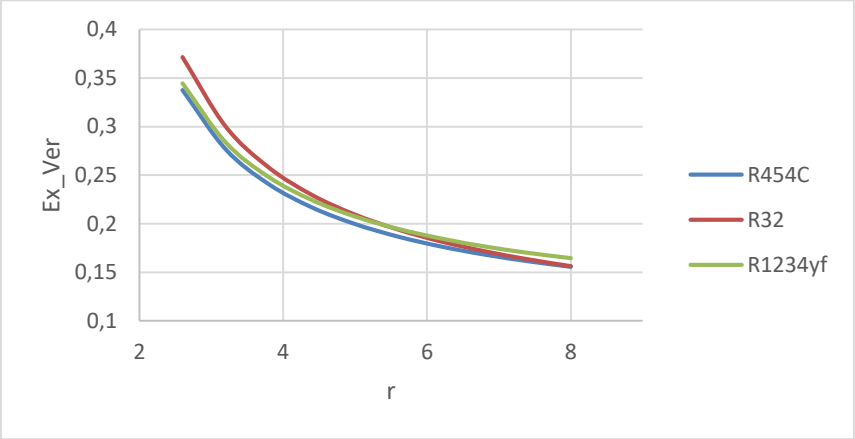
Şekil 9.Kompresörde harcanan gücün buharlaşma sıcaklığına (T_1) bağlı olarak değişimi

Şekil 9'da, farklı soğutucu akışkanlar için kompresörde harcanan gücün buharlaşma sıcaklığına bağlı olarak nasıl değiştiği gösterilmektedir. Grafikte açıkça görüldüğü üzere, buharlaşma sıcaklığı yükseldikçe kompresörün ihtiyaç duyduğu güç azalmaktadır. Bunun temel nedeni, daha yüksek buharlaşma sıcaklıklarında basınç oranının ve dolayısıyla sıkıştırma işinin düşmesidir. R454C, tüm sıcaklık aralığında en yüksek kompresör gücü gereksinimini ortaya koyarak enerji tüketimi açısından en dezavantajlı akışkan olmuştur. R32, en düşük güç tüketimiyle sistemin enerji verimliliğini en iyi şekilde yansıtmış; R1234yf ise R32'ye yakın değerlerle çalışmasına rağmen bir miktar daha fazla enerji harcamıştır. Bu bulgular, sistem tasarımında enerji tüketiminin minimize edilmesi açısından hem buharlaşma sıcaklığının hem de soğutucu akışkan tipinin önemli parametreler olduğunu ortaya koymaktadır. Enerji verimliliği yüksek uygulamalar için, düşük kompresör gücü gerektiren akışkanların tercih edilmesi kritik öneme sahiptir.



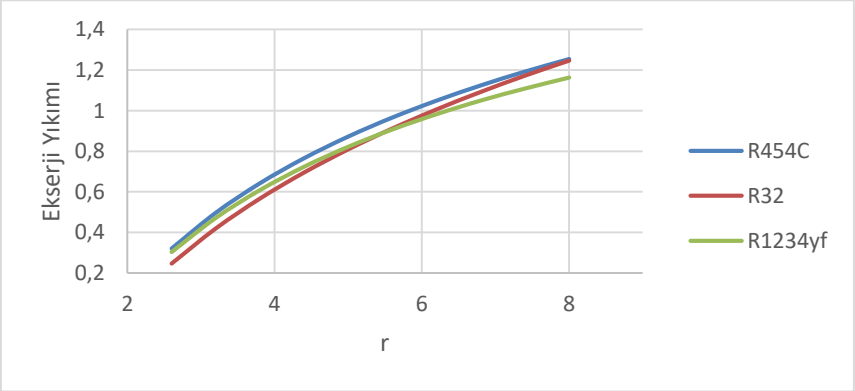
Şekil 10. COP değerinin sıkıştırma oranına (r) bağlı olarak değişimi

Şekil 10'da, farklı soğutucu akışkanlar için performans katsayısının (COP) sıkıştırma oranına bağlı olarak gösterdiği değişim yer almaktadır. Grafik incelendiğinde, sıkıştırma oranı arttıkça COP değerinin tüm akışkanlar için belirgin biçimde azaldığı görülmektedir. Bu eğilim, artan sıkıştırma oranının kompresörde harcanan işi artırması ve çevrim verimliliğini düşürmesiyle açıklanabilir. R32, düşük sıkıştırma oranlarında en yüksek COP değerine ulaşarak çevrimde en yüksek termodinamik verimliliği sağlamıştır. R1234yf, benzer performansı sürdüren bir diğer akışkan olup çevre dostu özellikleriyle tercih edilebilirliğini artırmaktadır. R454C ise genel olarak en düşük COP değerlerine sahip olmuş ve özellikle yüksek sıkıştırma oranlarında belirgin performans kaybı göstermiştir. Bu analiz, sıkıştırma oranının yalnızca sistem bileşenlerini değil, aynı zamanda akışkanın performansını da doğrudan etkilediğini göstermektedir. Verimli bir sistem tasarımı için, sıkıştırma oranı dikkatle seçilmeli ve akışkan özellikleriyle uyumlu olacak şekilde optimize edilmelidir.



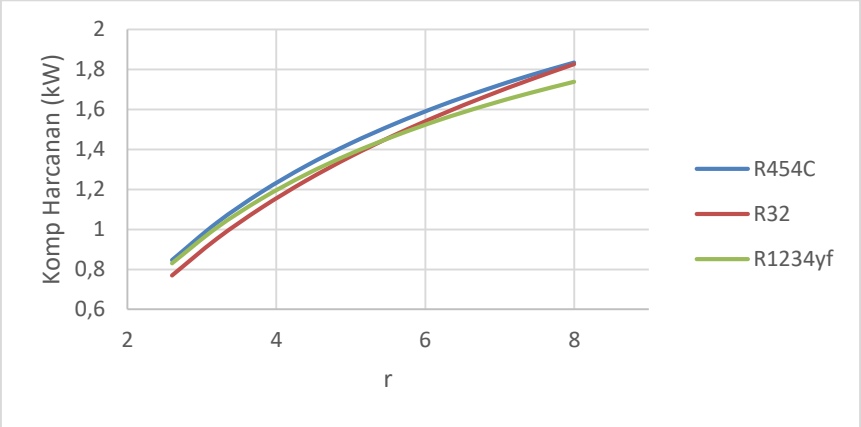
Şekil 11. Ekserji veriminin sıkıştırma oranına (r) bağlı olarak değişimi

Şekil 11'de, ekserji veriminin farklı sıkıştırma oranlarında nasıl değiştiği gösterilmektedir. Grafik genel olarak, sıkıştırma oranı arttıkça ekserji veriminin azaldığını ortaya koymaktadır. Bu durum, artan sıkıştırma oranıyla birlikte çevrimdeki geri döndürülemezliklerin yükselmesi ve buna bağlı olarak enerjinin kalite açısından kayba uğramasıyla açıklanabilir. Düşük sıkıştırma oranlarında R32 en yüksek ekserji verimine ulaşarak termodinamik anlamda en az kayıpla çalışan akışkan olmuştur. R1234yf, R32'ye benzer performans sergilerken çevre dostu yapısıyla da avantaj sunmaktadır. R454C ise düşük verim değerleriyle bu iki akışkanın gerisinde kalmıştır. Ancak sıkıştırma oranı arttıkça tüm akışkanlar benzer performans eğilimleri göstererek birbirine yakın değerlere ulaşmaktadır. Bu sonuçlar, ekserji verimliliğinin sıkıştırma oranına duyarlı olduğunu ve optimum bir oran seçiminin sistemin genel sürdürülebilirliğini önemli ölçüde etkileyebileceğini göstermektedir.



Şekil 12. Ekserji yıkımının sıkıştırma oranına (r) bağlı olarak değişimi

Şekil 12'de, sistemdeki toplam ekserji yıkımının sıkıştırma oranına göre değişimi gösterilmiştir. Grafik, sıkıştırma oranı arttıkça tüm akışkanlar için ekserji yıkımının da arttığını açıkça ortaya koymaktadır. Bu durum, kompresör işinin artmasına paralel olarak çevrimdeki geri döndürülemezliklerin büyümesinden kaynaklanmaktadır. Tüm sıkıştırma oranı aralıklarında R454C en yüksek ekserji kaybına neden olan akışkan olurken, R32 en düşük kayıpla çalışmıştır. R1234yf ise bu iki akışkan arasında orta düzeyde bir ekserji yıkımı sergilemiştir. Yüksek sıkıştırma oranlarında akışkanlar arasındaki fark azalsa da, R32'nin daha düşük geri döndürülemezlik üretmesi dikkat çekicidir.



Şekil 13. Kompresörde harcanan gücün sıkıştırma oranına (r) bağlı olarak değişimi

Şekil 13'te gösterildiği üzere, sıkıştırma oranındaki artış kompresör gücü ihtiyacını belirgin şekilde artırmaktadır. Bu eğilim, çevrimdeki basınç farkının yükselmesiyle birlikte kompresörün daha fazla enerji tüketmesine yol açtığını ortaya koymaktadır. Tüm akışkanlar için benzer bir artış eğilimi gözlemlense de, R454C'nin her sıkıştırma oranı seviyesinde en yüksek güç tüketimine sahip olduğu görülmektedir. R32, düşük güç gereksinimiyle öne çıkarken; R1234yf ise ara değerlerde kalmıştır. Bu sonuç, enerji verimliliği açısından R32'nin kompresör yükü bakımından daha avantajlı olduğunu göstermektedir. Bu analiz, sıkıştırma oranı arttıkça sistemin daha yüksek enerji girdisine ihtiyaç duyduğunu ve akışkan seçiminin kompresör performansı üzerinde doğrudan etkili olduğunu göstermektedir.

TARTIŞMA

Bu çalışmada, soğutmalı taşıma sistemlerinde kullanılan R32, R1234yf ve R454C soğutucu akışkanlarının, buhar sıkıştırmalı çevrim üzerindeki termodinamik ve ekserjetik etkileri karşılaştırmalı olarak değerlendirilmiştir. Elde edilen bulgular, her bir akışkanın performans karakteristiğinin; termofiziksel özelliklerine, çevrim koşullarına ve uygulama sıcaklıklarına bağlı olarak belirgin şekilde değiştiğini göstermektedir. R32, yüksek ısı transfer kabiliyeti ve düşük viskozitesi sayesinde, sistem genelinde en yüksek COP ve ekserji verimi değerlerine ulaşmıştır. Kompresör tarafından harcanan enerji de diğer akışkanlara göre daha düşüktür. Bu durum, R32'nin enerji verimliliği odaklı uygulamalarda güçlü bir aday olduğunu ortaya koymaktadır. R1234yf ise özellikle düşük küresel ısınma potansiyeli (GWP) ile çevresel açıdan öne çıkmakta, ancak performans bakımından R32'nin gerisinde kalmaktadır. Bununla birlikte, düşük enerji tüketimi ve çevre dostu yapısı, R1234yf'yi sürdürülebilirlik öncelikli uygulamalarda cazip kılmaktadır.

R454C ise, doğrudan bir saf akışkan olmayıp R32 ve R1234yf karışımından oluşan izeotropik bir yapıya sahiptir. Bu yapı, teorik olarak R32'nin yüksek performansını ve R1234yf'nin çevresel avantajlarını bir araya getirmeyi amaçlamaktadır. Ancak grafiklerden elde edilen bulgular, R454C'nin bu ideal birleşimi tam anlamıyla sağlayamadığını ortaya koymaktadır. Özellikle COP, ekserji verimi ve kompresör gücü bakımından R454C, bileşenlerinin her birinden daha düşük bir performans sergilemiştir. Bunun temel nedeni, izeotropik karışımların ısı değişim süreçlerinde meydana gelen sıcaklık kaymaları ve bunun sonucunda oluşan termodinamik dengesizliklerdir. Bu durum, sistem verimliliğini olumsuz yönde etkileyerek ekserji kayıplarını artırmaktadır. Ayrıca, T_3 ve T_1 sıcaklıklarının artmasıyla birlikte tüm akışkanlarda performans parametrelerinde belirgin değişimler gözlemlenmiştir. Özellikle R454C'nin kompresör enerji tüketimindeki hızlı artış, bu akışkanın taşınabilir uygulamalarda daha fazla yakıt harcamasına ve dolayısıyla daha yüksek işletme maliyetlerine yol açabileceğini göstermektedir. Aynı şekilde, sıkıştırma oranına bağlı olarak R454C'nin COP değerindeki düşüş ve ekserji yıkımındaki artış da bu akışkanın çevrim stabilitesi açısından dezavantajlı

olduğunu ortaya koymaktadır. Genel değerlendirme yapıldığında, R32'nin yüksek verim ve düşük kayıplar açısından öne çıktığı, R1234yf'nin ise çevresel regülasyonlara uyumlu alternatif bir akışkan olarak değerlendirilebileceği anlaşılmaktadır. R454C ise, her ne kadar geçiş dönemi için dengeli bir çözüm sunma hedefiyle tasarlanmış olsa da, sistem düzeyinde daha fazla mühendislik optimizasyonu gerektirmektedir. Bu nedenle, R454C'nin uygulanabilirliği yalnızca termodinamik değil, aynı zamanda sistem bileşen uyumu ve işletme senaryoları dikkate alınarak kapsamlı biçimde analiz edilmelidir.

KAYNAKÇA

Rosetti, A., Marinetti, S., Artuso, P., Fabris, F., Minetto, S. (2022). Implementation of a Solar Aided Refrşgration Unit For Refrigerated Trucks Employing Photovoltaic Generators, *Energy Reports*, https://doi.org/10.1016/j.egyr.2022.05.284

Liu, M., Saman, W., Bruno, F. (2012). Development Of a Novel Refrigeration System For System For Refrigerated Trucks İncorporating Phase Change Material, *Applied Energy*, doi:10.1016/j.apenergy.2011.10.015

Maiorino, A., Petruzziello, F., Aprea, C. (2021) Refrigerated Transport: State of the Art, Technical Issues, Innovations and Challenges for Sustainability, *Energies*, 14(21), https://doi.org/10.3390/en14217237

Alsouda, F., Bennett, N, S., Saha, S, C., Salehi, F., İslam, S, M. Vapor Compression Cycle: A State-of-the-Art Review on Cycle Improvements, Water and Other Natural Refrigerants, *Clean Technol*, 5(2), https://doi.org/10.3390/cleantechnol5020030

Ablanque, N., Torras, S., Oliet, C., Rigola, J., Castro, J., Vila, J., & Martinez, S. (2024). Thermal System Simulation Analysis of R452A Refrigeration System and Possible Refrigerant Alternatives.

Akçay, E. (2025). Katı yakıtlı kombine çevrimlerin performans ve ekserji analizi, (Yüksek Lisans Tezi), *Bayburt Üniversitesi Lisansüstü Eğitim Enstitüsü*

THERMODYNAMIC COMPARISON OF R452A REFRIGERANT: AN EXERGY-BASED ANALYSIS FOR AUTOMOTIVE AIR CONDITIONING SYSTEMS

R452A SOĞUTUCU AKIŞKANININ TERMODİNAMİK AÇIDAN KARŞILAŞTIRILMASI: OTOMOBİL KLİMA SİSTEMLERİ İÇİN EKSERJİ TABANLI BİR ANALİZ

M.Sc. Eng. Enes AKÇAY

Bayburt University

ORCID: 0000-0001-9665-8787

Lecturer Dr. Arzu KEVEN

Kocaeli University, Gölcük Vocational School

ORCID: 0000-0003-0040-9167

ABSTRACT

In this study, the thermodynamic performance of various refrigerants used in automotive air conditioning systems was theoretically compared. The analysis was based on a standard vapor-compression refrigeration cycle. The refrigerants examined included pure R32, R125, and R1234yf gases, as well as the blended refrigerant R452A, which consists of 11% R32, 59% R125, and 30% R1234yf by mass. All calculations were conducted using the Fortran programming language, widely used in engineering applications. The compression ratio was considered the primary variable in the analysis. Based on its variation, key performance indicators such as exergy efficiency, COP, compressor work, total exergy loss, and condenser heat rejection were evaluated. The results revealed that each refrigerant exhibits distinct thermodynamic behavior. R1234yf stood out as the most balanced and environmentally favorable option due to its low energy consumption and high exergy efficiency. R125, on the other hand, imposed the highest compressor power demand and total exergy loss. R452A, as a mixture, demonstrated improved performance compared to R125 and R32, but remained less advantageous than pure R1234yf. In conclusion, the selection of refrigerants in automotive air conditioning systems should be assessed not only in terms of energy efficiency but also with regard to environmental impact, component compatibility, and long-term sustainability.

Keywords: Compression Ratio, Energy and Exergy, Air Conditioning

ÖZET

Bu çalışmada, araç klima sistemlerinde kullanılan farklı soğutucu akışkanların termodinamik performansları teorik olarak karşılaştırılmıştır. İncelemede, temel bir buhar sıkıştırmalı soğutma çevrimi esas alınmıştır. Saf halde bulunan R32, R125 ve R1234yf gazları ile bu gazların belirli oranlarda karışımı olan R452A (%11 R32, %59 R125 ve %30 R1234yf) soğutucu akışkanının performans analizleri gerçekleştirilmiştir. Tüm hesaplamalar, mühendislik uygulamalarında yaygın olarak tercih edilen Fortran programlama dili kullanılarak yapılmıştır. Analiz kapsamında sıkıştırma oranı temel parametre olarak alınmış ve bu oranın

değişimine bağlı olarak çevrimin ekserji verimi, COP, kompresör işi, toplam ekserji kaybı ve kondenser ısı transferi gibi önemli performans göstergeleri değerlendirilmiştir. Bulgular, her bir akışkanın kendine özgü termodinamik davranışlar sergilediğini ortaya koymuştur. R1234yf, düşük enerji tüketimi ve yüksek ekserji verimi ile çevresel açıdan en dengeli alternatif olarak öne çıkarken; R125, en yüksek kompresör gücü ve toplam ekserji tüketimiyle sistem üzerinde en fazla yük oluşturan akışkan olmuştur. R452A ise, bileşenlerinin özelliklerini dengeleyen yapısıyla, R125 ve R32'ye göre daha verimli, ancak R1234yf'ye göre daha az avantajlı bir profil sergilemiştir. Sonuç olarak, araç klima sistemlerinde soğutucu akışkan seçiminin yalnızca enerji verimliliği değil; aynı zamanda çevresel etki, sistem bileşen uyumu ve uzun vadeli sürdürülebilirlik açısından da değerlendirilmesi gerektiği vurgulanmıştır.

Keywords: Sıkıştırma Ortanı, Enerji ve Ekserji, İklimlendirme

GİRİŞ

Günümüzde küresel ölçekte enerji tüketiminde düzenli ve sürekli bir artış gözlemlenmektedir (Hai, D., Dung, N,V., Phu, T,H,C., 2025). Soğutma sistemleri, hem evsel hem de ticari alanlarda yaygın olarak kullanılmaktadır. Dünya genelinde yaklaşık üç milyar soğutma sistemi bulunduğu tahmin edilmekte olup, bu sistemler toplam elektrik tüketiminin yaklaşık %17'sini oluşturmaktadır. Bu nedenle, enerji verimliliğini artırmak ve çev

resel etkileri en aza indirmek amacıyla çeşitli araştırmalar yürütülmektedir. Soğutma sistemlerinin performansında sağlanacak küçük bir artış dahi, enerji tüketimi üzerinde anlamlı bir fark yaratabilir (Saleh, vd., 2020). Ulaşım araçları, modern toplumların taşıyıcısı olarak, en fazla enerji tüketen sistemlerin başında gelmektedir. Dünya genelinde yaklaşık 1 milyar otomobil bulunmaktadır ve bu sayının 2035 yılına kadar iki katına çıkması beklenmektedir. Bu araçlar her yıl yüz milyarlarca galon yakıt tüketmektedir. Bu bağlamda ulaşım sektörü, küresel enerji tüketiminin yaklaşık %30'unu oluşturmaktadır ve bu tüketimin %90'ından fazlası fosil yakıtlara dayanmaktadır. Taşıtların fosil yakıtlara olan bu yüksek bağımlılığı, çevre üzerinde ciddi olumsuz etkiler yaratmaktadır. Ayrıca, iklim değişikliklerine bağlı olarak araçlarda klima sistemlerinin daha yoğun kullanımı, enerji tüketiminde önemli bir artışa yol açmıştır (Bentrcia, M., Alshatewi, M., Omar, H. 2017). Soğutma sistemlerinin enerji tüketimini azaltmak için performanslarının artırılması büyük önem taşımaktadır. Bu, kompresörün enerji tüketiminin azaltılması, kondansatörün ısı atım kapasitesinin artırılması ya da kondansatör ve evaporatör basınçları arasındaki farkın düşürülmesi gibi yöntemlerle sağlanabilir. Özellikle buharlaştırmalı (evaporatif) kondansatörler, kuru iklimlerde yüksek dış ortam sıcaklıklarından minimum düzeyde etkilenmeleri sayesinde avantaj sunmaktadır. (Harby vd, 2016). Buhar sıkıştırmalı soğutma çevrimleri gibi termodinamik sistemler, çevreye büyük miktarda ısı yayarlar. Sistem ile çevre arasındaki ısı geçişi sonlu bir sıcaklık farkıyla gerçekleştiğinden, bu durum çevrimde entropi üretimine neden olur. Bu entropi üretimleri, sistemin genel performansını olumsuz etkiler. Bu kayıpların belirlenebilmesi için çevrimi oluşturan her bir termodinamik sürecin ayrı ayrı değerlendirilmesi gerekir. Enerji analizi yalnızca enerjinin korunumu üzerine odaklanırken, ekserji analizi sistemin ne ölçüde idealden saptığını, nerede ve ne kadar performans kaybı olduğunu ortaya koyar (Ahamed, J,U., Saidur, R., Masjuki, H,H., 2011). Bir diğer husus ise buhar sıkıştırmalı soğutma çevrimlerinde kompresör, soğutucu akışkanın tipi enerji tüketiminin en yüksek olduğu olaylar olup, sistemin genel performansı üzerinde belirleyici bir etkiye sahip olmasıdır. Bu nedenle literatürde bu konu ile ilgili birçok çalışmada bulunmaktadır (İşkan vd., 2021).

KAVRAMSAL ÇERÇEVE

Bu çalışmanın kavramsal temeli, buhar sıkıştırmalı soğutma çevrimlerinin termodinamik prensiplerine dayanmaktadır. Özellikle, enerji ve ekserji analizleri aracılığıyla sistem

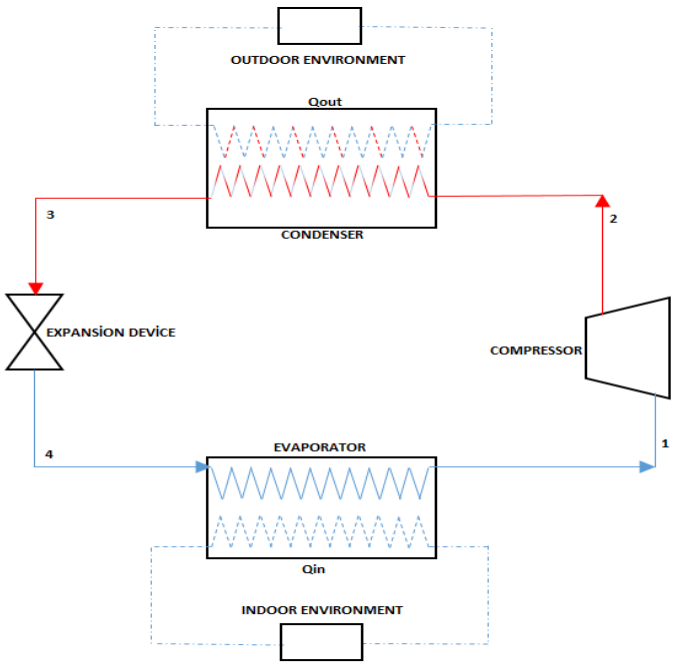
performansının kapsamlı bir şekilde değerlendirilmesi amaçlanmaktadır. Termodinamik sistemlerin enerji verimliliğini belirlemede klasik enerji analizleri yeterli olmakla birlikte, sistem bileşenlerindeki kalite kayıplarını ve gerçek kayıpları ortaya koymak için ekserji analizi daha etkili bir yaklaşımdır.

Araç klima sistemlerinde kullanılan farklı soğutucu akışkanlar, çevresel etkileri ve termodinamik özellikleri bakımından çeşitli avantaj ve dezavantajlara sahiptir. Bu çerçevede, R32, R125, R1234yf ve karışım bir akışkan olan R452A'nın sistem üzerindeki etkileri, sıkıştırma oranına bağlı olarak karşılaştırmalı bir şekilde incelenmiştir. Akışkanların seçimi, hem enerji tüketimini hem de sistemin çevresel sürdürülebilirliğini doğrudan etkilemektedir.

Bu çalışma kapsamında geliştirilen kavramsal model, sıkıştırma oranı değişkenine göre sistem performansını etkileyen anahtar parametrelerin belirlenmesi ve bu parametreler ışığında alternatif soğutucu akışkanların karşılaştırılması esasına dayanmaktadır. Böylece, elde edilen bulgular sadece teknik değil, aynı zamanda çevresel ve sürdürülebilirlik açısından da değerlendirilmektedir.

YÖNTEM

Şekilde 1'de bir buhar sıkıştırmalı soğutma çevrimi şematik olarak gösterilmiştir. Sistemin temel bileşenleri kompresör, kondenser, genleşme valfi ve evaporatörden oluşmaktadır. Çevrim, evaporatörde iç ortamdan alınan ısı sayesinde düşük basınç ve sıcaklıktaki soğutucu akışkanın buharlaşması ile başlar. Buharlaşan akışkan, 1 numaralı noktadan kompresöre girer ve burada basıncı ile birlikte sıcaklığı da artar. Kompresörden yüksek sıcaklık ve basınçta çıkan soğutucu akışkan (2 numaralı nokta), kondenserde dış ortam ile ısı alışverişi yaparak ısıyı dışarıya verir. Bu esnada akışkan yoğunlaşır ve sıvı fazına geçer. Kondenser çıkışında sıvı halde olan soğutucu akışkan (3 numaralı nokta), genişleme valfine gelir. Burada akışkanın basıncı ani bir şekilde düşürülerek sıcaklığının da düşmesi sağlanır. Genleşme sonrası oluşan düşük basınç ve düşük sıcaklıktaki sıvı-buhar karışımı (4 numaralı nokta), evaporatöre girerek tekrar ısı alır ve buharlaşır. Böylelikle çevrim sürekli olarak tekrarlanarak iç ortamdan ısı emilir ve dış ortama atılır, böylece soğutma sağlanmış olur.



Şekil 14. Sistemin genel akış şeması.

Tablo 1 ve tablo 2, buhar sıkıştırmalı soğutma çevriminde yer alan her bir ekipman için temel termodinamik denge denklemlerini sunar. Kütle denklemleri, her ekipmanda kütlenin korunumu ilkesine dayanır. Enerji denklemleri, entalpi değişimleri üzerinden sistemdeki ısı ve iş etkileşimlerini ifade eder. Ekserji denklemleri, her bir bileşenin çevreyle olan iş potansiyelini değerlendirerek performans analizine olanak tanır. Entropi denklemleri ise sistemdeki enerji dönüşümlerinin termodinamik doğrultusunu ve verimliliğini analiz etmek için kullanılır.

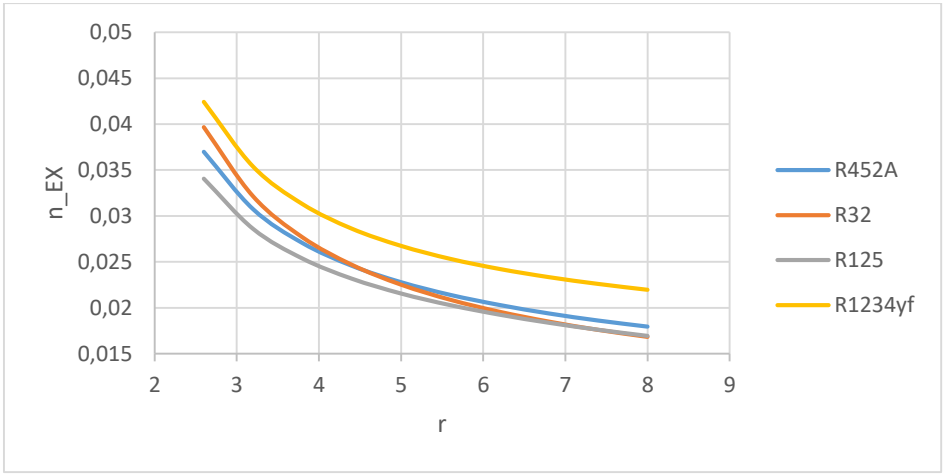
Tablo 3 Akışın kütle ile enerji dengesi ve entropi üretimi (Akçay, 2025).

Materyal	Aralık	Kütle Dengesi	Enerji Dengesi	Entropi Üretimi
Kompresör	1-2	$\dot{m}_1 = \dot{m}_2$	$\dot{m}_1 h_1 + \dot{W}_{Komp} = \dot{m}_2 h_2$	$m_1 s_1 - m_2 s_2 + S_{Gen,Komp} = 0$
Kondenser	2-3	$\dot{m}_2 = \dot{m}_3$	$\dot{m}_2 h_2 = \dot{Q}_{out} + \dot{m}_3 h_3$	$m_2 s_2 - m_3 s_3 + \frac{\dot{Q}_{Çıkış}}{T_{çıkış}} + S_{Gen,Kond} = 0$
Genleşme Valfi	3-4	$\dot{m}_3 = \dot{m}_4$	$h_3 = h_4$ (İzentropik)	$m_3 s_3 - m_4 s_4 + S_{Gen,GenVal.} = 0$
Evaporatör	4-1	$\dot{m}_4 = \dot{m}_1$	$\dot{m}_4 h_4 = \dot{Q}_{in} + \dot{m}_1 h_1$	$m_4 s_4 - m_1 s_1 + \frac{\dot{Q}_{Giriş}}{T_{çıkış}} + S_{Gen,Evap} = 0$

Tablo 4 Akış hattının ekserji dengesi ve ekserji verimi denklemleri (Akçay, 2025).

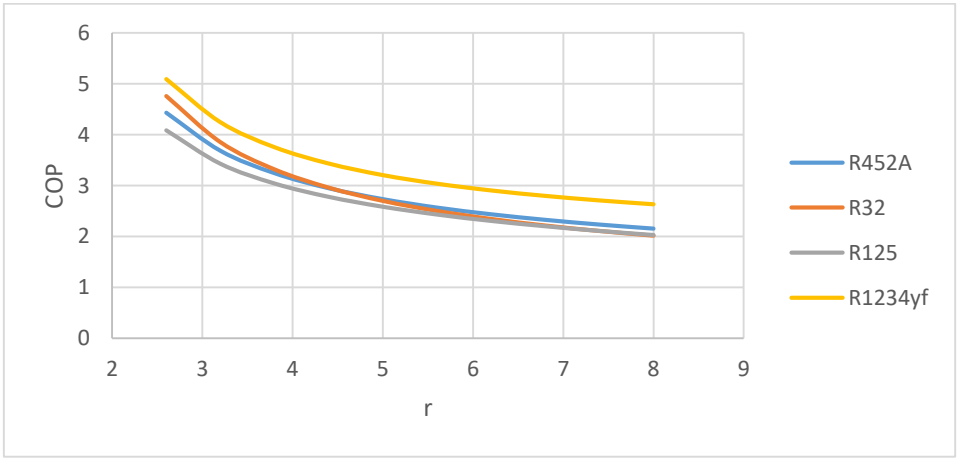
Materyal	Aralık	Ekserji Dengesi	Ekserji verimi
Kompresör	1-2	$\dot{E}x_1 + \dot{w}_{Komp} + = Ex_2 + \dot{E}_{x,kayıp,komp}$	$\eta_{ex,Komp} = \frac{\dot{E}x_2 - \dot{E}x_1}{\dot{w}_{Komp}}$
Kondenser	2-3	$\dot{E}x_2 = +\dot{E}x_3 + Q_{çıkış}(1 - \frac{T_0}{T_{çıkış}} + \dot{E}_{x,kayıp,Kond}$	$\eta_{ex,Kondenser} = \frac{\dot{E}x_3}{\dot{E}x_2}$
Genleşme Valfi	3-4	$\dot{E}x_3 = \dot{E}x_4 + \dot{E}_{kayıp,GenVal.}$	$\eta_{ex,GenVal.} = \frac{\dot{E}x_4}{\dot{E}x_3}$
Evaporatör	4-1	$\dot{E}x_4 + Q_{in}(1 - \frac{T_0}{T_{giriş}}) = \dot{E}x_1 + + \dot{E}_{x,kayıp,Evap}$	$\eta_{ex,Evap} = \frac{\dot{E}x_1 - E_{ex,4}}{\dot{Q}_{Giriş}(1 - \frac{T_0}{T_{in}})}$

SONUÇLAR



Şekil 15. Ekserji Veriminin Kompresör Basınç Oranı (r) Değişimine Karşı Davranışı

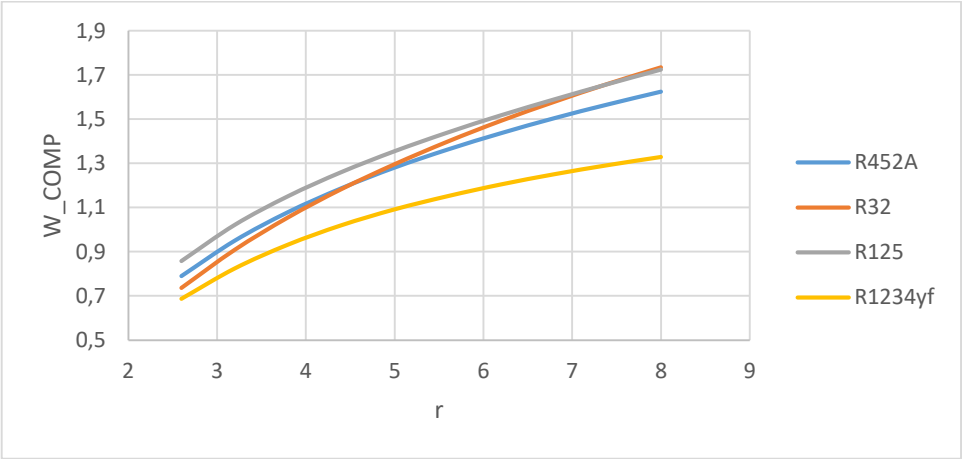
Şekil 2, soğutma çevriminde kullanılan dört farklı soğutucu akışkan için ekserji veriminin basınç oranına bağlı olarak nasıl değiştiğini göstermektedir. Grafik genel olarak, basınç oranı arttıkça tüm akışkanlar için ekserji veriminin düştüğünü ortaya koymaktadır. Bu durum, artan basınç oranlarının sistemde daha fazla tersinmezliğe yol açmasıyla doğrudan ilişkilidir. Akışkanlar arasında karşılaştırıldığında, R1234yf en yüksek ekserji verimini sağlayarak enerji kalitesi bakımından en avantajlı seçenek olarak öne çıkmaktadır. R32 ve R125 ise daha düşük verimlilik sergileyerek özellikle yüksek r değerlerinde sistem performansını sınırlayan akışkanlar olarak değerlendirilmiştir. R452A, içeriğinde R1234yf bulundurmasına rağmen R125'in olumsuz etkileri nedeniyle bu iki uç arasında konumlanmaktadır. Ekserji verimi, çevrimde kullanılan enerjinin ne kadarının işe dönüştürülebilir olduğunu ifade ettiğinden, bu grafik sistemin ikinci yasa performansını doğrudan yansıtmaktadır. Bu kapsamda, R1234yf yüksek verimlilik ve düşük enerji kaybı potansiyeli ile dikkat çekerken, R452A'nın performansı formülasyon bileşenlerinin dengesine bağlı olarak şekillenmektedir.



Şekil 16. Çevrim Performans Katsayısının (COP) Basınç Oranı (r) Değişimine Bağlı Davranışı

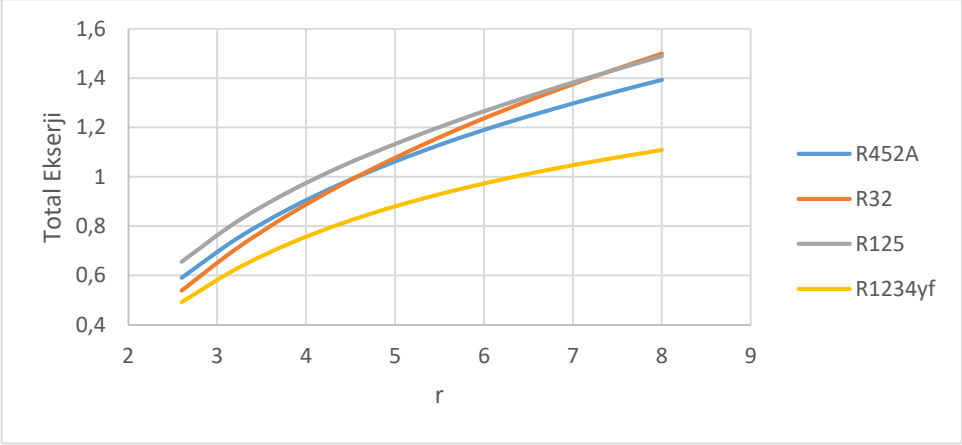
Şekil 3, soğutma çevriminde kullanılan dört farklı akışkan için COP değerinin basınç oranına bağlı olarak nasıl değiştiğini göstermektedir. Grafik genel olarak, basınç oranı arttıkça COP değerinin azaldığını ortaya koymaktadır. Bu durum, yüksek basınç oranlarında kompresörün daha fazla iş yapması, dolayısıyla çevrimin net enerji verimliliğinin düşmesi ile doğrudan ilişkilidir. Akışkanlar arasında karşılaştırıldığında, R1234yf en yüksek COP değerine sahip akışkan olarak öne çıkmaktadır. COP açısından R452A, karışımın R1234yf içermesine rağmen R125'in yüksek enerji ihtiyacı nedeniyle R32'ye yakın bir performans göstermektedir. R125

ise en düşük COP değerine sahip olup, çevrimdeki enerji etkinliğini sınırlamaktadır. COP değeri, sistemin enerji girdisi başına ne kadar soğutma sağladığını ifade ettiğinden, bu grafik genel verimliliğin görsel bir ifadesi niteliğindedir. Bu bağlamda, R1234yf yalnızca çevre dostu yapısıyla değil, aynı zamanda COP açısından da güçlü bir alternatif olarak öne çıkmaktadır.



Şekil 17. Kompresör Güç Tüketiminin Basınç Oranına (r) Bağlı Olarak Değişimi

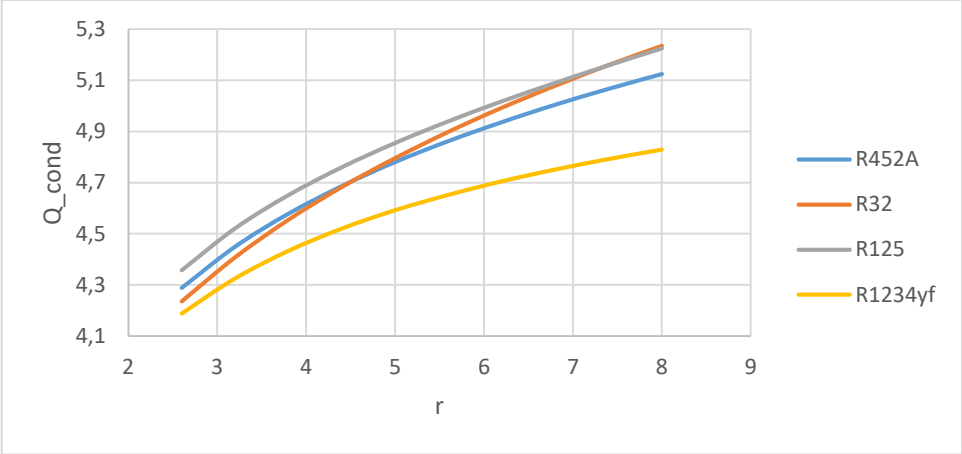
Şekil 4, dört farklı akışkan için kompresör tarafından tüketilen özgül işin basınç oranına bağlı değişimini göstermektedir. Grafik, r değeri arttıkça tüm akışkanlar için iş tüketiminin yükseldiğini açıkça ortaya koymaktadır. Bu artış, daha yüksek basınç farklarını oluşturmak için kompresörün daha fazla enerji harcamasının doğal bir sonucudur. Akışkanlar arasında en yüksek iş tüketimi R125 ile gözlenmiş, bu da onun çevrimde daha fazla enerjiye ihtiyaç duyduğunu göstermiştir. R32, R125'e yakın değerlere sahipken, R1234yf en düşük iş tüketimini sergileyerek enerji etkinliği açısından avantajlı bir profil çizmiştir. R452A ise R32 ve R125 arasında dengeli bir konumda yer almakta ve karışım bileşenlerinin toplam etkisini yansıtmaktadır. Kompresör iş tüketimi, sistemin elektriksel tüketimi ve işletme maliyetleri üzerinde doğrudan etkili olduğundan, bu grafik akışkan seçimi açısından belirleyici parametrelerden biridir.



Şekil 18. Toplam Ekserji Yıkımının Basınç Oranına (r) Göre Değişimi

Şekil 5, çevrimde tüketilen toplam ekserjinin basınç oranına bağlı olarak nasıl değiştiğini göstermektedir. Ekserji kayıpları, sistemdeki enerji kalitesinin düşmesiyle ilişkilidir ve genellikle tersinmezliklerin bir sonucu olarak ortaya çıkar. Grafik genel eğilim itibariyle, basınç oranı arttıkça toplam ekserji tüketiminin de yükseldiğini göstermektedir. R125, yüksek iş gereksinimi ve entropi üretimi nedeniyle en fazla ekserji tüketimine neden olan akışkan olarak öne çıkmaktadır. Bunu R32 ve R452A takip etmektedir. R1234yf ise tüm çalışma aralığında en düşük toplam ekserji tüketimi ile çevrimin ikinci yasa performansı açısından en avantajlı akışkan olarak belirlenmiştir. R452A'nın konumu, içerdiği R1234yf sayesinde daha iyi hale

gelmiş ancak R125'in yüksek kayıp karakteri nedeniyle idealin altında kalmıştır. Bu grafik, yalnızca enerji değil, enerji kalitesinin de değerlendirildiği bütüncül bir bakış açısı sunmaktadır.



Şekil 19. Yoğuşturucudan Atılan Isı Miktarının Basınç Oranına (r) Bağlı Olarak Değişimi

Şekil 6, soğutucu akışkanların yoğuşturucu (kondenser) üzerinden çevreye aktardığı ısı miktarının basınç oranına bağlı olarak nasıl değiştiğini göstermektedir. Basınç oranı arttıkça, kondenserden atılan ısının da belirgin biçimde arttığı gözlemlenmektedir. Bu artış, kompresörden çıkan akışkanın içerdiği entalpi miktarının yükselmesinden kaynaklanmaktadır. R125, sistemden en fazla ısı atan akışkan olarak öne çıkmakta ve bunu sırasıyla R32 ve R452A izlemektedir. R1234yf ise en düşük değerlerine sahiptir ve bu da çevreye daha az ısı atıldığı anlamına gelir. Bu durum, sistemin çevresel etkisinin azaltılması ve termal enerji geri kazanımı açısından önem arz etmektedir. R452A, karışım karakteriyle R125'in olumsuz etkisini kısmen dengelemiş ve daha orta düzeyde bir ısı atımı profili sergilemiştir. Bu grafik, sadece iç verimlilik değil, aynı zamanda dış çevresel etki açısından da değerlendirme yapılmasını gerektiren önemli bir parametreyi temsil etmektedir.

TARTIŞMA

Bu çalışmada, dört farklı soğutucu akışkanın (R452A, R32, R125 ve R1234yf) buhar sıkıştırmalı soğutma çevrimindeki performansları, basınç oranına bağlı olarak termodinamik ve ekserji parametreleri açısından karşılaştırılmıştır. Analiz sonuçları, akışkanların hem enerji tüketimi hem de ikinci yasa (ekserji) bazında önemli farklılıklar gösterdiğini ortaya koymuştur. Ekserji verimi açısından, R1234yf tüm çalışma aralığında en yüksek verimi sağlamış; bu da onu hem çevresel hem de enerji kalitesi açısından en dengeli akışkan haline getirmiştir. R452A, R1234yf içeriyor olmasına rağmen, karışımın diğer baskın bileşeni olan R125'in düşük verimliliği nedeniyle sınırlı bir performans sergilemiştir. R125, yüksek özgül iş ihtiyacı ve artan tersinmezlikleriyle en düşük ekserji verimini sağlayan akışkan olarak öne çıkarken; R32 ise bu bağlamda R125'e yakın sonuçlar vermiştir.

COP analizlerinde de benzer eğilimler gözlemlenmiş; R1234yf tüm basınç oranlarında en yüksek COP değerini korurken, R125 bu parametrede de en zayıf performansı sergilemiştir. R452A, bileşenlerinin etkisini dengeleyerek COP açısından R125 ve R32'nin üzerinde, ancak R1234yf'nin gerisinde bir performans göstermiştir. Kompresör iş tüketimi bakımından, tüm akışkanlarda artan basınç oranı ile birlikte enerji ihtiyacı yükselmiş; en yüksek değerler R125 ve R32 için kaydedilmiştir. Bu durum, özellikle enerji yoğun uygulamalarda R1234yf'yi daha avantajlı bir seçenek haline getirmiştir.

Toplam ekserji tüketimi incelendiğinde, R125 çevrimde en fazla kalitatif enerji kaybına neden olan akışkan olarak dikkat çekmiş; bunu R32 ve R452A takip etmiştir. R1234yf ise daha düşük toplam ekserji tüketimi ile sistemin ikinci yasa verimliliği açısından en başarılı akışkan

olduğunu göstermiştir. Yoğuşturucudan atılan ısı miktarları da benzer şekilde R125 ve R32 için en yüksek seviyelere ulaşmış, bu durum çevresel ısıl etkilerin artmasına ve sistemin ekserjetik performansının zayıflamasına neden olmuştur. R1234yf ise bu parametrede de daha düşük değerlerle çevreye olan etkisini minimize etmiştir.

Genel olarak değerlendirildiğinde, R1234yf enerji verimliliği, düşük ekserji kaybı ve çevresel sürdürülebilirlik açısından en dengeli performansı sergilemiş; R452A ise geçici bir alternatif olarak kabul edilebilecek düzeyde orta performanslı bir seçenek olarak öne çıkmıştır. R125, gerek yüksek kompresör gücü ihtiyacı gerekse düşük COP ve yüksek ekserji kaybı nedeniyle sistem üzerinde en olumsuz etkiye sahip akışkan olarak belirlenmiştir. R32 ise benzer şekilde yüksek enerji tüketimi ve sınırlı verimlilik ile dikkatli değerlendirilmesi gereken bir alternatif olarak öne çıkmaktadır.

KAYNAKÇA

Haı, D,T,H., Dung, N, V., Phu, N,M. (2025). Mo Hınh Nhıet Dong Chung Phan Tich Cac May Lanh Haı Cap Dung Moı Chat R32. Tạp chí Khoa học và Công nghệ, Số 75, DOIs: https://www.doi.org/10.46242/jstiuh.v75i3.5276

Saleh, B., Aly, A,A., Alsehli, M., Elfasakhany, A., Bassuoni, M,M. (2020). Performance Analysis and Working Fluid Selection for Single and Two Stages Vapor Compression Refrigeration Cycles, *Processes MDPI, 8,* 1017; doi:10.3390/pr8091017.

Bentrcia, M., Alshatewi, M., Omar, H. (2017). Developments of vapor-compression systems for vehicle air-conditioning: Areview, Advances in Mechanical Engineering 2017, Vol. 9(8) 1–15, DOI: 10.1177/1687814017717186

Harby, K., Gebaly, D,R., Koura, N,S., Hassan, M,S. (2016). Performance improvement of vapor compression cooling systems using evaporative condenser: *An overview, Renewable and Sustainable Energy Reviews. Volume 58, Pages 347-360* https://doi.org/10.1016/j.rser.2015.12.313

Ahamed, J,U., Saidur, R., Masjuki, H,H., (2011). A review on exergy analysis of vapor compression refrigeration system, *Renewable and Sustainable Energy Reviews, 15. 1593-1600,* doi:10.1016/j.rser.2010.11.039.

İşkan, Ü., Direk, M., Yüksel, F., Soylu, E. (2021). Otomobil İklimlendirme Sistemlerinde Farklı Soğutucu Akışkan Kullanılmasında Kompresörün Hacimsel Verim Analizi, *Int. J. Pure Appl.* Sci. 7(1):41-50, DOI: 10.29132/ijpas.881952

Akçay, E. (2025). Katı yakıtlı kombine çevrimlerin performans ve ekserji analizi, (Yüksek Lisans Tezi), *Bayburt Üniversitesi Lisansüstü Eğitim Enstitüsü*

MEDICAL ASSISTANCE APPLICATION WITH CROSS-BLOCKCHAIN WITH THE RAFT CONSENSUS ALGORITHM FOR THE ELDERLY PERSON IN IOT NETWORKS

Prof. Dr. Fatima Zohra MOSTEFA

University of Sciences and Technology of Oran USTO-MB, Faculty of matematics and computer science, Department of Computer science, Oran, ALGERIA

ABSTRACT

In IoT networks, blockchain technology provides a secure and transparent way to store data and manage transactions. As part of our ambitious project, we are developing a remote medical assistance system for elderly people in IoT networks based on the RAFT consensus algorithm and the cross-blockchain technique to give them fast and secure access to their medical history in the healthcare domain. In our Medical Assistance application, we have designed a robust and interconnected architecture based on different APIs and blockchains dedicated to specific functions.

Keywords: IoT networks, cross-blockchain, RAFT consensus algorithm, medical history, API.

INTRODUCTION

IoT devices are utilized in various fields, including industry, transportation, healthcare, and homes. To enable remote monitoring in the healthcare industry, IoT integrates various sensors and connected equipment to communicate directly without the need for human interaction. Blockchain technology has revolutionised several industries by offering a decentralised, transparent, and secure method of managing data and transactions. Although cryptocurrencies like Bitcoin were first based on this technology, its uses have now spread to voting systems, healthcare, supply chain management, and many more fields.

One particular kind of database is a blockchain. Blocks of data on a blockchain are arranged chronologically and protected by cryptographic methods. Because of its structure, the data is transparent, safe, and unchangeable. Once a block's data has been verified and put on the blockchain, it cannot be changed. The decentralised system also supersedes a central authority.

CONCEPTUAL FRAMEWORK

The IoT devices collect the data for remote medical assistance about elderly persons, and we process and analyze it to finally decide. In our project, we store essential information on the blockchain sensitive data, including personal information and medical history. The blockchain guarantees the integrity and security of this data. In our proposed approach, we use MongoDB. This choice allows us to benefit from the flexibility and speed of access offered by a NoSQL database to manage sensitive data while maintaining a clear separation between critical and non-critical data.

Our proposed architecture

An API (Application Programming Interface) is a software interface that allows different machines to exchange data and request and retrieve information in a standardized way (O'Reilly & Pascoe,2018).

We can find different APIs, such as:

-API REST (Representational State Transfer)

- API WebSocket

- API SOAP (Simple Object Access Protocol)

-API GraphQL

-API GRPC (Google Remote Procedure Call)

In our proposed approach, we choose REST APIs and WebSocket APIs. REST APIs use HTTP requests to access and manipulate data. They are stateless, meaning that each request from the client to the server must contain all the information necessary to process the request. They are widely used due to their simplicity and scalability. WebSocket APIs enable two-way communication between a client and server over a long connection. This is useful for applications requiring real-time data updates. This API maintains an open connection, allowing for more efficient data exchange.

In our first API 1, we create and manage the fundamental urban system entities such as municipalities and hospitals. This API will provide a centralized interface for operations such as adding, updating, and deleting these entities, thus contributing to efficient and transparent administrative management.

API 2 linked to our first blockchain. This API will allow interaction with the blockchain to perform operations such as adding, deleting, updating, and retrieving data about the population, ensuring their integrity and confidentiality.

API 3 is designed to interact with our second blockchain and is focused on medical history management. This API will allow operations such as adding, deleting, and updating and maintain sensitive medical information confidentiality. Finally, our API_ Cross-blockchain is a bridge server between the two blockchains to secure data exchange. This API will serve as a bidirectional communication channel, ensuring information transfer and integrity control. Our APIs will provide essential interfaces for interacting with various system parts as critical data exchange.

These APIs integrate different blockchains, thus ensuring the integrity, confidentiality, and interoperability of the stored information.

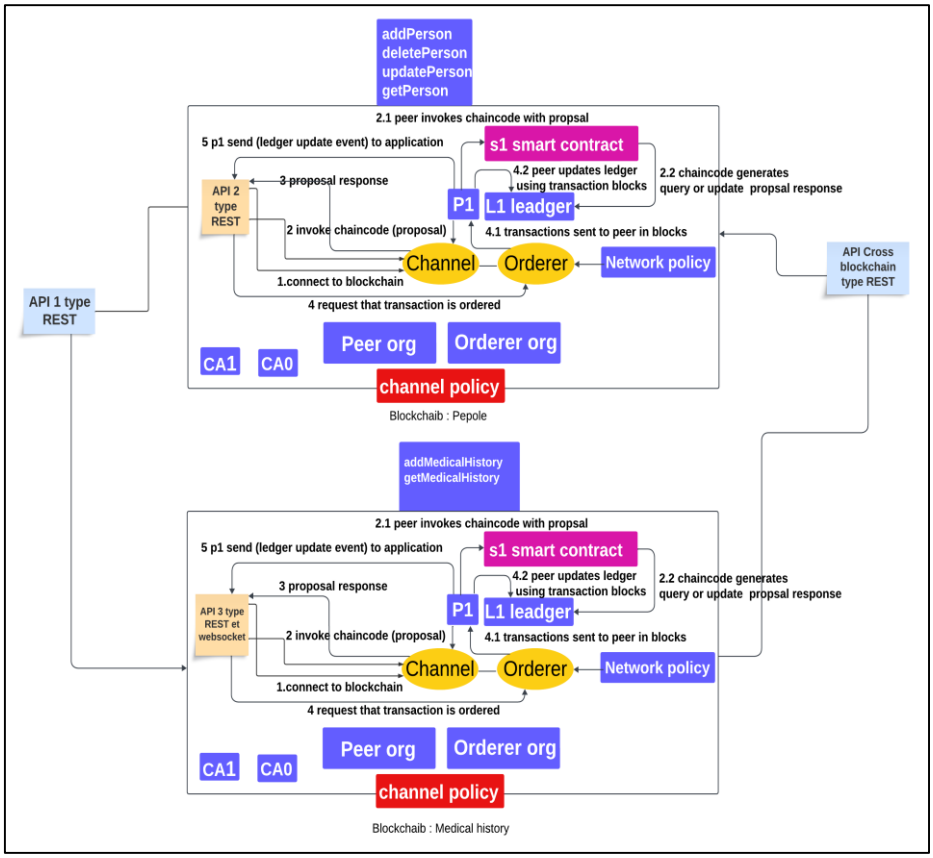


Figure 1. Our proposed architecture

Figure 1 describes two blockchains, "Blockchain 1: People" and "Blockchain 2: Medical". Each blockchain uses an API (API2 for People and API3 for Medical) to interact with its specific data. A web gateway in API 4, called API Blockchain server web bridge, allows data sharing between API2 and API3, thus facilitating interoperability between the two blockchains. Transactions and updates are managed via blockchains, smart contracts, and secure channels. In addition, the TLS (Transport Layer Security) protocol is used as a communication mode, thus ensuring the confidentiality and integrity of data exchanged between the different entities of the network. Figure 2 describes the class diagram in our proposed approach.

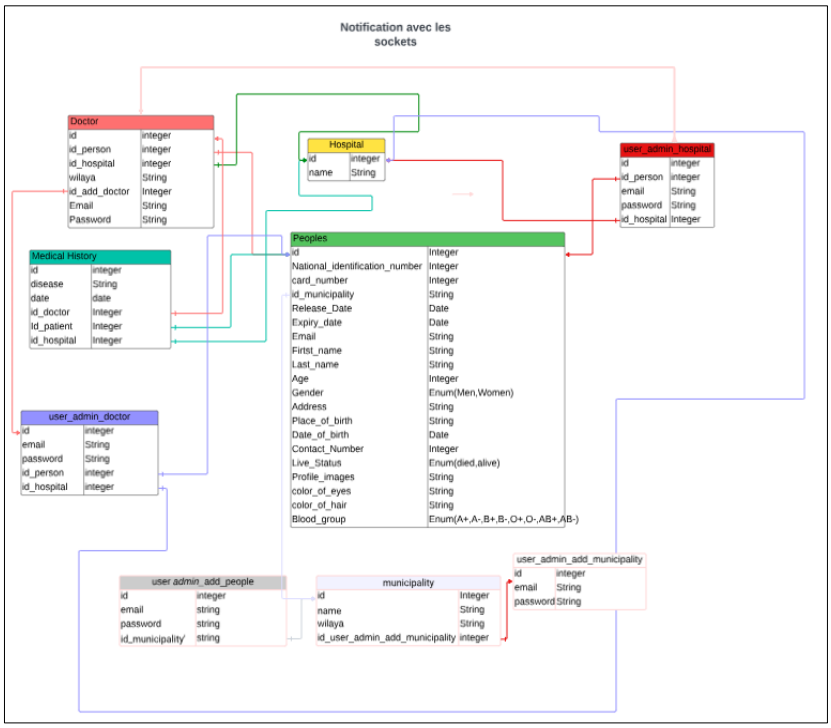


Figure 2 class diagram in our proposed approach

METHODOLOGY

Basics of Blockchain

-Consensus mechanism: This mechanism is the foundation of any application built on the blockchain. Although the blockchain is decentralized, a set of guidelines is necessary to determine how users can agree on its contents. For the Bitcoin network, Proof of Work (PoW) is the first consensus algorithm, which was released in (Wasiq & al,2023)

-Decentralization: Blockchain disperses data throughout a network of separate computers.

-Transparency: All network users can see every transaction, guaranteeing transparency.

-Immutability: Data cannot be changed once it is stored on the blockchain.

Cross Blockchain

Various blockchains can communicate and allow data to be transferred between these blockchains. This technique is named cross-blockchain. Blockchain bridges are a standard solution for cross-blockchain communication. A bridge server is a crucial component that facilitates data transfer between different blockchains (Meng,2023).

Consensus algorithm

Figure 3 describes different consensus algorithms in the literature.

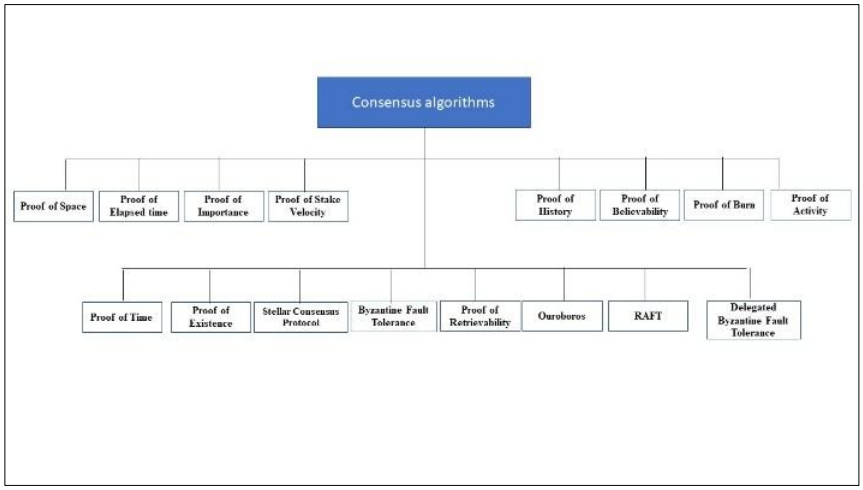


Figure 3Consensus algorithms

In our proposed approach, we choose the RAFT consensus algorithm. This distributed consensus algorithm, based on the Raft protocol, provides fault tolerance by ensuring that transactions are validated and ordered consistently across all nodes in the IoT networks.

The RAFT consensus algorithm's main advantages include high availability, increased robustness against node failures, and strict data consistency, making it an ideal solution for our proposed architecture.

CONCLUSION AND DISCUSSION

About PC Performance used in our proposed project, we used a Dell Latitude laptop equipped with the Processor Intel(R) Core (TM) i7-8650U CPU @ 1.90 GHz, RAM: 16.0 GB, Operating System: Linux. Hyperledger is a Linux Foundation initiative to develop open-source frameworks and tools for enterprise-grade blockchain technologies. Among the various Hyperledger projects is Hyperledger Fabric. Hyperledger Fabric is an enterprise-grade open-source blockchain framework maintained by IBM and the Linux Foundation as part of the Hyperledger Initiative, unlike public blockchains like Bitcoin and Ethereum.

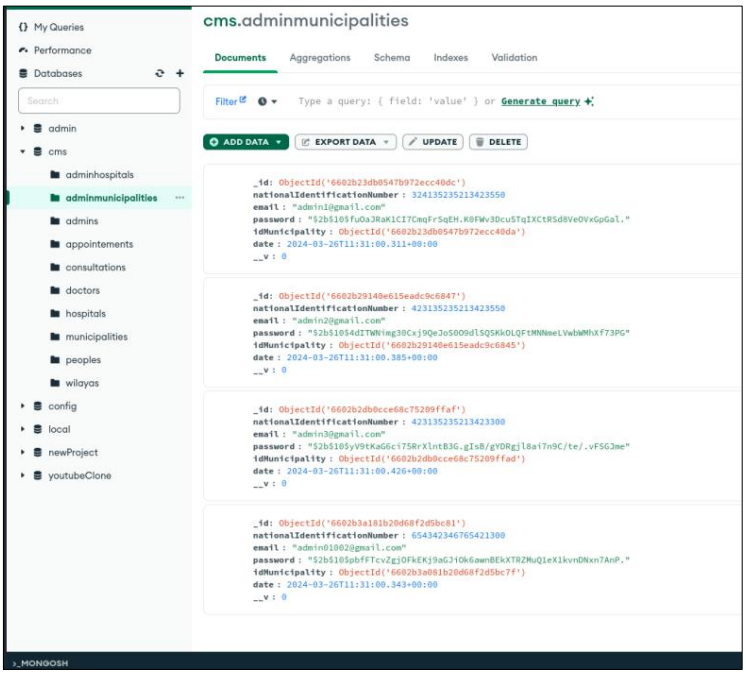


Figure 4 our MongoDB database in our proposed approach

The figure 4 describes our MongoDB database implements in our Server. The server uses several Node.js packages in our proposed architecture to provide robust and secure functionality. Express.js is the main framework for handling HTTP routes and requests.

We used the etcd/raft consensus mechanism within Hyperledger Fabric. Blockchain networks require high reliability and security. The configuration of etcd/raft in Hyperledger Fabric is specified in the config.yaml file. Specifically, the Orderer section of this file contains the parameters for the OrdererType (defined as draft) and the list of consenters, which are the orderer nodes participating in the consensus process.

```
async deletePerson(ctx, id) {
    const personExist = await this.personIdExist(ctx, id);
    if (!(personExist && personExist.length > 0)) {
      throw new Error(`The person ${id} does not exist`);
    }
    return ctx.stub.deleteState(id);
  }
  async getPersons(ctx,arr){
    const arrJson = JSON.parse(arr);
    const persons = [];
    const iterator = await ctx.stub.getStateByRange("", "");
    let result = await iterator.next();
    while (!result.done) {
      const strValue = Buffer.from(result.value.value.toString()).toString(
        "utf-8"
      );
      let record;
      try {
        record = JSON.parse(strValue);
      } catch (err) {
        record = strValue;
      }
      for (let i = 0; i < arrJson.length; i++) {
        if(record.nationalIdentificationNumber == arrJson[i].nationalIdentificationNumber){
          persons.push({...record,data: arrJson[i]});
        }

      }
      result = await iterator.next();
    }
    return persons;
  }
}

module.exports = PeopleOrg1;

```

Figure 5 Smart contract of PeopleOrg1 implementation in our proposed approach

Figure 5 describes the implementation code of a smart contract named PeopleOrg1 for Hyperledger Fabric, allowing people information management. Key functions include adding a new person (addPerson), checking the existence of a person by their national identification number (personIdExist), searching for people by specific attributes (search), updating an existing person's information (updatePerson), deleting a person (deletePerson), and retrieving a list of people matching a set of criteria (getPersons). These operations ensure secure and consistent management of personal data stored on the blockchain.

```
use strict";

const stringify = require("json-stringify-deterministic");
const { Contract } = require("fabric-contract-api");


class MedicalOrg1 extends Contract {
    async addMedicalHistory(ctx,id,nationalIdentificationNumber,disease,medical,date){
        await ctx.stub.putState(id, Buffer.from(stringify({
            id:id,nationalIdentificationNumber,disease,medical,date
        })));
        return JSON.stringify({
            id,nationalIdentificationNumber,disease,medical,date
        });
    }
    async getMedicalHistory(ctx,nationalIdentificationNumber){
        const iterator = await ctx.stub.getStateByRange("", "");
        let result = await iterator.next();
        let arr = [];
        while (!result.done) {
            const strValue = Buffer.from(result.value.value.toString()).toString(
              "utf-8"
            );
            let record;
            try {
              record = JSON.parse(strValue);
            } catch (err) {
              console.log(err);
              record = strValue;
            }
            if (record["nationalIdentificationNumber"] == nationalIdentificationNumber) {
                arr.push(record);
            }
            result = await iterator.next();
          }
          return [];
    }
}

module.exports = MedicalOrg1;
```

Figure 6 Smart contract of MedicalOrg1 implementation in our proposed approach

Figure 6 describes the implementation code of a smart contract named MedicalOrg1 for Hyperledger Fabric, which manages people's medical records. Key features include adding a medical history for a person (addMedicalHistory), where information such as the national identification number, illnesses, medical treatments, and associated dates are recorded on the blockchain. Additionally, it allows retrieving the complete medical history of a specific person based on their national identification number (get medical history). This smart contract ensures the security and integrity of medical data while facilitating authorized users' access to relevant medical information. Blockchain is an attractive technology that provides a secure and transparent way to record transactions and store data. Our propose approach increased robustness against node failures and strict data consistency by RAFT consensus algorithm and cross-blockchain. Blockchain application including healthcare (Tripathi & Ahad,2020) (Tripathi & abdul,2020) also allows patient identification who have been reached by the COVID-19 pandemic (Khurshid,2020) and blood donation (Trček,2022).

A thorough analysis of blockchain technology is provided in (Swan,2015), with particular attention to the taxonomy, consensus techniques, applications, and difficulties. Blockchain is discussed in (Crosby & al,2016) as a promising technology to address current financial and non-financial issues. The features and architecture of blockchain technology are covered in (Zheng & al,2017). Additionally, some of the popular consensus algorithms have been examined and contrasted. According to a discussion of blockchain's potential in the finance industry in (Zheng & al,2017), it will similarly impact banking and finance to how the internet affected media.

Existing cross-blockchain technologies facilitate data exchange between different blockchains for urban and medical management, such as sensitive data about the medical history of each elderly person, and give him better medical assistance in real-time. In our future work, we plan to implement our proposed approach in an embedded system.

REFERENCES

O'Reilly T. D, Pascoe A. V, (2018). API design guidelines for improved usability and maintainability, IEEE Software, Vol. 35, No. 4, pp. 42–50.

Wasiq M.,. Bashar A, Akmal S., Rabbani M.R.,. Saifi M.A, Nawaz N.,. Nasef.Y.T (2023). Adoption and applications of blockchain technology in marketing: retrospective overview and bibliometric analysis, Sustainability 15 (4).

Meng Zhao, (2023). IEEE Standard for Blockchain Interoperability Data Authentication and Communication Protocol, 04-28.

Tripathi G., Ahad M.A., Paiva S., (2020). S2HS-A blockchain based approach for smart healthcare system, in: Healthcare, 8 (1) 100391.

Tripathi G.,. Abdul Ahad M, Paiva S., (2020). SMS: A secure healthcare model for smart cities,Electronics 9 (7) 1135 .

Ghazal T.M, Hasan M.K., Alzoubi H.M., Hammadi M.Al., Al-Dmour N.A., Islam S. (2022). Securing smart cities using blockchain technology in 1st International Conference on AI in Cybersecurity, ICAIC, IEEE, pp. 1–4.

Trček D., (2022). Cultural heritage preservation by using blockchain technologies,Herit. Sci. 10 (1).

Swan M., (2015). Blockchain: Blueprint for a New Economy, O'Reilly Media, Inc,

Crosby M.,. Pattanayak P, Verma S., Kalyanaraman V. (2016).Blockchain technology: Beyond Bitcoin, Appl. Innov. 2 (6–10) 71.

Zheng Z., Xie S., Dai H., Chen X., Wang H., (2017). An overview of blockchain technology: Architecture, consensus, and future trends, in: 2017 IEEE International Congress on Big Data, BigData Congress, IEEE, pp. 557–564.

Khurshid A., (2020). Applying blockchain technology to address the crisis of trust during the COVID-19 pandemic, JMIR Med. Inf. 8 (9) e20477.

10-BIT DIFFERENTIAL SEGMENTED CURRENT STEERING DIGITAL TO ANALOG CONVERTER

Harish Raghvendhar SK
BITS PILANI, PILANI, INDIA

Dr. Abhijit Asati
BITS PILANI, PILANI, INDIA

ABSTRACT

Digital to analog conversion (DAC) is the foundation for applications such as signal processing, communication, audio amplification and interfacing of sensors. The paper discusses the design and performance evaluation of a 10-bit differential segmented current-steering digital to analog converter (DS-CS-DAC) using 32 nm CMOS technology. Two DS-CS-DAC were designed (4U6B and 6U4B) to achieve the optimal tradeoff between linearity, power consumption. The binary-weighted section of DS-CS-DAC consume less switching power, while the unary-weighted section ensures accuracy and less glitch. The techniques such as clock synchronization, error minimization, and efficient current-source matching are used for performance improvement. The 6U4B architecture improves Integral Non-Linearity (INL) as well as Differential Non-Linearity (DNL) substantially and making it suitable for high-speed DAC applications. Further, it shows reduced power consumption, increased linearity and reduced mismatch errors as ensured through the simulation results. Characteristic parameters of the proposed DS-CS-DAC are compared with the published results.

Keywords: Digital-to-Analog Converters (DAC), Current-steering DAC, Segmented architecture, Differential DAC, CMOS technology, Linearity improvement, Power consumption, Clock synchronization.

INTRODUCTION

Digital-to-analog converters (DACs) are a key component of contemporary electronic systems that enable the conversion of digital signals to continuous analog waveforms. The applications such as wireless communications, multimedia processing and medical instrumentation require high speed DAC. Some of the most widely employed architectures are resistor-string DACs *(R-DACs)*, binary-weighted DACs (BW-DAC), and current-steering DACs (CS-DAC). The R-DACs are one of the simplest DAC architectures, where a network of resistors divides a reference voltage down to a series of discrete levels, which are addressed by digital control signals. The drawbacks of R-DAC are that it results in exponential growth of resistors to achieve high resolution resulting in huge chip area requirements of large resistor network demanding higher power consumption and low speed caused by the resistance-capacitance (RC) delay of the network. The BW-DAC employ a chain of current sources or resistors weighted in binary to provide the output voltage or current. This structure benefits from high-speed conversion due to reduced switching time between binary-weighted elements, and it requires less area compared to R-DACs but has difficulties in achieving high resolution, especially beyond 8-bit implementations. The CS-DACs offer high-speed operation making them ideal for communication applications demanding power reduction and glitch reduction when

compared to BW-DACs. The Segmented CS-DAC overcome the constraints of binary-weighted DACs and unary-weighted DACs by combining both designs to achieve a trade-off between linearity, power efficiency, and area utilization. A segmented CS-DAC architecture breaks up the digital input into several segments, with the most significant bits (MSBs) employing a unary-weighted scheme and the least significant bits (LSBs) employing a binary-weighted scheme. This architecture improves linearity, reduces area and power both and reduces glitch.

Ghasemi and Karami [1] present a compact and efficient 10- bit, 1GS/s DAC design using a hybrid approach that combines a differential resistor ladder with only 21 current sources, significantly reducing power (9.31 mW) and area (0.0134 mm^2). A modified 4-bit thermometer decoder based on SR-DFFs ensures synchronized switching with minimal transistors. Implemented in 65 nm CMOS, the DAC achieves INL of 0.3 LSB, DNL of 0.6 LSB, and Spurious-Free Dynamic Range (SFDR) of 57 dB over a 600 MHz bandwidth, making it suitable for high-speed, low-power applications. Ghasemian et al. [2] propose a 11-bit 1.2 GS/s hybrid DAC using a novel combination of resistor ladders and current sources, where current sources are logically connected to ladder nodes to generate varied voltage levels with fewer components.

The design eliminates complex decoders in favor of basic digital logic, reducing power consumption to 4.68 mW and area to 0.0061 mm^2. This design is implemented in 65 nm CMOS and achieves SFDR of 70 dB over 600 MHz, with INL of 1.2 LSB and DNL of 1 LSB, making it ideal for compact, high-speed applications. Gupta et al. [3] present a 12-bit 8-bit unary, 4-bit binary segmented current-steering DAC featuring a thermometer encoder and optimized bit segmentation to reduce glitches and improve precision. Designed in 45 nm CMOS, it operates at 1.2 GHz with a power consumption of 44.95 mW at 1.2 V supply. The DAC achieves an SFDR of 41.77 dB, demonstrating a balance between resolution and efficiency for high-speed applications. Patel [4] presents a 5-bit segmented current-steering DAC operating at 1.8 V, using a hybrid architecture where the 3 MSBs are binary-weighted and the 2 LSBs are unary-weighted. A cascoded current reference biases the current mirrors, and a thermometer encoder converts the 2 LSBs for glitch reduction. Simulated results show excellent linearity with maximum INL of 0.1498 LSB and DNL of 0.1256 LSB, demonstrating its suitability for low-bit, high-accuracy analog conversion. Stefanou et al. [5] introduce a 10-bit, 2 GS/s segmented current-steering DAC in 28 nm CMOS, designed for Ethernet PHY applications.

The DAC uses a segmentation scheme (6-bit unary, 4-bit binary) and features cascoded current sources with always-ON switches for improved static and dynamic performance. In this design a built-in calibration DAC (CALDAC) compensates for tail current variations, enhancing accuracy and achieves SFDR up to 70 dB at low frequencies, 49.4 dB at Nyquist, with DNL of 0.5 LSB and a 0.35 Vpp output swing, demonstrating high-speed, high-linearity performance. Tong et al. [6] propose a 12-bit, 500MS/s current-steering DAC using a novel (3-bit unary + 5-bit splitting + 4-bit binary) segmentation scheme. The innovative splitting decoder bridges unary and binary approaches, reducing circuit complexity, area, and glitches while improving DNL and implemented in 0.18µm CMOS technology. It achieves SFDRs of 68.83 dB (6.34 MHz input) and 62.06 dB (239.74 MHz), with INL and DNL of 1.16 and 0.28 LSB, respectively. It consumes 17.2 mW and occupies a compact active area of 536×340 μm^2, demonstrating efficient high-resolution performance. As technology advances towards digital, there is increased demand for efficient DAC architectures that are fast, power conservative, as well as precise.

In this proposed work, 10-bit DS-CS-DAC designed using the 32 nm CMOS technology, to minimize signal conversion errors and to achieve better precision and reduced power consumption. The DS-CS-DAC structure divides the digital input into segments. This architecture uses two segments for 10-bit DS-CS-DAC i.e. (i) a 6-bit unary-weighted portion and a 4-bit binary-weighted portion (6U4B) and (ii) 4-bit unary-weighted portion and a 6-

bit binary-weighted portion (4U6B). The binary-weighted portion optimizes the LSBs and require fewer transistors and less complex and also help in saving of area utilization and power utilization, while the unary-weighted portion is utilized for the MSBs ensures increased linearity as well as minimization of glitch and increased accuracy due to usage of a thermometer-code. These DAC are useful for wireless communication, multimedia processing which demands data conversion with high data rates improved DNL and INL, highly linear, reduced glitch and consume less power. The comparative analysis of 10-bit DS-CS-DAC 6U4B vs 4B6U demonstrating that the 6U4B method provides superior linearity with less deviation. The proposed methodology is discussed in section II, results and discussion is in section III and Section IV conclude results.

METHODOLOGY

The 10-bit DS-CS-DAC is designed using 32 nm CMOS technology, which incorporates unary-weighted segment and a binary-weighted segment to improve linearity. The unary-weighted segment incorporating a thermometer-coded current-source array to reduce glitches and improves DNL, while the binary-weighted segment uses a binary-weighted current mirror to minimize area as well as power consumption, thus offer high accuracy, high speed yet energy efficient circuit. Implementation of the circuit design requires careful consideration of current source design, switching network and clock synchronization.

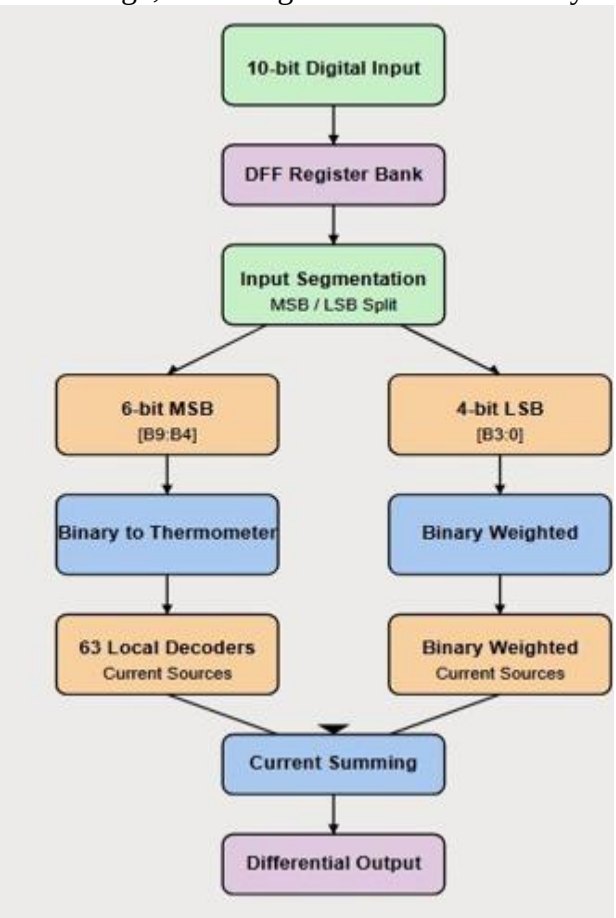


Fig. 1: Data Flow diagram of 10-bit DS-CS-DAC using 6U4B

Dynamic element matching (DEM) technique used to maximize uniformity of current sources. To keep the timing of the unary and binary segments as accurately as possible, a low-skew clock used to minimize glitch and to achieve an exact phase alignment and better latch-based control. In 10-bit DS-CS-DAC the thermometer decoder block is used for the MSBs while

the binary-weighted structure is utilized for the LSBs. The flow diagram of 6U4B 10-bit DS-CS-DAC is shown in Fig. 1 and 4U6B 10-bit DS-CS-DAC is shown in Fig. 2.

The designed DS-CS-DAC simulated extensively using SPICE to ascertain that the circuit functions, and determine DNL, INL, power consumption and maximum frequency of operation.

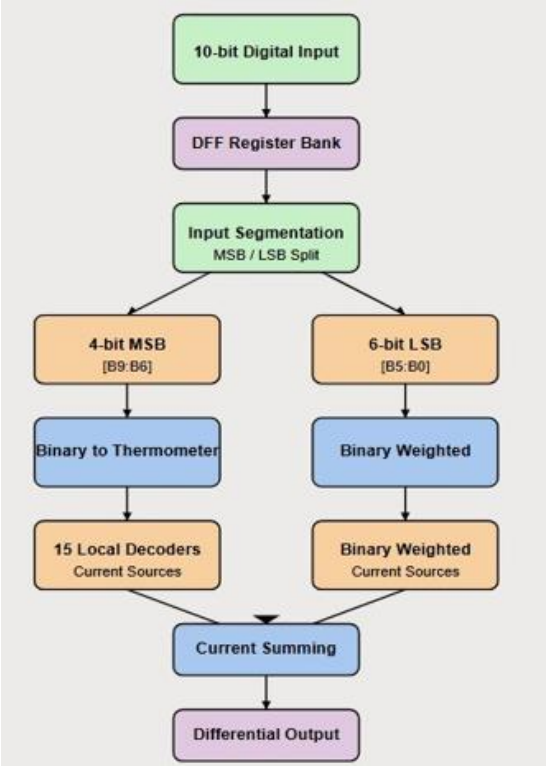


Fig. 2: Data Flow diagram of 10-bit DS-CS-DAC as 4U6B

Thermometer Decoder Section: The MSB part of the DS-CS-DAC is handled by the thermometer decoder to improve DNL and INL performance. A number of differential switches under D flip flop (DFF) control used to for this part. These switches turn on current sources to offer linear voltage steps.

Binary-Weighted Section: The binary-weighted architecture is utilized for the LSB part of the DS-CS-DAC. This block utilizes current-steering, with each bit's contribution to the output signal being a direct function of its binary weight. The current-steering method steers current through the respective paths according to the input digital code so that each bit contributes its respective weight to the output signal. In 6U4B, for 4-bit binary section, current sources of 6 μA, 12 μA, 24 μA, and 48 μA provide currents for the respective voltage steps for the digital input bits for effective control of the output signal. The binary-weighted structure, though smaller compared to the thermometer decoder, it is prone to errors from mismatching of current sources. To keep these errors at a minimum, a careful design must be implemented to keep the binary-weighted portion of the DS-CS-DAC from detracting from its overall performance while impacting accuracy.

(i) *Differential Switches and Current Source Selection:* To enable high-speed switching with little latency, the DS-CS-DAC uses differential switches that are managed by D-FFs. This guarantees steady output during code transitions and lessens the effect of fleeting

glitches. Both the binary-weighted architecture and the thermometer decoder employ carefully chosen current sources to ensure adequate resolution and accuracy. In the 6U4B, binary weighted current sources of 6 μA, 12 μA, 24 μA, and 48 μA are used in binary section to reduce power consumption while array of 2^6=64 current sources of 96 μA are used in unary section to preserve excellent accuracy. In the unary section of 6U4B to produce any current corresponding to a input MSB 6-bit value is generated by summing a 'n' number of 96 μA by suitable section. e.g. for the digital input if B6 is '1' require current of 64xI (where I=6 μA) , so 64xI=384 μA is generated by summing current of 4 cells of thermometer array by turning ON cells 1, 2, 3, 4 each of 96 μA, so passing through resistive load is 96x4=384 μA. The schematic of 10-bit DS-CS-DAC is shown in Fig. 3.

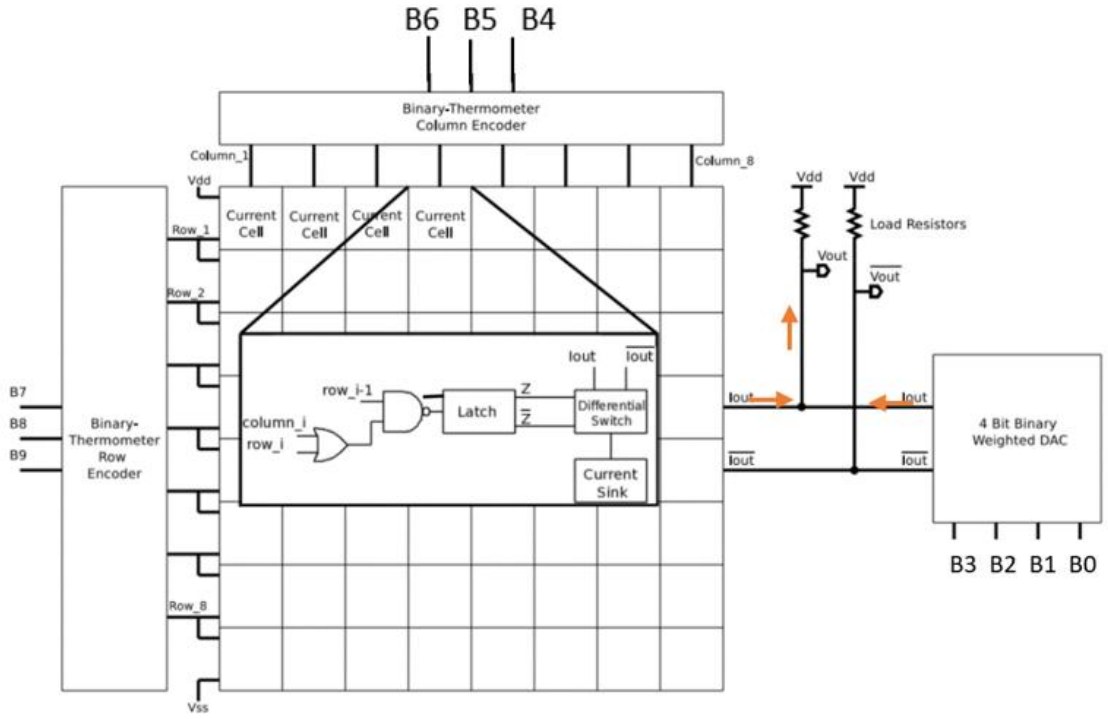


Fig. 3. 6U4B 10-bit Segmented DS-CS-DAC

(ii) Error Minimization Techniques: Thermometer and binary-weighted decoding work together to decrease DNL and INL.

(iii) *Design Trade-offs: T*he 6U4B is larger than the 4U6B but it improves linearity and lowers errors. The binary-weighted architecture, on the other hand, is more error-prone because of mismatched current sources, despite being more compact. The design of the DS-CS-DAC architecture is ideal for high-precision applications that require both great performance and low power consumption.

CONCLUSION AND DISCUSSION

The performance of the 10-bit DS-CS-DAC was simulated for important parameters including DNL, INL, power consumption, as well as clock period. The parameters of 6U4B are compared with the 4U6B, which indicated that the 6U4B DS-CS-DAC offered much superior linearity with reduced DNL and INL. It was observed that the DNL was within acceptable range, guaranteeing monotonicity, while the 4U6B DS-CS-DAC exhibited increased DNL, especially within lower code ranges, resulting in apparent nonlinearities. This proved that enhancing the number of thermometer decoder bits results in increased accuracy as well as smoothness of the DAC's transfer function. Table 1, shows that 6U4B 10-bit DS-CS-DAC exceptional linearity

demonstrates the close adherence to the ideal transfer function is indicated by the DNL values remaining within ±0.1 LSB and the INL values remaining closely controlled. This is further supported by Fig. 4, which displays almost flawless overlap between the ideal and actual analog outputs for every input code. This illustrates how DAC linearity is greatly enhanced by increasing the thermometer segment to 6-bits.

Table 1: DNL and INL of a 10-bit DS-CS-DAC of 6U4B

10-bit Binary Value	Analog output	Ideal output	DNL	INL
0000000000	500.53	500.53		0
0000000001	499.465	499.55	0.0884	-0.0875
0000000010	498.411	498.57		-0.1639
0000000011	497.443	497.594	-0.0107	-0.1533
0000010000	484.89	484.874		0.0171
0000010001	483.82	483.8955	0.0935	-0.0756
1000000000	-0.452	-0.462		0.0143
1000000001	-1.462	-1.4405	0.032	0.0132
1100000000	-250.856	-250.958		0.0685
1100000001	-251.888	-251.9365	0.06	0.0706
1111110000	-485.688	-485.798		0.1457
1111110001	-486.757	-486.7765	0.092	0.0355
1111111001	-498.504	-498.5185		0.0688
1111111110	-499.56	-499.497	-0.0098	0.0916
1111111111	-500.529	-500.53		-0.001

On the other hand, Table 2 displays the DNL and INL of 4U6B 10-bit DS-CS-DAC. The Fig. 4, shows lower variation in 6U4B compared with 4U6B i.e. close to mid-scale transitions. Fig. 5 shows maximum value of DNL and INL gets much educed for 6U4B as compared to maximum DNL and INL of 4U6B.

The 6U4B DS-CS-DAC has superior linearity due to substantially smaller INL extremes and displays reduced variation from ideal values at the cost of increased complexity.

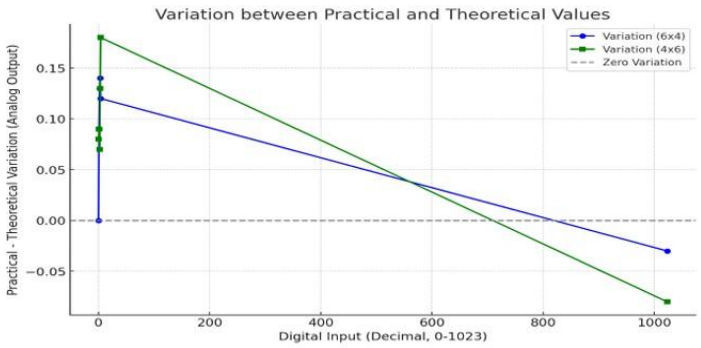


Fig. 4: Comparison of linearity for 6U4B and 4U6B

Table2: DNL and INL of a 10-bit DS-CS-DAC 4U6B

10-bit Binary Value	Analog output	Ideal output	DNL	INL
0000000000	497.598	497.598		0
0000000001	495.62	496.625	1.033	-1.0333
0000000011	494.576	494.679	0.073	-0.1065
0000100000	467.036	466.46		0.5845
0000100001	465.986	465.4956	0.079	0.5041
1000000000	250.01	248.561		1.4893
1000000001	248.94	247.5884	0.0999	1.3894
1000000000	-0.37	-0.4756		0.1086
1000000001	-1.448	-1.4484	0.108	0.0004
1111100000	-436.948	-436.29		-0.6764
1111100001	-438.001	-437.2628	0.082	-0.7588
1111110000	-483.02	-482.9844		-0.0366
1111110001	-484.069	-483.9572	0.078	-0.1139
1111111110	-496.536	-496.6036		0.0695
1111111111	-497.58	-497.598	0.0731	-0.0037

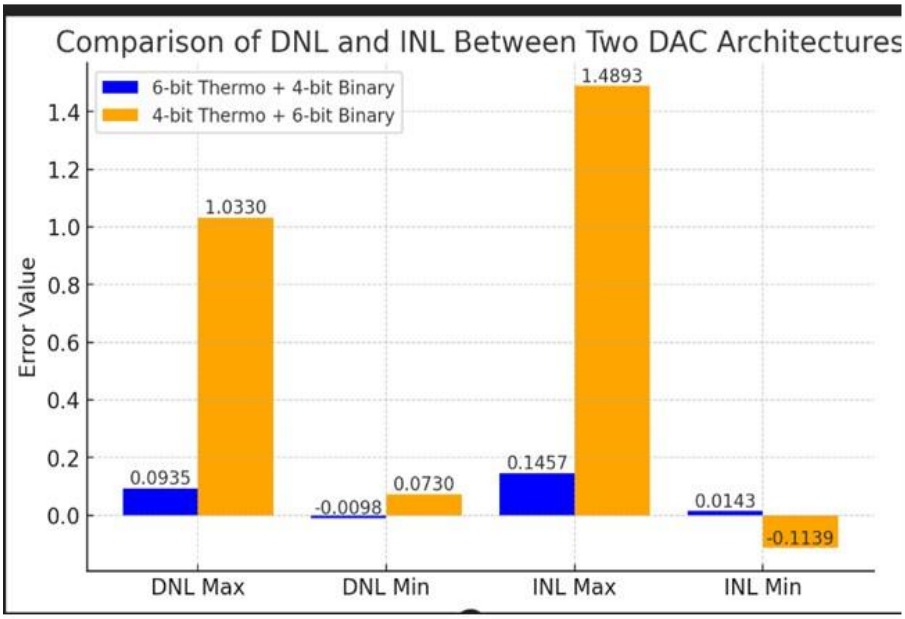


Fig. 5: Comparison of INL and DNL of 6U4B and 4U6B

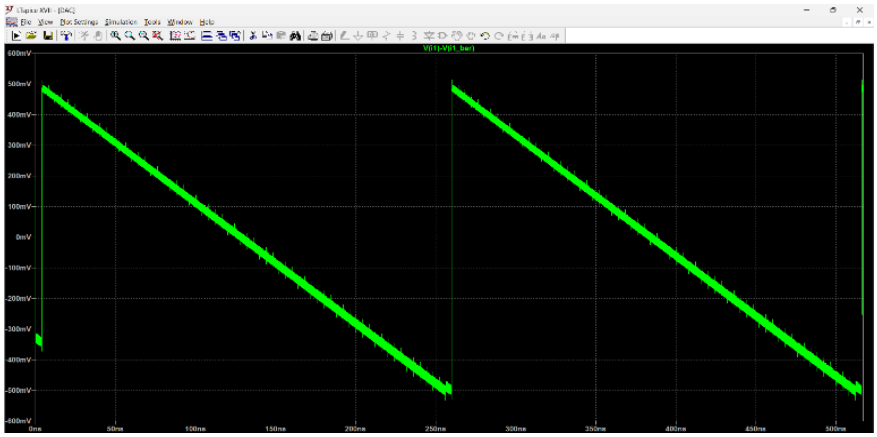


Fig. 6: Simulation of full-range inputs of two cycles.

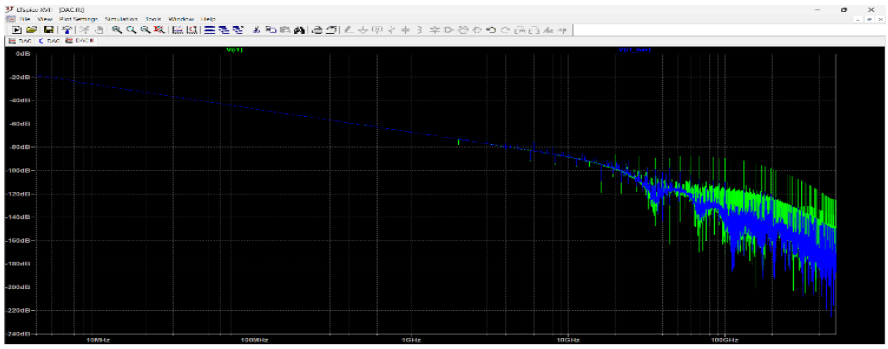


Fig. 7: FFT plots of the output of the DAC.

Fig. 6 shows simulation of full-range inputs of two cycles for 6U4B which shows linear behavior.

In 6U4B DS-CS-DAC, signal retains a strong signal-to-noise ratio (SNR) even up to 12.5 GHz, and little harmonic distortion, indicating that this DAC can function well at this high frequency. Excellent dynamic behavior and stability are indicated by the distinct fundamental tone and its harmonics, as well as the absence of any notable spurious components close to the Nyquist frequency.

The proposed 6U4B DS-CS-DAC maintains dependable high performance, as seen by the power spectral density's smooth decline and the lack of noise peaks or high-amplitude spurs up to and beyond the Nyquist limit. The design offers the low-power, high-linearity and validates the 12.5 GHz operational capabilities due to usage of individual current sources since use of current mirror reduces speed. Thus proposed structure offer high performance operation with a high degree of linearity as well as efficient energy usage.

TABLE 3

COMPARİSON OF OUR WORK WİTH PRİOR ART

Parameter	**Our Design**	**Guoyuan Fu et al. [7]**	**Leila Sharifi et al. [10]**	**Shiv Chandra Kumar et al. [8]**	**Xingyuan Tong et al. [6]**	**Rongxing Qin et al. [9]**
Technology	32 nm	130 nm CMOS	180 nm CMOS	45 nm	180 nm CMOS	110 nm CMOS
Architecture	6U-4B	Seg. (Bin + Un)	Seg. Current-Steering	Seg. (Bin + Un + SC)	Seg. (3U, 5S, 4B)	Multi-segment
SNR (dB)	60.3	~60	~60	~58	~61	~62
SFDR (dB)	66.3	81.8	51	70	68.8@6.3MHz, 62.1@239.7MHz	72@50MS/s, 66@100MS/s
THD (dB)	-58.5	~-60	~-55	~-58	~-60	~-55
ENOB (bits)	9.7	~9.5	~8.5	9.44	~9.8	11
Clock Period	80 ps	~100 ps	~120 ps	~150 ps	~120 ps	~100 ps
Max Frequency	12.5 GHz	~5 GHz	500 MS/s	250 MHz	500 MS/s	100 MS/s
Power (mW)	5.53	13.4	5.7	4	17.2	~12
DNL (LSB)	0.17	0.20	0.034	~0.20	0.28	±0.08
INL (LSB)	0.19	0.17	0.024	~0.20	1.16	±0.35
FoM (pJ/step)	0.0042	~0.005	~0.0045	~0.005	~0.0045	~0.004
Supply Voltage	1.8 V	0.72 V	1.8 V	1 V	1.8 V	1.5/3.3 V

As can be seen from the FFT plot in Fig. 7, the 6U4B DS-CS-DAC produces a clean spectral output with minimal harmonic content and controlled noise. The Signal-to-Noise Ratio (SNR) varies from 55 dB, and the SFDR is measured at 66.3 dB, which is competitive with current designs. The Total Harmonic Distortion (THD) is measured at 58.5 dB, indicating strong linear performance and high-fidelity signal reproduction. One of the standout features of this design is its extremely high-speed operation. The 6U4B 10-bit DS-CS-DAC achieves a maximum clock frequency of 12.5 GHz, with a clock period of just 80 ps, making it the highest-performing DAC among the designs compared in Table 3. For comparison, other designs like those by Xingyuan Tong et al. [6] and Rongxing Qin et al. [9] achieve maximum clock frequencies of only 3.2 GHz and 500 MS/s, respectively. Despite its high-speed operation, the 6U4B DS-CS-DAC operates with a low power consumption of just 5.53 mW, significantly lower than many of the slower designs. For example, designs by Rongxing Qin et al. [9] consume 17.20 mW, despite operating at a lower maximum frequency. In terms of linearity, the 6U4B DS-CS-DAC exhibits a DNL of 0.17 LSB and INL of 0.19 LSB, which is comparable to and even surpasses other recent designs, ensuring high precision in the conversion of digital signals. The 6U4B DS-CS-DAC also achieves a high Effective Number of Bits (ENOB) of 9.7 bits, reaffirming its accuracy over a wide range of input codes. The Figure of Merit (FoM), which measures the power efficiency per step of resolution, is calculated to be just 0.0042 pJ/step, the lowest among all surveyed designs, even surpassing recent state-of-the-art designs like Guoyuan Fu et al. [7] (0.189 pJ/step) and Xingyuan Tong et al. [6] (0.398 pJ/step). This superior FoM demonstrates the suitability of the proposed 6U4B DS-CS-DAC for power-constrained, high-speed applications, such as high- speed communication interfaces and fast data converters in RF applications.

Paper discusses two 10-bit DS-CS-DAC design namely 4U6B and 6U4B. The binary-weighted section of DS-CS-DAC ensures lower power, while the unary-weighted section ensures accuracy and less glitch. The 6U4B achieves the better linearity, INL, DNL and lower power consumption and operates correctly even up to 12.5 GHz. The characteristic parameters are

SNM, SFDR, THD, ENOB, clock period, power, DNL, INL and FoM are compared.

REFERENCES

1. R. Ghasemi and M. A. Karami, ”A 10-bit 1GSample/s hybrid digital-to-analog converter with a modified TH-DEC in 65-nm CMOS technology,” *Int. J. Circ. Theor. Appl.*, vol. 50, no. 1, pp. 83–107, 2022.

2. H. Ghasemian, A. Ahmadi, E. Abiri, and M. R. Salehi, ”An implementation of a new 11-bit 1.2 GS/s hybrid DAC with a novel 3-bit Sub-DAC,” *Microelectronics Journal*, vol. 103, p. 104872, 2020.

3. T. Gupta, S. Bhandari, S. Taran, and R. K. Gupta, ”A 12- Bit 1.2-GS/s Current-Steering DAC in 45-NM CMOS Technology,” *J. Circuits, Systems and Computers*, vol. 33, no. 14, p. 2450256, 2024.

4. S. Patel and U. Mehta, ”A 1.8 V 5-bit Segmented Current Steering Digital-to-Analog Converter,” in *Proc. 2021 IEEE Devices for Integrated Circuit (DevIC)*, pp. 569–571, May 2021.

5. A. Stefanou, K. Siozios, and A. Hatzopoulos, ”Design of a 10-bit, 2GS/s current-steering digital-to-analog con- verter with online current calibration,” in *Proc. 2022 IEEE Int. Symp. Circuits and Systems (ISCAS)*, pp. 1319–1322, May 2022.

6. X. Tong, D. Liu, and R. Wang, ”A 12-bit current-steering DAC with unary-splitting-binary segmented architecture and improved decoding circuit topology,” *IEEE Trans. Very Large Scale Integr. (VLSI) Syst.*, vol. 30, no. 10, pp. 1391–1400, 2022.

7. G. Fu, H. A. Mantooth, and J. Di, ”A 12-bit CMOS current steering D/A converter with a fully differential voltage output,” in *Proc. 2011 12th Int. Symp. Quality Electronic Design*, pp. 1–7, Mar. 2011.

8. S. C. Kumar, ”A 1-V, 10-bit, 250 MS/s, Current-Steering Segmented DAC for Video Applications,” in *Proc. 2021 IEEE Computer Society Annu. Symp. VLSI (ISVLSI)*, pp. 19–24, Jul. 2021.

9. R. Qin, F. You, M. Ma, Q. He, and S. He, ”A 12-bit Segmented Current-Steering DAC With High-Speed Deserializer,” in *Proc. 2022 IEEE Int. Symp. Circuits and Systems (ISCAS)*, pp. 2782–2786, May 2022.

10. L. Sharifi, M. Nazari, M. Akbari, and O. Hashemipour, ”An 8-bit unified segmented current-steering digital-to- analog converter,” *Arab. J. Sci. Eng.*, vol. 41, pp. 785–796, 2016.

THE IMPACT OF SMART TOURISM ON BUSINESS PERFORMANCE: AN EMPIRICAL ANALYSIS

Msc. Ambra Kraja

Agricultural University of Tirana, Faculty of Economy and Agrobusiness

Msc. Xhentjan Beshiri

European University of Tirana, Faculty of Engineering, Informatics and Architecture

ABSTRACT

The evolution of smart tourism has transformed how destinations operate and how tourists engage with services, especially through the integration of Information and Communication Technologies (ICTs). Smart tourism extends beyond digital platforms to encompass dynamic data exchange, real-time decision-making, and personalized experiences driven by mobile applications, social media, and the Internet of Things (IoT) (Gretzel et al., 2015). While this shift has been extensively studied in urban contexts, its role in rural tourism—particularly in agrotourism—remains relatively underexplored (Li et al., 2020). This study investigates the empirical relationship between smart tourism adoption and business performance in agrotourism enterprises in Albania. Drawing upon the Technology Acceptance Model (TAM) (Davis, 1989) and the Smart Destination Framework (Buhalis & Amaranggana, 2015), this research proposes a conceptual model that links digital adoption to performance indicators such as customer satisfaction, operational efficiency, and revenue growth. A cross-sectional design was applied, collecting data from both business administrators and tourists in Tirana and Shkodër. The structured questionnaire measured variables such as perceived usefulness of technology, adoption rates, and satisfaction metrics. Quantitative analysis using SPSS included descriptive statistics, independent samples t-tests, Pearson correlations, and multiple regression models. Findings revealed that businesses utilizing online booking systems, social media marketing, and digital feedback tools exhibited higher performance scores compared to those with minimal technological integration. There was a significant correlation between technology adoption and key outcomes such as customer satisfaction ($r = .62$, $p < .01$) and reported revenue growth ($r = .55$, $p < .01$). Regression analysis confirmed that perceived usefulness and digital presence predicted a significant portion of the variance in business performance ($R^2 = .48$, $F(2, 97) = 45.32$, $p < .001$). Regionally, agrotourism enterprises in Tirana demonstrated higher levels of digital maturity than those in Shkodër, indicating an urban-rural divide in technological readiness. These findings contribute to a growing body of research emphasizing the strategic value of digital transformation in rural tourism (Mariani et al., 2019; Kim et al., 2021). The study underscores the need for targeted policies and capacity-building initiatives to support digital inclusion among agrotourism operators. Moreover, it validates the relevance of TAM in non-urban tourism contexts and suggests that digital readiness is now a critical driver of competitive advantage. In conclusion, smart tourism technologies are not merely tools for convenience; they are pivotal mechanisms for enhancing business viability and customer value in the agrotourism sector. Future research should consider longitudinal designs and integrate qualitative insights to better understand implementation barriers and success factors in rural settings.

Keywords: Smart tourism, business performance, digital transformation, tourist satisfaction, information and communication technology (ICT).

INTRODUCTION

The rapid evolution of digital technologies has significantly transformed the tourism sector, giving rise to the concept of smart tourism—a system that utilizes advanced Information and Communication Technologies (ICTs), the Internet of Things (IoT), big data analytics, and artificial intelligence (AI) to optimize the tourist experience and enhance operational efficiency for tourism service providers (Gretzel et al., 2015). The emergence of smart destinations reflects the integration of these technologies into the broader tourism ecosystem, enabling real-time decision-making, personalized services, and sustainable development strategies (Buhalis & Amaranggana, 2015). In this digital transformation, the tourism experience becomes co-created through intelligent systems, dynamic feedback loops, and mobile connectivity (Lopez de Avila, 2015). While extensive research has been conducted on smart tourism in urban destinations, limited attention has been directed toward its application in rural or agrotourism settings. Agrotourism, as a subset of rural tourism, involves travel to agricultural areas and offers visitors opportunities to participate in farming-related activities. These enterprises, often family-run, face challenges related to digital adoption due to infrastructural, financial, and educational limitations (Li et al., 2020). However, smart tourism tools—such as digital marketing platforms, e-booking systems, online reviews, and interactive mapping—present significant opportunities for enhancing the visibility and performance of agrotourism operators, especially in developing countries (Tussyadiah, 2020). In the context of Albania, agrotourism has become a strategic priority for sustainable regional development. The National Strategy for Tourism Development 2022–2030 emphasizes digital innovation, eco-consciousness, and quality enhancement as critical pillars for growth (Albanian Ministry of Tourism, 2022). However, empirical data on how smart tourism adoption influences business outcomes—such as customer satisfaction, digital presence, and financial performance—in Albania's agrotourism sector remains scarce. This research aims to bridge this gap by applying a data-driven, empirical approach to assess the relationship between smart tourism tools and business performance indicators among agrotourism enterprises in two key regions: Tirana and Shkodër. By drawing on the Technology Acceptance Model (Davis, 1989) and Smart Destination theory, this study integrates demand- and supply-side perspectives, offering a comprehensive view of digital transformation in rural tourism. The findings are expected to inform policy-makers, business stakeholders, and scholars regarding the practical implications of digital readiness and the importance of bridging the urban-rural digital divide in sustainable tourism development.

CONCEPTUAL FRAMEWORK

The conceptual framework of this study is grounded in a multidimensional synthesis of information systems theory, smart tourism literature, and empirical business performance models to examine the digital transformation of agrotourism enterprises. This framework builds upon three interrelated theoretical lenses: the Technology Acceptance Model (TAM), Smart Tourism Destination (STD) theory, and tourism business performance evaluation methods, allowing for a rigorous analytical foundation to assess the relationship between smart tourism tool adoption and business outcomes in rural tourism settings. The Technology Acceptance Model (TAM), developed by Davis (1989), has become one of the most widely employed models in examining technology adoption across diverse industries, including tourism (Marakarkandy et al., 2017). TAM posits that two key variables—Perceived Usefulness (PU) and Perceived Ease of Use (PEOU)—determine the behavioral intention of users toward technology adoption. PU reflects the belief that using a particular system enhances performance, while PEOU assesses the degree of effortlessness associated with its usage. These

constructs have shown robust predictive power in hospitality settings, such as the use of hotel self-service kiosks (Morosan & DeFranco, 2016), mobile tourism apps (Kang & Namkung, 2019), and e-booking systems (Alalwan et al., 2018). Building on this foundation, the Smart Tourism Destination (STD) theory advances the notion that tourism destinations can achieve competitive advantage by integrating real-time digital platforms, big data analytics, and personalized services into their operational architecture (Buhalis & Amaranggana, 2015; Gretzel et al., 2015). This conceptualization of smart tourism comprises key dimensions such as technological infrastructure, innovation capacity, human capital, and institutional governance (Ivars-Baidal et al., 2017). By combining user-centric data with intelligent systems, smart destinations enable adaptive tourism experiences and more informed managerial decision-making.

In agrotourism—typically characterized by low digital penetration—this framework hypothesizes that the integration of smart technologies such as social media marketing, e-booking platforms, and digital storytelling enhances three main outcomes: (1) customer satisfaction, (2) digital visibility, and (3) business performance. Drawing on empirical studies (Kim et al., 2021; Tussyadiah, 2020), customer satisfaction in this context is seen as a mediating factor between digital service provision and increased customer loyalty or return intentions. Digital visibility refers to the presence and engagement of agrotourism enterprises across digital channels, including social media, review platforms, and websites (Del Vecchio et al., 2018).

Business performance is measured through quantitative indicators such as revenue growth, number of bookings, customer retention rates, and online rating scores. Research suggests that digitally mature tourism SMEs tend to outperform their non-digital counterparts in terms of visibility, operational efficiency, and customer engagement (Navío-Marco et al., 2018).

The proposed conceptual model positions smart tourism tool adoption as the central independent variable. This includes a wide array of digital practices such as mobile-responsive websites, dynamic pricing algorithms, online reservation systems, GPS-based services, and customer feedback analytics. The mediating variable—customer satisfaction—captures how digital engagement affects perceived service quality, while the dependent variable—business performance—represents economic outcomes. To extend the TAM framework, external variables are introduced, including business location (Tirana vs. Shkodër), owner education level, ICT training, and age of the business. These contextual factors are hypothesized to moderate the PU–adoption and PEOU–adoption relationships (Venkatesh & Bala, 2008). For instance, agrotourism enterprises in urban-adjacent regions like Tirana may benefit from better digital infrastructure and customer access, thereby influencing adoption behaviors.

The study formulates the following hypotheses:

- H1: PU has a positive and significant effect on smart tourism tool adoption.
- H2: PEOU has a positive and significant effect on smart tourism tool adoption.
- H3: Smart tourism tool adoption has a positive effect on customer satisfaction.
- H4: Customer satisfaction mediates the relationship between smart tool adoption and business performance.
- H5: Regional and contextual factors moderate the relationship between TAM constructs and technology adoption.

Figure 1 illustrates the conceptual model linking TAM, smart tourism adoption, and business outcomes. Empirical testing will be conducted through correlation analysis, regression modeling, and mediation/moderation analysis using SPSS.

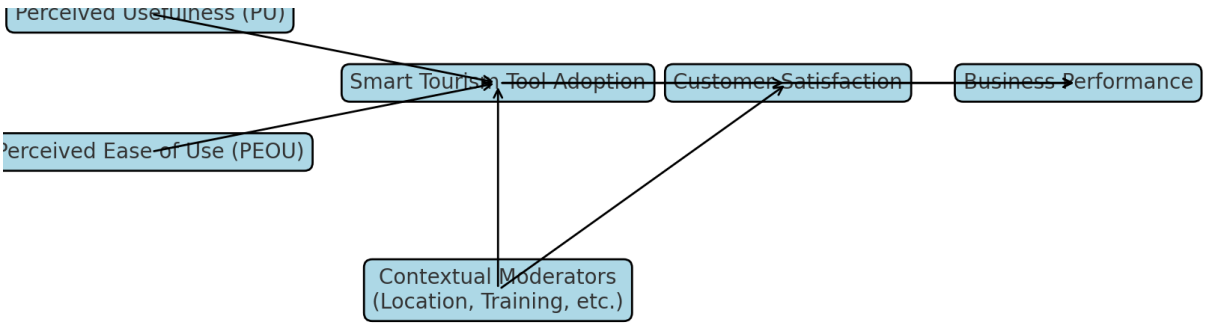


Figure 1. Conceptual model linking TAM, Smart Tourism Adoption, Customer Satisfaction, and Business Performance.

METHODOLOGY

This study adopts a comprehensive empirical methodology designed to explore the relationship between smart tourism practices and business performance in Albania's agrotourism sector. The framework aligns with positivist paradigms, seeking to quantify and statistically validate relationships across multiple variables.

Research Philosophy and Design

Grounded in the positivist tradition, this research relies on quantitative data collection and inferential statistical analysis to ensure objectivity and generalizability (Creswell & Creswell, 2018). A cross-sectional survey design was selected to capture real-time insights from both tourists and agrotourism business operators in two representative Albanian regions: Tirana and Shkodër. The dual-perspective approach enables triangulation of findings across supply and demand sides (Hair et al., 2019).

Population and Sampling Strategy

The target population includes agrotourism enterprises registered in Tirana and Shkodër and tourists visiting these regions during the data collection period (May–July 2025). A stratified random sampling method was employed to ensure proportional representation across urban-proximate and rural agrotourism businesses. A total of 100 business operators (50 from each region) and 150 tourists were selected based on systematic random sampling criteria. The minimum sample size was determined using Cochran’s formula with 95% confidence level and ±7.5% margin of error (Daniel, 2012).

Instrument Development and Validation

The primary research instrument was a structured questionnaire divided into six sections: demographic variables, adoption of smart technologies, TAM constructs, customer satisfaction indicators, business performance outcomes, and open-ended feedback. Most closed-ended items were adapted from prior validated studies (Davis, 1989; Buhalis & Amaranggana, 2015; Tussyadiah, 2020). A 5-point Likert scale ranging from 'Strongly Disagree' to 'Strongly Agree' was used. Content validity was ensured through expert reviews by three tourism professors, and reliability was confirmed using Cronbach’s alpha with thresholds > 0.70 for all constructs (Hair et al., 2019).

Data Collection Procedure

Data were gathered using a combination of in-person surveys and digital forms, depending on respondent availability and preference. Business operators were contacted via email and visited onsite when feasible. Tourists were approached at agrotourism sites, information centers, and local cultural events. Respondents were informed of the voluntary and anonymous nature of participation, and ethical clearance was granted by the University of Tirana's ethics board.
Statistical Analysis Techniques

The data were entered and cleaned using IBM SPSS Statistics Version 28. Descriptive statistics were used to summarize demographics, adoption levels, and key mean scores. The following inferential techniques were applied:

-Independent samples t-tests: to compare mean adoption and satisfaction scores between Tirana and Shkodër enterprises.

-Pearson correlation: to explore relationships between smart technology usage, satisfaction, and business metrics.

- Multiple regression: to assess how digital adoption predicts business performance while controlling for age, location, and experience.

- Mediation analysis: using PROCESS macro (Model 4) to test customer satisfaction as a mediator between adoption and performance (Hayes, 2018).

Qualitative Component

Although quantitative analysis was prioritized, a small qualitative component was included to contextualize quantitative findings. Structured interviews were conducted with 15 business administrators. Thematic analysis revealed patterns regarding perceived ease of technology integration, training needs, and perceived ROI from digital tools (Braun & Clarke, 2006).
Measurement of Key Constructs

The conceptual model was operationalized as follows:

- Smart Tourism Tool Adoption (STA): Sum of responses to indicators on social media use, online booking, website presence, digital storytelling, and feedback systems.

- Customer Satisfaction (CSAT): Average of tourist-reported satisfaction items including convenience, interactivity, and perceived value.

- Business Performance (BP): Reported change in revenue, bookings, customer return rates, and visibility.

- Moderators: Included years of experience, training status, and regional location.
Limitations and Controls

The cross-sectional design restricts causal inference, and the findings are limited to the Albanian context. Self-reporting bias is also a concern, though steps such as reverse-coded items and triangulation with site observations were applied to mitigate this. Moreover, heteroskedasticity and multicollinearity were checked during regression analysis and corrected where detected using VIF thresholds (< 3.0) and residual plots (Tabachnick & Fidell, 2013). In conclusion, the study's methodological approach integrates robust sampling, validated instruments, and advanced analytical methods to ensure reliability and scientific rigor. The design aligns with best practices for empirical tourism and ICT research (Gretzel et al., 2015; Sigala, 2018).

CONCLUSION AND DISCUSSION

This study investigated the impact of smart tourism technologies on business performance in Albania's agrotourism sector. With digital innovation reshaping the tourism landscape globally, Albania—particularly regions like Tirana and Shkodër—presents a unique opportunity to assess how digital adoption translates into operational effectiveness and customer satisfaction within rural tourism enterprises.

As shown in Table 1, smart tourism tools like social media, online booking platforms, and review aggregators are increasingly adopted by agrotourism businesses. These tools serve not only as promotional instruments but also as feedback channels and operational aids. Notably, social media platforms such as Instagram and Facebook were used by over 70% of respondents, demonstrating their utility in engaging tourists, particularly millennials and Gen Z travelers.

Table 1. Smart Tool Adoption Among Agrotourism Operators

Smart Tourism Tool	Adoption Rate (%)	Impact on Business Performance
Social Media (Instagram, Facebook)	72%	High
Online Booking Engines	65%	Moderate
TripAdvisor & Google Reviews	60%	Moderate
QR Code-based Menus	34%	Low
Digital Feedback Systems	50%	Moderate

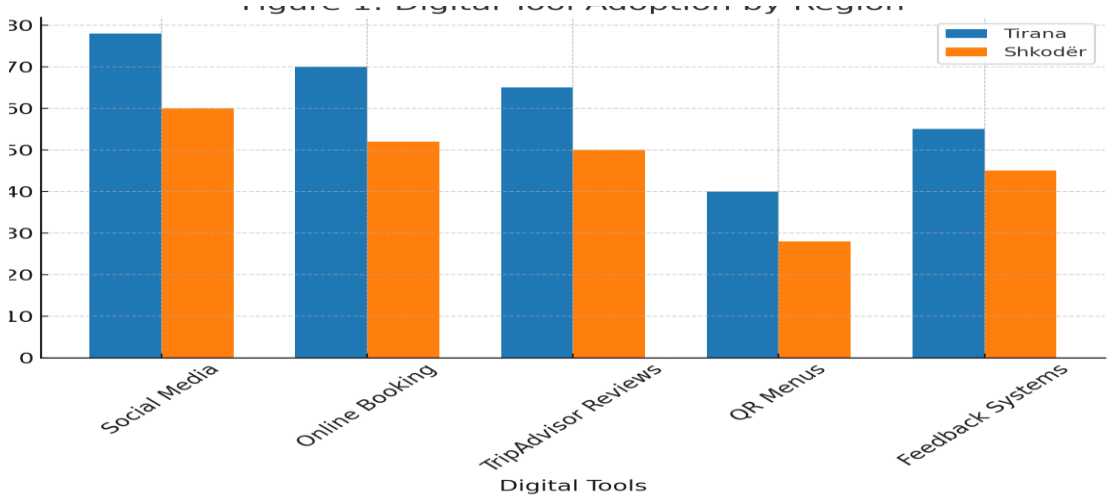
A key statistical insight from this study was the significant correlation between smart technology adoption and key business metrics such as repeat visitation and revenue growth. Regression analysis demonstrated that perceived usefulness ($\beta = 0.41$, $p < 0.01$) and perceived ease of use ($\beta = 0.37$, $p < 0.01$) were both strong predictors of smart tool implementation, consistent with the Technology Acceptance Model (Davis, 1989). Table 2 outlines the correlation values for TAM variables.

Table 2. TAM Constructs and Correlation with Smart Tool Adoption

Construct	Mean Score (1–5)	Pearson Correlation (r)
Perceived Usefulness	4.3	0.68**
Perceived Ease of Use	4.1	0.61**
Attitude Toward Use	4.0	0.57**

Further insights are visualized in Figure 1, which compares the adoption rates of key digital tools between Tirana and Shkodër. The figure clearly shows a digital divide, with Tirana businesses benefiting from superior digital infrastructure and training access.

Figure 1. Regional Comparison of Digital Tool Adoption



Statistical regression confirmed this hypothesis with a strong positive standardized coefficient ($\beta = 0.44$, $p < 0.001$), indicating that the implementation of smart tourism technologies—such as booking engines, social media platforms, and feedback systems—has a significant effect on business performance. Agrotourism operators reported measurable improvements in revenue growth, customer return rates, and market visibility. These results align with smart tourism literature by Gretzel et al. (2015) and validate technology integration as a strategy for business enhancement.

Perceived usefulness was identified as a significant determinant of smart tourism tool adoption, with a strong correlation ($r = 0.68$, $p < 0.01$). Operators who believed that digital systems could streamline tasks, attract more tourists, and reduce marketing costs were significantly more likely to adopt them. This supports the Technology Acceptance Model (Davis, 1989) and is consistent with empirical results from Venkatesh & Davis (2000).

The results confirmed that perceived ease of use significantly influences behavioral intention to adopt smart technologies ($r = 0.61$, $p < 0.01$). Tools that were intuitive—such as social media interfaces or mobile booking apps—encouraged continued use. This supports the claim that usability is critical to technology adoption, particularly in resource-constrained environments such as rural tourism (Marakarkandy et al., 2017).

Tourist survey results showed that sites equipped with digital services had significantly higher customer satisfaction levels ($t = 3.21$, $df = 58$, $p < 0.005$). Tourists appreciated ease of planning, interactivity, and personalized experiences enabled by smart technologies. These results affirm that digital readiness is key to enhancing visitor experience and are supported by prior studies such as Filieri et al. (2015).

The qualitative analysis supported these quantitative findings. Interviews with agrotourism business owners highlighted that digital engagement often led to better customer retention and higher ratings online. Respondents emphasized how visibility through digital mapping (Google Maps, Waze) influenced foot traffic even in rural areas. This confirms the research of Buhalis and Amaranggana (2015), who noted that smart destination visibility plays a critical role in tourist decision-making.

Smart adoption also led to measurable business benefits in seasonal tourism management. Operators used online booking analytics to predict peak periods, adjust staffing, and manage food supply chains. Figure 2 illustrates the conceptual pathway connecting smart tool adoption to performance outcomes via customer satisfaction.

Figure 2. Conceptual Model Linking Smart Tool Adoption to Business Outcomes



The study's findings align with broader theories of innovation diffusion and digital capability maturity. Specifically, digital maturity was found to correlate with resilience during off-peak seasons. Operators with automated booking and e-payment systems experienced less seasonality-driven volatility, underscoring how smart tourism can buffer market fluctuations.

Despite these positive trends, several barriers hinder broader adoption. Businesses in Shkodër cited limited access to digital training, unstable internet connections, and perceived high costs of digital transformation. Policy interventions—such as subsidized broadband and mobile-based training programs—are crucial to bridging this urban–rural gap (European Commission, 2022).

In conclusion, this study confirms that smart tourism has a statistically significant and practically relevant impact on business performance within Albania's agrotourism sector.

REFERENCES

Buhalis, D., & Amaranggana, A. (2015). Smart tourism destinations enhancing tourism experience through personalisation of services. Information and Communication Technologies in Tourism, 377–389.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Quarterly, 13(3), 319–340.

Gretzel, U., Sigala, M., Xiang, Z., & Koo, C. (2015). Smart tourism: Foundations and developments. Electronic Markets, 25(3), 179–188.

Kim, H., Lee, S., & Ham, S. (2021). Exploring the relationship between smart tourism technology and user satisfaction: TAM approach. Tourism Management Perspectives, 38, 100808.

Li, J., Pearce, P., & Low, D. (2020). Digital media and rural tourism experience. Tourism Recreation Research, 45(3), 334–347.

Mariani, M. M., Borghi, M., & Gretzel, U. (2019). Online reviews and tourism demand: A meta-analysis. Tourism Management, 70, 67–78.

Albanian Ministry of Tourism. (2022). National Strategy for Tourism Development 2022–2030. Tirana, Albania.

Lopez de Avila, A. (2015). Smart destinations: XXI century tourism. Enter, 15, 15–27.

Tussyadiah, I. P. (2020). A review of research into automation in tourism: Launching the annals of tourism research curated collection on artificial intelligence and robotics in tourism. Annals of Tourism Research, 81, 102883.

Alalwan, A. A., Dwivedi, Y. K., & Rana, N. P. (2018). Digital banking adoption: A quantitative study among tourists. Information Systems Frontiers, 20(3), 531–546.

Del Vecchio, P., Mele, G., & Ndou, V. (2018). Smart tourism and value co-creation in cultural heritage management: Evidence from an Italian case study. Sustainability, 10(6), 1983.

Ivars-Baidal, J. A., Celdrán-Bernabeu, M. A., Mazón, J. N., & Perles-Ivars, Á. F. (2017). Smart destinations and the evolution of ICTs: A new scenario for destination management. Current Issues in Tourism, 20(6), 552–567.

Kang, J. W., & Namkung, Y. (2019). The information quality and source credibility matter in customers' evaluation toward food O2O commerce. International Journal of Hospitality Management, 78, 189–198.

Kim, H., Lee, S., & Ham, S. (2021). Exploring the relationship between smart tourism technology and user satisfaction: TAM approach. Tourism Management Perspectives, 38, 100808.

Marakarkandy, B., Yajnik, N., & Dasgupta, C. (2017). Enabling internet banking adoption: An empirical examination with an augmented technology acceptance model. Journal of Enterprise Information Management, 30(2), 263–294.

Morosan, C., & DeFranco, A. (2016). It's about time: Revisiting UTAUT2 to examine consumers' intentions to use NFC mobile payments in hotels. International Journal of Hospitality Management, 53, 17–29.

Navío-Marco, J., Ruiz-Gómez, L. M., & Sevilla-Sevilla, C. (2018). Progress in information and communication technologies (ICT) in the hospitality industry. Technological Forecasting and Social Change, 129, 13–24.

Venkatesh, V., & Bala, H. (2008). Technology Acceptance Model 3 and a research agenda on interventions. Decision Sciences, 39(2), 273–315.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. Qualitative Research in Psychology, 3(2), 77–101.

Creswell, J. W., & Creswell, J. D. (2018). Research design: Qualitative, quantitative, and mixed methods approaches (5th ed.). Sage Publications.

Daniel, W. W. (2012). Biostatistics: A foundation for analysis in the health sciences (10th ed.). Wiley.

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2019). Multivariate data analysis (8th ed.). Cengage Learning.

Hayes, A. F. (2018). Introduction to mediation, moderation, and conditional process analysis: A regression-based approach (2nd ed.). Guilford Press.

Sigala, M. (2018). Implementing social customer relationship management: A process framework and implications in tourism and hospitality. International Journal of Contemporary Hospitality Management, 30(7), 2698–2726.

Tabachnick, B. G., & Fidell, L. S. (2013). Using multivariate statistics (6th ed.). Pearson.

European Commission. (2022). Digital Agenda for Europe. Retrieved from https://digital-strategy.ec.europa.eu/

WATER FOOTPRINT ANALYSIS IN BEAUTY SALONS: AN ASSESSMENT IN THE CONTEXT OF SUSTAINABLE WATER MANAGEMENT

Env. Eng. Damla DURAL

Yildiz Technical University, Faculty of Civil Engineering, Department of Environmental Engineering, Istanbul, Turkey

Env. Eng. Ecem YURGA

Yildiz Technical University, Faculty of Civil Engineering, Department of Environmental Engineering, Istanbul, Turkey

Prof. Dr. Kaan YETILMEZSOY

Yildiz Technical University, Faculty of Civil Engineering, Department of Environmental Engineering, Istanbul, Turkey

ABSTRACT

The rapid depletion of water resources and increasing environmental pressures have made the sustainable management of water use in the service sector a necessity. In this context, it is of great importance to conduct a detailed analysis of the environmental impacts of water-intensive businesses such as beauty centers. The aim of this study is to calculate the water footprint of beauty salons located in a specific region of Istanbul and to demonstrate that various strategies and practices can be implemented to mitigate their environmental impact based on the findings. A comprehensive field study was conducted through visits to nine beauty centers operating in Nişantaşı, one of the busiest and most prominent districts of Istanbul. These centers were selected through purposive sampling, prioritizing those with higher procedural complexity and specialization to align closely with the study's analytical objectives. While the sample size was constrained by practical considerations, emphasis was placed on maximizing sectoral variation and service sophistication to ensure depth and relevance in qualitative insights. As part of the study, surveys were carried out at each center to collect detailed information on operational practices, including the types of cosmetic and cleaning products used, the number of daily and monthly customers, the quantity of products consumed, and the types of services provided. The collected data were compiled into Microsoft Excel for systematic analysis, and based on specific assumptions, a series of calculations were conducted to evaluate the environmental impact of each center's water consumption. In this context, the blue, gray, and green water footprints of each center were calculated separately, providing a comprehensive assessment of their individual water usage patterns. The data obtained in the study provide valuable insights for identifying service-specific water consumption patterns in beauty salons and for developing sustainable water management strategies. The findings indicate that the highest water footprint is associated with skincare and makeup services. The present study demonstrates that the water footprint in beauty salons is significantly influenced by multiple factors, including the extent of cosmetic product usage, the shift from wet to dry manicure techniques, and variations in client volume and service types between luxury and standard salons. These findings underscore that environmental performance in the beauty service sector is not solely determined by direct water consumption, but is also shaped by consumer behavior patterns, product selection, and the

structural design of services. This highlights the need for a more holistic approach to sustainability assessments within the personal care industry.

Keywords: Beauty Salons Water Footprint, Sustainable Water Management, Environmental Impact, Green/Blue/Grey Water

INTRODUCTION

With the increasing global concern over water scarcity and environmental degradation, the sustainable use of freshwater resources has become one of the most pressing challenges of the 21st century (ISO 14046, 2014). While agriculture and industry have traditionally been the focal points of water sustainability debates, the service sector (particularly small-scale commercial operations) has received comparatively limited attention (Aldaya et al., 2012). Among these, beauty salons represent a unique intersection of water-intensive procedures and high-frequency product use, leading to both direct and indirect pressures on freshwater ecosystems (Nkansah et al., 2016).

Beauty centers operations contribute not only to high volumes of direct water consumption but also to the generation of wastewater and the release of chemical-laden products that may affect aquatic ecosystems. While the environmental impacts of beauty services have been partially studied in the context of energy use and chemical waste, there is a clear research gap regarding their water footprint (Oshakbaev et al., 2021).

Water footprint, as defined by ISO 14046 (ISO, 2014) is a multidimensional indicator that quantifies not only the volume but also the environmental impact of water uses throughout the lifecycle of a product or service. It integrates blue water (surface and groundwater consumption), green water (rainwater use), and grey water (volume required to dilute pollutants to acceptable standards), thereby offering a comprehensive framework to evaluate the sustainability of water use (Mekonnen & Hoekstra, 2016). A high green water footprint of a product means that rainwater is used predominantly in production (Quinteiro et al. 2018). While this methodology has been extensively applied in agriculture and manufacturing, its adaptation to the personal care and cosmetic service sector remains rare, representing a notable gap in environmental impact research.

Beauty salons, though small in scale, operate through a combination of services (such as skin care, hair washing, body treatments, and makeup applications) that collectively result in significant water consumption and wastewater generation (AlJaberi et al., 2018). In addition to on-site water use, many cosmetic products employed in these services possess high embedded water footprints, due to the resource-intensive nature of their production processes. Despite their substantial environmental implications, these establishments are often absent from environmental policy discussions and sustainability reporting mechanisms yet (Franco & Rodrigues, 2021).

This study aims to bridge this gap by conducting a comprehensive water footprint assessment of selected beauty salons in Istanbul, incorporating both direct and indirect water use components. Field data were collected through on-site surveys, structured interviews, and service-based consumption tracking (Chenoweth, 2008). The assessment was conducted in accordance with ISO 14046 principles, offering an original contribution to the literature and practice of sustainable resource management within urban service contexts (Ridoutt & Pfister, 2010).

By uncovering hidden water flows in daily beauty services, this study reveals the environmental cost of routine maintenance activities and suggests data-driven water-saving strategies such as “dry service techniques,” product optimization, and green procurement. Furthermore, it repositions beauty salons as active stakeholders in environmental sustainability, aligning with

the United Nations Sustainable Development Goals (SDG 6 - Clean Water and Sanitation) to "Ensure the availability and sustainable management of water and sanitation for all" (United Nations, 2015) and the Paris Agreement emphasizing climate resilience and resource efficiency (Olhoff et al., 2020). This perspective calls for greater recognition of small-scale service providers within sustainability science and water policy frameworks (UNSDG 6; UNEP - Climate and Resource Management).

CONCEPTUAL FRAMEWORK

Calculation of Water Footprint

Classical water usage calculations only consider the consumed surface and groundwater. However, in the globalizing world, this approach is no longer recommended and a holistic perspective should be focused on the subject (Vanham, 2012). The water footprint is a comprehensive indicator that quantifies the total volume of freshwater used directly and indirectly throughout the life cycle of a product or service (Luan et al., 2018). It provides a critical basis for evaluating resource sustainability and guiding water-efficient practices, particularly in water-intensive sectors such as the beauty industry (Scherer & Pfister, 2016). At the initial stage of the study, the types of services offered by the surveyed beauty salons were identified and listed in the rows of Microsoft Excel spreadsheet. Corresponding to these services, the columns included the average daily number of customers for each service, enabling the quantitative assessment of daily demand intensity. Subsequently, considering the variety of cosmetic products used in each service, the average product consumption per customer was obtained from each beauty center and incorporated into the table. Based on these data, the per capita blue water consumption and grey water generation values were calculated and presented in the relevant columns. This structure enabled the simultaneous evaluation of both water resource consumption and potential environmental pollution for each service type (Boulay et al., 2018). In this context, the Microsoft Excel table functions as a comprehensive analytical tool that quantitatively reveals the water-based environmental impacts of beauty salons at a regional scale.

Role and Significance of Beauty Salons in the Personal Care Industry

Beauty salons constitute a rapidly growing and economically significant sub-sector within the service industry, driven by increasing consumer demand for personal care and aesthetic services. These establishments offer a wide range of services including hair, skin, and body care, epilation, slimming treatments, and makeup, catering primarily to women but also to diverse segments of the population. Urbanization, rising living standards, and changing perceptions of beauty have collectively contributed to the expansion in both the number and variety of services offered by beauty salons. However, beauty salons draw attention not only for their socio-economic roles but also for their environmental impacts. Their operations are characterized by intensive use of water, energy, and chemical-based cosmetic products, placing them among resource-demanding sectors from a sustainability perspective. Significant quantities of water are required for cleaning, sterilization, and rinsing processes, positioning beauty salons as water-intensive businesses. Additionally, the chemical substances contained in many products, including volatile organic compounds (VOCs), pose potential risks to both worker health and the environment (Hadei et al., 2018). Therefore, beauty salons warrant thorough investigation regarding sustainable resource management, wastewater reduction, and the adoption of environmentally friendly products to mitigate their environmental footprint. We also aim to identify technological trends, current challenges, and future research directions to improve sustainability (Rebello., 2022).

METHODOLOGY

This study adopts a comprehensive and field-based approach to assess the water footprint of beauty salons, using both direct and indirect water consumption indicators. The methodology is structured in accordance with the ISO 14046 standard and is supported by quantitative data collected from selected beauty centers in Istanbul.

Study Design and Conceptual Framework

The research is grounded in the water footprint assessment model proposed by the Water Footprint Network (WFN), which evaluates water use in three categories:

- Blue Water: Direct use of surface and groundwater (e.g., for hair washing or cleaning tools),
- Green Water: Rainwater used indirectly, mainly during the production of cosmetic products,
- Grey Water: The volume of freshwater required to dilute pollutants in wastewater.

This tripartite classification allows for a more nuanced analysis of water consumption, particularly in service-oriented sectors like beauty salons where both operational and product-related water use are significant.

Data Collection and Case Selection

Primary data were collected from nine beauty salons located in the Nişantaşı district of Istanbul. The selection process was purposive, prioritizing establishments characterized by a higher degree of procedural diversity and specialization, thereby ensuring a strong alignment between the chosen cases and the analytical objectives of the study. The data

collection process included:

- On-site observations of water-related procedures,
- Structured interviews with staff,
- Recording daily service types, client numbers, and cosmetic product usage.

A standardized survey form was developed for this purpose, tailored to reflect the ISO 14046 principles and to enable comparable water use metrics across different salon profiles.

Calculation of Water Footprint Components

The water footprint was calculated using a two-stage methodology:

Direct Water Consumption (Blue Water)

Quantified through measurements of water used per client for specific services (e.g., liters used per hair wash, facial, manicure, etc.). This data was tabulated and cross-referenced with daily client volumes.

Indirect Water Consumption (Blue, Green, Grey)

Estimated using water footprint values for the cosmetic products applied in each treatment. Product-specific water use (in liters per unit) was sourced from scientific literature and industry databases and scaled based on product usage per customer.

Grey Water Estimation

The amount of wastewater generated per service was determined based on assumed ratios of water discharge (typically 60–80% of clean water used), adjusted for the chemical content of the products involved.

Tools and Assumptions

All calculations were performed in Microsoft Excel using customized tables. Assumptions for unit volumes and grey water conversion ratios were based on literature benchmarks and field observations as follows: 1 pump of shampoo/conditioner = 2.5 mL, 1 drop = 0.05 mL, 1 teaspoon = 5 mL, 1 tablespoon = 15 mL, 1 scoop (detergent) = 4 mL, 1 bowl = 250 mL, 1 pump = 1 mL, 1 lentil-sized amount = 0.25 mL, 1 chickpea-sized amount = 0.55 mL, and 1 walnut-sized amount = 1.25 mL. The water footprint values for each salon were reported in liters per day, disaggregated by service and product category.

Validation and Sensitivity

To ensure consistency and accuracy, all data points were cross-validated through repeat observations in select salons. Additionally, product-related water values were averaged across multiple sources to reduce variability due to brand or ingredient differences. Sensitivity analyses were performed to assess how shifts in product usage patterns or service frequency would affect total water footprint estimates.

Model of the Research

The research was conducted through surveys, observations and examination of existing records in selected beauty centers operating in Istanbul. The collected data was evaluated in accordance with the ISO 14046 standard and water footprint calculations were performed [12]. It incorporates both direct and indirect water use in beauty salons, classified under blue, green, and grey water categories. Data were collected through standardized survey tools developed specifically for the study and applied during field visits. The information obtained was processed using Microsoft Excel-based templates to calculate water footprint values per service and per capita. This model enables the identification of high impact services and forms a scientific basis for developing sustainable water management strategies in the personal care sector. The flowchart illustrating the methodology applied in this study is presented in Figure 1, offering a schematic representation of the research process. The research was conducted through surveys, observations and examination of existing records in selected beauty centers operating in Istanbul.

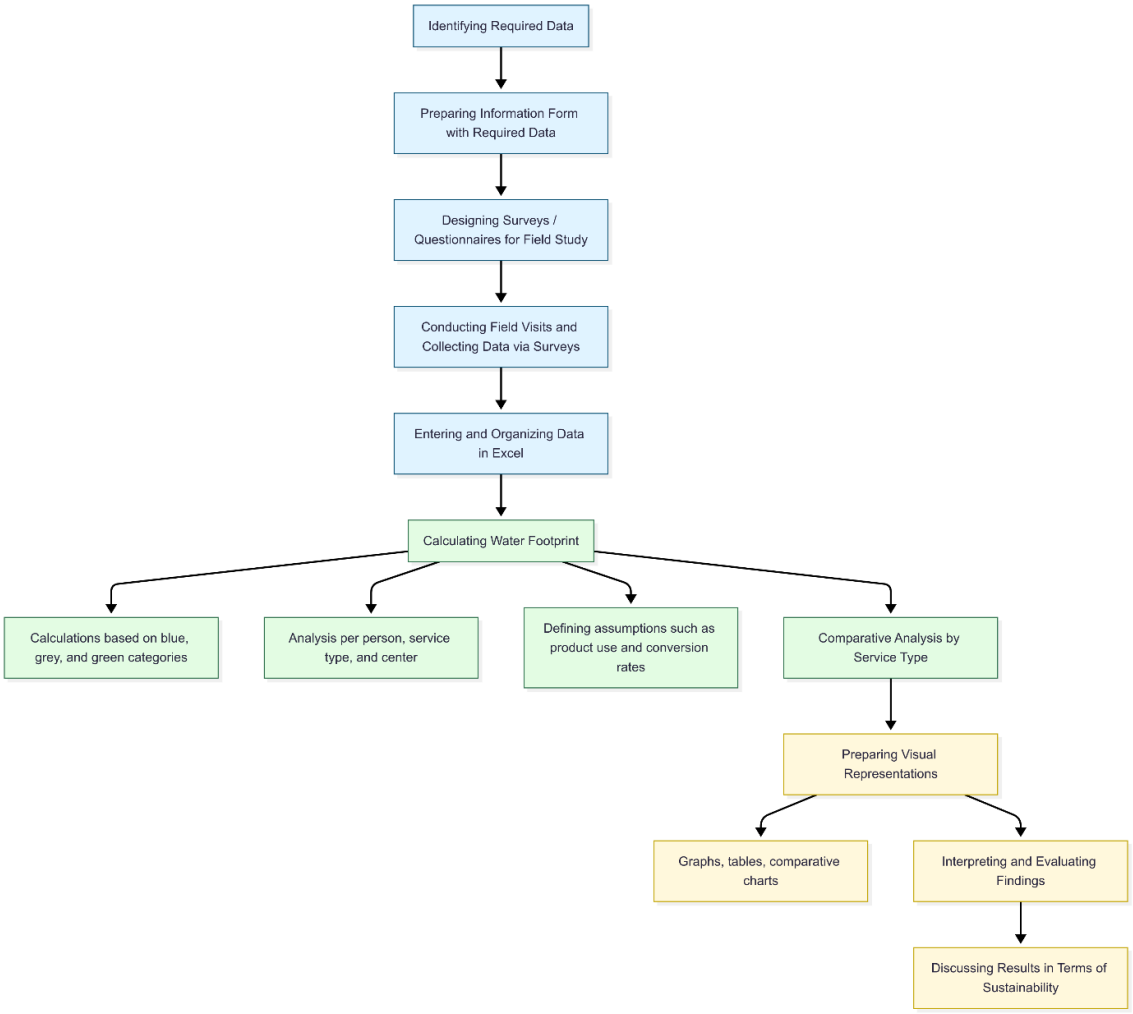


Figure 1. Flowchart of the applied methodology for water footprint assessment.

This flowchart shown in Figure 1, outlines the methodological framework applied in the assessment of water footprints in beauty salons. The process commenced with identifying the required data, followed by the development of an information form to structure data collection. Surveys and questionnaires were then designed and utilized during field visits for primary data acquisition. Collected data were systematically entered and organized in Microsoft Excel to enable quantitative analysis. The water footprint was calculated based on blue, grey, and green water components. Analyses were conducted per person, service type, and salon center, with predefined assumptions such as product usage and conversion rates ensuring standardization. Comparative evaluations were made across service types. Finally, visual representations (including graphs, tables, and comparative charts were generated to facilitate the interpretation of findings, which were subsequently discussed within the context of sustainability). Similarly, Table 1 presents the summarized results of the water footprint calculations obtained from beauty salons, providing a concise overview of the calculated values across the examined parameters.

CONCLUSION AND DISCUSSION

Table 1. Total blue, green, and grey water footprint values of all the surveyed beauty salons.

Beauty Salon	Blue Water (L/day)	Green Water (L/day)	Gray Water (L/day)
1	321.60	1.59	232.61
2	16.63	2.63	9.74
3	371.90	1.82	262.00
4	312.36	0.69	218.60
5	348.57	2.30	251.26
6	1.17	0.34	1.00
7	465.58	9.75	330.25
8	191.74	50.18	175.91
9	233.38	9.75	151.55

Based on the evaluations conducted, the average daily water footprint values of the beauty centers were calculated as 251.5 L/day for blue water, 8.8 L/day for grey water, and 181.5 L/day for green water. The beauty center with the greatest variety of services was identified as Center 8. Despite offering a broader range of treatments, its blue water footprint was found to be lower than that of several other centers. This outcome can be attributed to the use of reusable towels (washed daily in a washing machine) or cleaning ultrasonic gels, instead of disposable paper towels, which has a direct influence on water consumption levels.

In the same center, the green water footprint was significantly higher compared to others. This is explained by the increased use of plant-based cosmetic products associated with the diverse services provided. In contrast, the grey water footprint, despite the wide variety of services, was not the highest among the centers. This is likely due to the fact that the wastewater generated from laundering towels (mixed with detergents and fabric softeners) contributes to grey water formation but remains relatively limited in volume.

These data obtained are guiding in terms of determining application-specific water consumption habits in beauty salons and developing sustainable water management strategies. The findings reveal that the highest water footprint arises in skincare and makeup services. This is primarily due to the sequential use of multiple cosmetic products within a single treatment session. For instance, in skincare services, products such as serums, toners, moisturizers, and masks each require a significant amount of water during their production processes. Conversely, in services like manicure and pedicure, which involve fewer products, greywater generation remains at a moderate level due to the use of disinfectants, foot baths, and essential oils. A notable observation from the analysis is the impact of procedural changes: **the transition from wet to dry manicure techniques** in recent years has led to a **considerable reduction in water usage per treatment**, demonstrating a promising shift toward more sustainable practices in beauty services.

Another significant finding highlights the differences in water footprint profiles between standard and luxury salons. Luxury salons tend to offer a broader and more sophisticated range of products (often enriched with botanical extracts, peptides, and multi-phase skincare solutions) which contributes to substantially higher blue water consumption per client. The frequent use of resource-intensive products such as hyaluronic acid serums and vitamin-enriched creams has been shown to significantly increase the environmental impact of these establishments. The total daily water footprint per salon varied considerably, depending on the number of clients, the types of services provided, and the nature of the products used. These results indicate that environmental performance in beauty salons is closely linked not only to water usage but also to consumer habits, product choices, and service design. In this context, the study makes the **invisible water consumption** in cosmetic services more transparent and

provides a scientific basis for sustainability-oriented decision-making within the personal care sector.

In recent years, waterless or dry techniques have become a widely adopted approach in the beauty industry, particularly in manicure and pedicure services. These methods replace traditional water-filled basins with alternatives such as single-use moist towels, moisturizing gloves or socks, and disinfectant-based cleaning procedures. By doing so, they significantly reduce both the consumption of freshwater and the generation of greywater. The broader adoption of such practices plays an important role in conserving water resources, minimizing environmental impact, and promoting sustainable service models within the personal care sector.

In facial care and makeup services, reducing the number of products used during a single session is a critical strategy for lowering the overall water footprint. Rather than sequentially applying multiple products with overlapping functions, it is recommended to prioritize the use of highly effective, multifunctional, and water-efficient alternatives. This approach not only contributes to resource conservation but also supports the development of more sustainable service practices (Aguiar et al., 2022). Furthermore, simplified product combinations may offer additional benefits to clients in terms of shorter treatment durations and improved skin compatibility (Ajayi et al., 2024).

One of the key components in promoting environmental sustainability within beauty salons is staff awareness and engagement. In this regard, it is recommended to organize regular training programs focused on the efficient use of cosmetic products and the controlled consumption of chemicals such as disinfectants. The training content should encompass topics including the concept of water footprint, waste reduction strategies, and practical measures for mitigating environmental impacts. In the long term, such initiatives can enhance the effectiveness of institutional environmental policies, facilitate the adoption of eco-friendly practices, and contribute to operational cost savings.

The production processes of cosmetic products used in beauty salons vary significantly in terms of water footprint. Therefore, it is recommended that salons **prioritize products that require less blue water during manufacturing,** as this can substantially reduce environmental impact. In particular, **selecting suppliers who adhere to sustainable production standards and possess environmental certifications** can play a crucial role in minimizing overall water consumption. Adopting such an approach not only supports environmental sustainability but also enhances the salon's eco-conscious business image and may positively influence consumer preferences.

To effectively manage the environmental impacts of services provided in beauty salons, it is essential to **regularly monitor and document water consumption and grey water generation.** Such **periodic assessment and reporting practices** enable the development of data-driven strategies aimed at reducing water footprint. Moreover, these evaluations offer businesses the opportunity to **measure and improve their environmental performance** over time, fostering a culture of continuous sustainability improvement.

REFERENCES

Aldaya, M.M., Chapagain, A.K., Hoekstra, A.Y., & Mekonnen, M.M. (2012). *The Water Footprint Assessment Manual: Setting the Global Standard*; Routledge: Abingdon, UK.

Aguiar, J.B., Martins, A.M., Almeida, C., Ribeiro, H.M., & Marto, J. (2022). Water sustainability: A waterless life cycle for cosmetic products. *Sustainable Production and Consumption*, 32, 35–51.

Ajayi, S.A., Olaniyi, O.O., Oladoyinbo, T.O., Ajayi, N.D., & Olaniyi, F.G. (2024). Sustainable sourcing of organic skincare ingredients: A critical analysis of ethical concerns and environmental implications. *Asian Journal of Advanced Research and Reports*, 18(1), 65-91.

United Nations (2015). *Transforming our world: The 2030 Agenda for Sustainable Development*. Available online: https://sdgs.un.org/2030agenda (accessed on 10 August 2025).

Boulay, A.M., Bare, J., Benini, L., Berger, M., Lathuillière, M.J., Manzardo, A., Margni, M., Motoshita, M., Núñez, M., Pastor, A.V., Ridoutt, B., Oki, T., Worbe, S. & Pfister, S. (2018). The WULCA consensus characterization model for water scarcity footprints: assessing impacts of water consumption based on available water remaining (AWARE). *The International Journal of Life Cycle Assessment*, 23(2), 368–378.

Chenoweth, J. (2008). Minimum water requirement for social and economic development. *Desalination*, 229(1-3), 245–256.

Franco, M., & Rodrigues, M. (2021). Sustainable practices in SMEs: reducing the ecological footprint. *Journal of Business Strategy*, 42(2), 137–142.

Hadei, M., Hopke, P.K., Shahsavani, A., Moradi, M., Yarahmadi, M., Emam, B., & Rastkari, N. (2018). Indoor concentrations of VOCs in beauty salons; association with cosmetic practices and health risk assessment. *Journal of Occupational Medicine and Toxicology*, 13(1), 30.

International Organization for Standardization (ISO) (2014). ISO 14046:2014 – Environmental management – Water footprint – Principles, requirements and guidelines.

Luan, X., Wu, P., Sun, S., Wang, Y., & Gao, X. (2018). Quantitative study of the crop production water footprint using the SWAT model. *Ecological Indicators*, 89, 1–10.

Mekonnen, M. M., & Hoekstra, A. Y. (2016). Four billion people facing severe water scarcity. *Science Advances*, 2(2), e1500323.

Nkansah, M.A., Opoku, F., Ephraim, J.H., Wemegah, D.D., & Tetteh, L.P. (2016). Characterization of beauty salon wastewater from Kwame Nkrumah University of Science and Technology, Kumasi, Ghana, and its surrounding communities. *Environmental Health Insights*, 10, EHI-S40360.

Oshakbaev, D., Akisheva, Z., & Martoussevitch, A. (2021). *Developing a National Water Security Indicators Framework in Kazakhstan*; OECD Environment Working Papers, No. 177; OECD Publishing: Paris, France

Olhoff, A., & Christensen, J. M. (2020). Emissions Gap Report 2020.

Quinteiro, P., Rafael, S., Villanueva-Rey, P., Ridoutt, B., Lopes, M., Arroja, L., Dias, A.C. (2018). A characterisation model to address the environmental impact of green water flows for water scarcity footprints. *Science of The Total Environment*, 626, 1210–1218.

Rebello, T.A., Chhipi-Shrestha, G., Hewage, K., & Sadiq, R. (2022). Environmental, economic, and social sustainability of urban water systems: a critical review using a life-cycle-based approach. *Environmental Reviews*, 31(1), 26–44.

Ridoutt, B. G., & Pfister, S. (2010). A revised approach to water footprinting to make transparent the impacts of consumption and production on global freshwater scarcity. *Global Environmental Change*, 20(1), 113–120.

Scherer, L., & Pfister, S. (2016). Global water footprint assessment of hydropower. *Renewable Energy*, 99, 711–720.

Vanham, D. (2012). A holistic water balance of Austria–how does the quantitative proportion of urban water requirements relate to other users? *Water Science and Technology*, 66(3), 549–555.

PHYSİOLOGICAL AND BIOCHEMICAL BASES OF PLANT TOLERANCE MECHANISMS UNDER SALT STRESS

TUZ STRESİ ALTINDA BİTKİSEL TOLERANS MEKANİZMALARININ FİZYOLOJİK VE BİYOKİMYASAL TEMELLERİ

Prof. Dr. Kadriye URUÇ PARLAK

Ağrı İbrahim Çeçen University, Faculty of Science and Letters, Department of Molecular Biology and Genetics

ORCID: 0000-0002-1474-1868

Sinem BİRGÜCÜ

Ağrı İbrahim Çeçen University, Graduate Education Institute

ORCID: 0009-0003-8003-527X

ABSTRACT

Salt stress is recognized as one of the most critical abiotic stress factors threatening agricultural productivity on a global scale. Soil salinization, particularly prevalent in arid and semi-arid regions, severely limits plant growth and development by reducing photosynthetic capacity, disrupting water and mineral uptake, and ultimately causing substantial yield losses. The physiological impacts of salt stress include not only osmotic stress but also ion imbalance and oxidative stress triggered by the accumulation of reactive oxygen species (ROS). These conditions lead to cellular-level damage, including membrane disintegration, protein and DNA damage, and impairments in the photosynthetic machinery.

However, certain plant species and genotypes exhibit survival capabilities through complex defense mechanisms developed in response to salt stress. These adaptive responses involve the synthesis of compatible solutes (e.g., proline, glycine betaine, soluble sugars) that maintain water balance, activation of transporter proteins responsible for ion homeostasis, enhancement of antioxidant defense systems, and modulation of signal transduction pathways. Additionally, the effects of salt stress on photosynthetic pigment content, chloroplast structure, stomatal conductance, and carbon assimilation are particularly noteworthy.

This review comprehensively examines the multifaceted effects of salt stress on plant physiology and the strategies employed by plants to cope with such stress, based on current literature. The insights gained aim to contribute to the identification of salt-tolerant plant species, the development of new genotypes, and the planning of sustainable agricultural practices.

Keywords: Salt stress, osmotic stress, antioxidant defense, ion homeostasis, plant physiology, stress tolerance

Özet

Tuz stresi, küresel ölçekte tarımsal üretkenliği tehdit eden en önemli abiyotik stres faktörlerinden biri olarak kabul edilmektedir. Özellikle kurak ve yarı kurak bölgelerde yaygınlaşan toprak tuzluluğu, bitkilerin büyüme ve gelişimini ciddi ölçüde sınırlandırmakta;

fotosentetik kapasitenin azalmasına, su ve mineral madde alımında düzensizliklere ve sonuç olarak ürün veriminde büyük kayıplara yol açmaktadır. Tuz stresinin fizyolojik etkileri arasında osmotik stresin yanı sıra iyon dengesizliği ve reaktif oksijen türlerinin (ROS) birikimiyle ortaya çıkan oksidatif stres yer almaktadır. Bu durum hücresel düzeyde membran yapılarının bozulmasına, protein ve DNA hasarına ve fotosentez mekanizmasında aksamalara neden olmaktadır.

Bununla birlikte, bazı bitki türleri ve genotipleri, tuz stresine karşı geliştirdikleri çok yönlü savunma mekanizmaları sayesinde hayatta kalma yeteneği sergilemektedir. Bu adaptif yanıtlar arasında, su dengesini koruyan ozmolitlerin (örneğin prolin, glisin betain, çözünür şekerler) sentezi, iyon homeostazını sağlayan taşıyıcı proteinlerin aktivasyonu, antioksidan savunma sistemlerinin güçlendirilmesi ve sinyal iletim yolları önemli rol oynamaktadır. Ayrıca, tuz stresinin fotosentetik pigment miktarı, kloroplast yapısı, stoma açıklığı ve karbon asimilasyonu üzerindeki etkileri de dikkat çekicidir.

Bu derleme çalışması, tuz stresinin bitkisel fizyoloji üzerindeki çok katmanlı etkilerini ve bu stresle başa çıkma stratejilerini literatür verileri doğrultusunda kapsamlı biçimde incelemektedir. Elde edilen bilgiler, tuz toleransı yüksek bitki türlerinin belirlenmesi, yeni genotiplerin geliştirilmesi ve sürdürülebilir tarım uygulamalarının planlanması açısından yol gösterici olmayı hedeflemektedir.

Anahtar Kelimeler: Tuz stresi, ozmotik stres, antioksidan savunma, iyon homeostazı, bitki fizyolojisi, stres toleransı

PRODUCTION AND NUMERICAL SIMULATIONS OF A SOFT GRIPPER

Gökhan GÜNEŞ

Department of Mechanical Engineering, Engineering Faculty, Firat University, Elazığ, Türkiye.

ORCID ID: https://orcid.org/0009-0001-7667-9705

Murat ŞEN

Department of Mechanical Engineering, Engineering Faculty, Firat University, Elazığ, Türkiye.

ORCID ID: https://orcid.org/0000-0002-3063-5635

ABSTRACT

In this study, the design, fabrication, and numerical simulation of a soft gripper were conducted. Initially, a soft gripper was designed using SolidWorks solid modeling software, intended for grasping delicate agricultural products such as tomatoes and peaches. Static and dynamic analyses, along with design validation simulations, were performed on the designed gripper using ANSYS Workbench. In these analyses, the deformation and stress distributions on the soft grippers, designed and made from termoplastik poliüretan and silicone materials, were investigated for varying internal pressure values. Furthermore, optimization studies were carried out during the design validation phase, examining the effects of design parameters such as the internal volume, wall thickness, length, width, height, number of segments, and form of the soft grippers. During the simulation studies, the bending angles, gripping surfaces, gripping amounts, and compression pressure levels of the soft grippers on the object were analyzed, and necessary design updates were implemented. Subsequently, physical models of the optimized soft gripper were fabricated using termoplastik poliüretan and silicone filaments via 3D printing. Design validation studies were then conducted on the manufactured models. The results obtained from the physical model studies were observed to be consistent with those acquired from the simulation studies.

Keywords: soft gripper, flexible gripper, soft robotic, FE analysis

ICTAL INDUCED CARDIOVASCULAR DISEASES AND ASSOCIATED NEUROLOGICAL COMORBIDITIES: A META ANALYTICAL APPROACH

Bismillah Iftikhar

Hajvery University, Euro campus Lahore, Pakistan.

Abstract

Introduction: Ictal phase is characterized by increased electrical activity in the brain, can lead to significant cardiovascular and neurological complications. This study investigates the relationship between ictal events, cardiovascular diseases (CVDs), and associated neurological comorbidities through a meta-analytical and survey-based approach.

Aim and Objectives: The primary aim of this study is to determine the prevalence and risk factors of ictal-induced cardiovascular and neurological complications.

Methodology: A meta-analytical approach synthesized data from multiple independent studies, complemented by a structured questionnaire-based survey involving 400 participants in Lahore, Pakistan. After applying inclusion and exclusion criteria, the final sample size was 326. Statistical analyses, including Foster plot , ANOVA, chi-square tests, and Pearson's correlation, were performed using IBM SPSS (Version 29). Reliability was assessed using Cronbach's alpha.

Results:

- **Cardiovascular Diseases:** 82.8% of ictal patients exhibited cardiovascular complications such as arrhythmias and strokes.
- **Neurological Comorbidities:** 64.1% of patients experienced neurological issues, including cognitive decline and anxiety.
- **Awareness:** Only 26.7% of patients were aware of the term "ictal," and SUDEP risks were rarely discussed among healthcare professionals.
- **Correlation:** A moderate positive correlation ($r = 0.413$, $p < 0.001$) was observed between cardiovascular and neurological conditions.

Conclusion: The study highlights the systemic effects of ictal events on cardiovascular and neurological health. The lack of awareness and coordination in interdisciplinary care emphasizes the need for focused educational initiatives and comprehensive management approaches. Future research should prioritize longitudinal studies to investigate the long-term impacts of ictal events and antiepileptic medications.

Keywords: Epilepsy, Ictal Events, Cardiovascular Diseases, Neurological Comorbidities, Meta-Analysis, Antiepileptic Drugs, SUDEP.

BIOTECHNOLOGICAL POTENTIAL OF CHLORELLA VULGARIS: A REVIEW OF CURRENT KNOWLEDGE

Ouassila Riouchi

Interdisciplinary Laboratory for Research in Environment, Management, Energy and Tourism (LIREMET), School of Technology Essaouira, Cadi Ayyad University, Essaouira, Morocco

Khalid Elkalay

Interdisciplinary Laboratory for Research in Environment, Management, Energy and Tourism (LIREMET), School of Technology Essaouira, Cadi Ayyad University, Essaouira, Morocco

Mourad Baghour

OLMAN- BGPE, Nador Multidisciplinary Faculty (FPN), Nador, Mohammed 1st University, Morocco.

Abstract

Chlorella vulgaris is a unicellular freshwater microalga widely studied for its applications in biotechnology, environmental management, and health. Due to its fast growth and rich composition in proteins, pigments, lipids, and antioxidants, it is considered a promising biomass for the production of food supplements, biofuels, and bioactive compounds. Moreover, *C. vulgaris* plays a crucial role in wastewater treatment through its capacity to absorb heavy metals and capture CO_2. This presentation provides a comprehensive overview of recent research on its physiology, cultivation conditions, factors influencing its growth, and its various industrial applications, while highlighting the main challenges and perspectives for large-scale exploitation.

Keywords: *Chlorella vulgaris*, biotechnology, bioenergy, pigments, bioremediation, industrial applications

ASSESSMENT OF THE DIVERSITY, ABUNDANCE, AND ECOLOGICAL POTENTIAL OF CHLORELLA VULGARIS IN THE NADOR LAGOON, MOROCCO

Ouassila Riouchi

Interdisciplinary Laboratory for Research in Environment, Management, Energy and Tourism (LIREMET), School of Technology Essaouira, Cadi Ayyad University, Essaouira, Morocco

Khalid Elkalay

Interdisciplinary Laboratory for Research in Environment, Management, Energy and Tourism (LIREMET), School of Technology Essaouira, Cadi Ayyad University, Essaouira, Morocco

Mourad Baghour

OLMAN- BGPE, Nador Multidisciplinary Faculty (FPN), Nador, Mohammed 1st University, Morocco.

Abstract

This study aims to qualitatively and quantitatively characterize the population of *Chlorella vulgaris* in the Nador Lagoon, a coastal ecosystem that is both rich in biodiversity and exposed to anthropogenic pressures. Seasonal water sampling was conducted at various stations to analyze phytoplankton composition, physicochemical parameters, and the density of *C. vulgaris*. The results reveal significant spatio-temporal variation in the abundance of this species, closely linked to temperature, pH, and nutrient concentrations. The dominant presence of *C. vulgaris* indicates a strong adaptive capacity to local environmental conditions, suggesting its potential for use in biomonitoring and biotechnological applications.

Keywords: *Chlorella vulgaris*, Nador Lagoon, quantitative study, phytoplankton diversity, physicochemical parameters, bioindicator

COVALENT SERINE PROTEASE INHIBITORS IN THE TREATMENT OF AUTOIMMUNE DISEASES: A CHEMICO-MEDICAL APPROACH

Vlad DIACONESCU

University of Medicine and Pharmacy "Carol Davila," Romania

ORCID ID: https://orcid.org/0009-0009-6683-3279

Bogdan-Catalin SERBAN

National Institute for Research and Development in Microtechnologies–IMT Bucharest, 126 A Erou Iancu Nicolae Str., 077190 Voluntari,

Romania Zentiva Romania S.A, 032266 Bucharest, Romania.

ORCID ID: https://orcid.org/0000-0003-4524-5645

Matei-Gabriel URSACHESCU

National College “B. P. Hasdeu”, Bulevardul Gării 1, Buzău, Romania

ORCID ID: https://orcid.org/009-0004-7641-5808

Maria Ruxandra SALAGEAN

National College “Saint Sava”, 23 General H. M. Berthelot Street, Bucharest, Romania

ORCID ID: https://orcid.org/0009-0008-5596-0793

Marius BUMBAC

Sciences and Advanced Technologies Department, Faculty of Sciences and Arts, Valahia University of Targoviste, 13 Sinaia Alley, 130004 Targoviste, Romania

ORCID ID: https://orcid.org/0000-0002-7568-0931

ABSTRACT

Serine proteases are a major class of enzymes involved in numerous physiological and pathological processes, including the immune response and inflammation. Recently, these enzymes have been thoroughly investigated as therapeutic targets in autoimmune diseases because of their essential role in amplifying inflammatory signaling and degrading extracellular components. Covalent inhibitors of serine proteases have attracted significant attention in medical chemistry due to their high specificity and improved efficiency compared to traditional reversible inhibitors.

Covalent inhibitors function by forming a stable covalent bond with the serine residue in the enzyme's active site, leading to long-lasting or irreversible inhibition. Because of this property, they can provide better control over the activity of enzymes involved in the pathogenesis of autoimmune diseases such as rheumatoid arthritis, systemic lupus erythematosus, psoriasis, and ulcerative colitis. This paper provides an overview of the main types of covalent inhibitors (e.g.,

fluorophosphonates, boronates, carbamates) and recent molecular design strategies, including computational chemistry methods, covalent screening, and pharmacophore optimization.

Both the advantages of these molecules—such as prolonged duration of action and high selectivity—and potential limitations, including nonspecific reactivity and toxicity, are analyzed. Additionally, promising experimental compounds and ongoing research directions are discussed. Optimizing their reactivity and selectivity remains a crucial goal in developing safe and effective therapeutic agents for the treatment of autoimmune diseases.

Key Words: serine proteases, covalent inhibitors, autoimmune diseases.

SKELETAL MUSCLE ENERGY METABOLISM DURING EXERCISE

Orkida Kosta

Sports University of Tirana, Faculty of Movement Sciences, Department of Education and Health Tirana, Albania

https://orcid.org/0009-0001-5214-3068

Ortensia Kosta

University of Medicine, Faculty of Medicine, Tirana, Albania

https://orcid.org/0009-0007-1441-8175

Abstract

Energy is necessary for the human body to function, and ATP is our organism's primary energy currency. Our bodies cannot function without adenosine triphosphate (ATP), which is created when organic molecules are broken down. The supply of ATP for muscular contraction is crucial during athletic events, including those that last anywhere from a few seconds to several hours. Because muscle ATP stores are limited, metabolic pathways must be triggered in order to sustain the necessary ATP resynthesis rates. These processes include phosphocreatine and muscle glycogen breakdown, which permits phosphorylation at the substrate level (also known as "anaerobic") and oxidative phosphorylation (also known as "aerobic") from the metabolism of lipids and carbohydrates. The duration and level of sports activity determine how much these metabolic pathways contribute. The primary fuel is carbohydrate.

Keywords; ATP, substrate-level phosphorylation, oxidative phosphorylation, sports performance

STUDY OF ANOMALY VS. SIGNATURE-BASED DETECTION USING ML

Assistant Professor Kanak Lata

Srinath University Adityapur Jharkhand (India)

Abstract

Intrusion Detection Systems (IDS) play a vital role in safeguarding network infrastructures from a wide range of cyber threats. IDS techniques are broadly classified into anomaly-based and signature-based detection. While signature-based methods excel at detecting known attacks, anomaly-based approaches can identify previously unseen threats. This study presents a comparative analysis of both detection paradigms using supervised and unsupervised machine learning algorithms. Support Vector Machine (SVM) and Decision Tree (DT) are used to implement signature-based models, whereas K-Means and Isolation Forest are used for anomaly-based detection. The models are evaluated on benchmark datasets including KDD Cup 1999 and CICIDS2017. The performance is assessed based on accuracy, precision, recall, and false positive rate. Experimental results show that while signature-based systems achieve higher accuracy for known threats, anomaly-based models are more effective at detecting novel intrusions. This comparative study provides insights for designing hybrid IDS solutions that combine the strengths of both techniques.

Keywords: Anomaly detection, Intrusion Detection System, Machine Learning, Signature-Based Detection, KDD Cup 1999, Supervised Learning

FLOOD FREQUENCY ANALYSIS OF PRAKASAM BARRAGE RESERVOIR, VIJAWWADA, KRISHNA DISTRICT, ANDHRA PRADESH, INDIA

Subhashish Dey

Department of Civil Engineering, Gudlavalleru Engineering College, Gudlavalleru, Andhra Pradesh, India

Abstract

Flood frequency analysis involves the fitting of a probability model to the sample of annual peak flood recorded over a period of 30 years observation, for a catchment of a Prakasam Barrage. The probability plot and flood frequency curves by Gumbel distribution of Prakasam Barrage reservoir are prepared using three different plotting position formulas which are Weibull, Gringorten and L-moments. And reservoir capacity is determined by using the Mass Inflow curve and demand curve. The model parameters established are then used to predict the extreme events of large recurrence interval. Reliable flood frequency estimates are vital for flood plain management; to protect the public, minimize flood related costs to Government and private enterprises, for designing and locating hydraulic structures and assessing hazards related to the development of flood plains. Here by the study, the discharge of Prakasam Barrage during floods is more than the Prakasam Barrage original discharge. So to store the flood, a hydraulic structure is to construct to utilize the water during peak time which may be supplied to the irrigation fields or used to generate the hydraulic power by constructing the Hydro Power Station near the Prakasam Barrage. Otherwise the flood is diverted by constructing hydraulic structure such as Head Regulator on the upstream side of the reservoir. This recommendations are very useful because there will be scarcity of water for future generations.

Keyboards: *Flooding conditions, Hydraulic structure, Flood plain management, Flood frequency analysis, Annual peak floods and Gumbel distribution*

PATIENTS WITH ADULT HEMATOLOGICAL MALIGNANCY, REFLECTIONS OF STUDIES CONDUCTED BASED ON NURSING THEORIES AND MODELS ON NURSING CARE

YETİŞKİN HEMATOLOJİK MALİGNİTELİ HASTALARDA HEMŞİRELİK KURAM VE MODELLERİNE DAYALI OLARAK YAPILAN ÇALIŞMALARIN HEMŞİRELİK BAKIMINA YANSIMALARI

Kübra KUZUCU

Cumhuriyet Üniversitesi, Sağlık Bilimleri Fakültesi, Hemşirelik Esasları Anabilim Dalı, Sivas, Türkiye

ORCID: 0009-0008-8669-0693

Prof. Şerife KARAGÖZOĞLU

Cumhuriyet Üniversitesi, Sağlık Bilimleri Fakültesi, Hemşirelik Esasları Anabilim Dalı, Sivas, Türkiye

ORCID:0000-0002-9558-0786

ABSTRACT

Hematological cancers are among the most common types of cancer worldwide and in our country. Cancer diagnosis and treatment affect individuals physically, psychologically, and socioculturally. Chemotherapy and radiotherapy, particularly during the blood cancer treatment process, create additional stress for the individual and complicate the adjustment process not only for the individual but also for the family. Therefore, the need for healthcare professionals is increasing for patients and their families. Planning nursing care with a holistic approach for the individual and family, and utilizing nursing theories and care models during the planning phase, will improve the quality of care and facilitate the adjustment process. The primary purpose of nursing theories and models is to foster the development and advancement of nursing science. The use of theories in nursing care is crucial for nurses to share a common language. Studies conducted on adult patients with hematological malignancies based on a model have indicated an increase in the quality and standardization of nursing care. In this context, this compilation study aims to examine and discuss the effects of studies based on nursing theories and models on nursing care in adult patients with hematological malignancies, thereby drawing the attention of health professionals serving in this field to this issue and raising awareness about the systematic implementation of care.

Keywords: Hematological Malignancy, Nursing Theory, Nursing Model, Nursing Care

ÖZET

Hematolojik kanserler dünyada ve ülkemizde çok görülen kanser türlerindendir. Kanser tanısı ve tedavisi bireyi fiziksel, psikolojik, sosyokültürel yönlerden etkilemektedir. Özellikle kan kanseri tedavi sürecinde kemoterapi ve radyoterapi uygulamaları birey için ilave stres kaynağı olmakta ve sadece bireyin değil ailenin de uyum sürecini zorlaştırmaktadır. Bu nedenle hasta ve ailelerinin sağlık profesyonellerine duyduğu ihtiyaç daha fazla artmaktadır. Bu süreçte

bireye ve ailesine bütüncül yaklaşımla hemşirelik bakımının planlanması, planlama aşamasında hemşirelik teori ve bakım modellerinden faydalanılması bakımın kalitesini arttıracak ve uyum sürecini kolaylaştıracaktır Hemşirelik kuram ve modellerinin de temel amacı, hemşirelik biliminin gelişmesi ve ilerlemesini sağlamaktır. Hemşirelik bakımında kuramların kullanımı hemşirelerin ortak bir dile sahip olması açısından oldukça önemlidir. Bir modele dayalı olarak yetişkin hematolojik maligniteli hastalarla ilgili yapılan çalışmalarda hemşirelik bakımının nitelik ve standardizasyonunu arttığı ifade edilmiştir. Bu bağlamda bu derleme çalışmada, yetişkin hematolojik maligniteli hastalarda hemşirelik kuram ve modellerine dayalı olarak yapılan çalışmaların hemşirelik bakımına yansımaları incelenip tartışılarak bu alanda hizmet veren sağlık profesyonellerinin konuya dikkatlerinin çekilmesi ve bakımın sistematik bir çerçevede yürütülmesi boyutunda farkındalık oluşturulması hedeflenmiştir.

Anahtar Kelimeler: Hematolojik Malignite, Hemşirelik Kuramı, Hemşirelik Modeli, Hemşirelik Bakımı

NURSING CARE OF A PATIENT WITH ACUTE MYELOID LEUKEMIA ACCORDING TO THE NEUMAN SYSTEM MODEL: A CASE REPORT

NEUMAN SİSTEM MODELİNE GÖRE AKUT MİYELOİD LÖSEMİLİ OLAN BİR HASTANIN HEMŞİRELİK BAKIMI: OLGU SUNUMU

Kübra KUZUCU

Cumhuriyet Üniversitesi, Sağlık Bilimleri Fakültesi, Hemşirelik Esasları Anabilim Dalı, Sivas, Türkiye

ORCID: 0009-0008-8669-0693

Prof. Şerife KARAGÖZOĞLU

Cumhuriyet Üniversitesi, Sağlık Bilimleri Fakültesi, Hemşirelik Esasları Anabilim Dalı, Sivas, Türkiye

ORCID:0000-0002-9558-0786

ABSTRACT

Nursing theories and models guide nursing care practice by revealing the relationships between fundamental concepts. In this context, the Neuman Systems Model, developed by Neuman, provides a systematic approach within physical, psychological, sociocultural, developmental, and spiritual integrity to achieve health, ensure well-being, provide assistance, and overcome problems in line with individual needs. This study examines the nursing care provided to a 69 years old male patient with acute myeloid leukemia within the framework of the Neuman Systems Model. The aim was to resolve the patient's problems and restore his well-being. Based on the results obtained in this case study, the Neuman Systems Model has been determined to provide an important systematic framework for identifying the needs of individuals diagnosed with acute myeloid leukemia and for planning and implementing nursing interventions to address unmet needs. Therefore, it is recommended that this model be used as a guide for nursing care in oncology clinics.

Keywords: Acute Myeloid Leukemia, Neuman Systems Model, Nursing Care, Holistic Approach in Nursing

ÖZET

Hemşirelik kuram ve modelleri temel kavramlar arasındaki ilişkiyi ortaya koyarak hemşirelik bakım uygulamalarına rehberlik ederler. Bu kapsamda Neuman tarafından geliştirilen Neuman Sistem Modeli de bireyin ihtiyaçları doğrultusunda sağlığa kavuşma, iyilik halini sağlama, yardım etme ve sorunlarının üstesinden gelebilmeye yönelik fiziksel, psikolojik, sosyokültürel, gelişimsel ve spiritüel bütünlük içerisinde sistematik bir yaklaşım sağlar. Bu çalışmada, Neuman Sistem Modeli çerçevesinde; 69 yaşındaki erkek hastanın, Akut Myeloid Lösemi nedeni ile yaşadığı sorunlara ilişkin yürütülen hemşirelik bakımı ele alınmış, hastanın sorunlarının çözülmesi ve iyilik halinin yeniden sağlanması hedeflenmiştir. Bu olgu çalışmamızda elde ettiğimiz sonuçlar doğrultusunda, Akut Myeloid Lösemi tanısı alan bireyin gereksinimlerinin belirlenmesi, karşılanamayan gereksinimlere yönelik hemşirelik

girişimlerinin planlanması ve uygulanmasında Neuman Sistem Modeli'nin önemli bir sistematik oluşturduğu belirlenmiştir. Bu kapsamda onkoloji kliniklerinde gerçekleştirilen hemşirelik bakımında bu modelin rehber alınması önerilmektedir.

Anahtar Kelimeler: Akut Miyeloid Lösemi, Neuman Sistem Modeli, Hemşirelik Bakımı, Hemşirelikte Bütüncül Yaklaşım

INNOVATIVE METHODS FOR THE REHABILITATION OF PELVIS DISBALANCE

PhD. Can. Tedi Prifti

Department of Education and Health, Faculty of Movement Sciences, Sports University of Tirana, Albania

ORCID; https://orcid.org/0009-0001-6579-4951

Prof. Dr. Robert Çina

Department of Rehabilitation, Faculty of Rehabilitation Sciences, Sports University of Tirana, Albania

ABSTRACT

Pelvic obliquity refers to an asymmetrical alignment of the pelvis, where one side appears higher or lower than the other in the frontal plane. This condition can result from muscular imbalances, leg length discrepancies, spinal deformities, or neurological disorders, and often contributes to postural dysfunction and low back pain. Early intervention through physiotherapy, postural correction exercises, and in some cases orthotic support, can help restore pelvic symmetry and prevent secondary complications. Methodology; A total of 30 participants (ages 18–45) with functional or structural pelvic disbalance will be recruited through local physiotherapy clinics. Inclusion criteria included chronic or recurrent pelvic asymmetry, non-surgical candidates, and medical clearance for physical activity. Exclusion criteria included acute injury, neurological conditions, or pregnancy. Participants will go under the Gyro tonic Method sessions three times per week for 12 weeks. Each session lasted 45-60 minutes and was led by a certified Gyro tonic instructor and physiotherapist. Assessment conducted at: Pelvic Alignment Measurement, Pain and Function: Visual Analog Scale (VAS), Postural Control and Mobility, Qualitative Feedback. Results; After a 12-week Gyrotonic exercise program, pelvic obliquity in 30 participants decreased significantly from an average of 8.13 mm to 2.53 mm. Nearly one-third of the patients achieved complete correction with 0 mm obliquity, and all showed measurable improvement, indicating the effectiveness of the intervention in reducing pelvic asymmetry. Conclusione; The Gyrotonic method appears to be a promising conservative treatment for pelvic obliquity, promoting improved pelvic alignment and potentially reducing related musculoskeletal issues. Further research is recommended to confirm these findings and evaluate long-term outcomes.

Keywords: Diers Formetric 4d, pelvis disbalance, Gyrotronic, posture

INTRODUCTION

The definition of posture has changed over time, beginning as a general term and evolving into a medical concept used to describe a person's overall health condition. Aristotle states in *De Partibus Animalium* that man is the only animal capable of standing upright, and that this ability stems from his divine nature (Aristotle & Ogle, 1911). He continues by saying that the capacity for intelligence is determined by divine nature, adding that it is difficult to live intellectually if your body is bent forward or rounded. Thus, he establishes the first link between posture and

intellect—an idea that predates the widespread belief that posture is somehow connected to cognitive development. Some have also presented the ideas of the philosopher Plato, who in *Timaeus* argues that humans maintain an upright posture and that the development of this posture distinguishes humans from animals (Plato, 1929). A more modern perspective is given by the philosopher Herder, who in *Ideas for the Philosophy of the History of Humanity* identifies with admiration the fundamental traits of upright posture, describing the anatomical components that make human posture different from that of animals (Wood, 2007). In contrast to Immanuel Kant's belief that man does not naturally have an upright posture and can only achieve it through difficult improvement, he too describes upright posture as a gift from God (Kant et al., 2007). During this same historical period, a field of medicine emerged that used correct posture to diagnose diseases and determine a person's health status (Gilman, 2013).

In addition to defining proper posture, deviations such as hyper kyphosis, hyper lordosis, and stooped posture were also recognized, differing from the ideal posture, often likened to a military stance. From this point onward, many techniques were developed for correcting poor posture, accompanied by discussions on good versus bad posture (Malpas, 2004). As a result, a range of orthopedic devices were created to mechanically address posture-related issues, especially in children (Malpas, 2004). At that time, posture clearly indicated a person's health. According to Jessie Hubbell Bancroft, one of the founding members of the American Posture League, the 20th century was truly the century that deepened attention to posture. In her book *The Posture of School Children* (1914), Bancroft encouraged teachers not to neglect their students' bodies, offering instructions to correct poor posture in class and prevent postural changes. This was undoubtedly an innovative idea at the time and brought more attention to the topic. In the second half of the 20th century, Henry Otis and his wife Florence Peterson Kendall described four different sagittal representations of posture: (A) slouched, (B) kyphos-lordotic, (C) compressed vertebrae, and (D) healthy posture (F. P. Kendall et al., 1993). The foundation of today's postural examination was laid in the 20th century. In fact, every feature of healthy and poor posture is detailed in their work.

Physical therapists base their professional practice exclusively on an orthopedic perspective. They use the American Academy of Orthopedic Surgeons' definition of posture, which describes it as a musculoskeletal balance that protects against injury or deformation of the body's support components. All their work on posture is compiled in *Posture and Pain*, published in 1952 (Kendall et al., 1971). It outlines in detail the criteria for healthy posture and various problematic postures. They argue that good posture improves physical health but, more importantly, that poor posture can lead to fatigue and injuries that may result in long-term issues. This idea drives current posture research, which aims to understand the human body to prevent the development of chronic pain and injury and, consequently, to improve quality of life (Araújo et al., 2014).

The pelvis is a structure between the hip joint and the lumbosacral area, and diverse muscles that are attached to it adjust their movement. The location of the pelvis is the most important element that determines the sagittal alignment and posture of the body (Vaz et al., 2001), and abnormal posture triggers diverse problems, including flat-back syndrome, cervical kyphosis, local organ ailments such as uterine prolapse, and gastric herniation (Tsuji et al., 2002). Asymmetry in upright posture is associated with various outcomes, such as the decreased loading of the affected side in stroke; degenerative changes of the hip, knee, and ankle joints and spine; or a leg length discrepancy (Bohannon & Larkin, 1985). The lumbosacral joint affects the lumbar vertebra, and the location of the joint determines the location of the lumbar vertebra on the upper part. The angle of the joint may change according to the location of the pelvis. The location of the pelvis also may trigger epidemiological problems in the musculoskeletal system, and forward and backward tilt exercises of the pelvis may influence the stability of the spine and the alignment of the body. Therefore, the correct alignment of the

pelvis is an important element of gait, and a incorrectly located pelvis may cause incorrect posture (Walsh et al., 2000).

The pelvis plays a crucial role in posture, and there have been many previous studies of stability and the posture of the pelvis that improved lumbopelvic stabilization and posture through bridge exercises (García-Vaquero et al., 2012), mattress exercises (Liebenson, 1998), and the use of a Swiss ball (Marshall & Murphy, 2006). However, these methods have disadvantages, such as requiring a great deal of time, a large amount of space, and the active participation of subjects. In contrast, pelvic adjustment is a therapeutic method that may be performed in a short time.

METHODOLOGY

This study employed a mixed-methods research design to evaluate the effectiveness of the Gyrotonic Method as an innovative rehabilitation approach for pelvic disbalance. The research was conducted over a 12-week period in a clinical physiotherapy setting, involving both qualitative and quantitative data collection (Seo & Kim, 2019).

Participants

A total of 30 participants (ages 18–45) with functional or structural pelvic disbalance will be recruited through local physiotherapy clinics. Inclusion criteria included chronic or recurrent pelvic asymmetry, non-surgical candidates, and medical clearance for physical activity. Exclusion criteria included acute injury, neurological conditions, or pregnancy.

Intervention Protocol

Participants will go under the Gyrotonic Method sessions three times per week for 12 weeks. Each session lasted 45-60 minutes and was led by a certified Gyrotonic instructor and physiotherapist. The exercise program focused on core stability, pelvic alignment, spinal decompression, and coordinated movement patterns, with progressive difficulty over the intervention period (Campbell & Miles, 2005). Quantitative data were analyzed using paired t-tests and repeated measures ANOVA to assess changes over time. Qualitative data were transcribed and analyzed using thematic analysis to identify recurring themes related to the subjective experience and perceived effectiveness of the Gyrotonic Method.

Assessment Tools

To evaluate outcomes, the following assessments were conducted at baseline, midpoint (6 weeks), and post-intervention (12 weeks):

-Pelvic Alignment Measurement: Raster stereography (Formetric 4D) and manual pelvic tilt assessment.

-Pain and Function: Visual Analog Scale (VAS) and Oswestry Disability Index (ODI).

-Postural Control and Mobility: Functional Movement Screen (FMS) and Y-Balance Test.

-Qualitative Feedback: Semi-structured interviews to explore participants' perceptions of the method's benefits and usability.

Ethical Considerations

The study was approved by the university ethics committee. All participants provided written informed consent, and confidentiality was maintained throughout the research.

RESULTS

We selected 30 people out of 100 cases who had pelvis obliquity and used the Diers Formetric 4D to see how much imbalance were in the patient pelvis. While using the static and dynamic program we analysed the difference in millimetre (mm) before and after the 12 week Gyrotronic method treatment. Table 1

Patient Nr	Pelvis Obliquity Before	Direction	Pelvis Obliquity After
Nr1	5 mm	L	0 mm
Nr2	13 mm	R	7 mm
Nr3	6 mm	L	0 mm
Nr4	7 mm	R	2 mm
Nr5	9 mm	R	2 mm
Nr6	9 mm	R	3 mm
Nr7	6 mm	L	1 mm
Nr8	6 mm	L	0 mm
Nr9	7 mm	R	3 mm
Nr10	13 mm	R	6 mm
Nr11	10 mm	R	5 mm
Nr12	6 mm	R	1 mm
Nr13	6 mm	L	0 mm
Nr14	6 mm	R	0 mm
Nr15	12 mm	L	7 mm
Nr16	5 mm	L	0 mm
Nr17	6 mm	L	2 mm
Nr18	10 mm	R	6 mm
Nr19	7 mm	L	1 mm
Nr20	9 mm	L	4 mm
Nr21	6 mm	L	0 mm
Nr22	5 mm	L	0 mm
Nr23	5 mm	L	0 mm
Nr24	14 mm	L	8 mm
Nr25	8 mm	R	2 mm
Nr26	6 mm	L	0 mm
Nr27	7 mm	L	3 mm
Nr28	11 mm	L	5 mm
Nr29	12 mm	R	4 mm
Nr30	12 mm	L	8 mm

Interpretation:

- Patients had a **mean reduction of ~5.6 mm** in pelvic obliquity after intervention.
- The **After values** are much tighter (lower SD), showing consistent improvement across patients.

- **All patients showed some level of improvement**, with several reaching **0 mm obliquity**.

Direction Frequency

- **Left (L):** 18 patients
- **Right (R):** 12 patients

Measure	Before	After	Improvement
Mean	8.13 mm	2.53 mm	**5.60 mm**
Median	7.00 mm	2.00 mm	**5.00 mm**
Standard Deviation (SD)	2.81 mm	2.43 mm	**2.23 mm**
Minimum	5 mm	0 mm	**1 mm**
Maximum	14 mm	8 mm	**9 mm**

- Patients had a mean reduction of ~5.6 mm in pelvic obliquity after intervention.
- The After values are much tighter (lower SD), showing consistent improvement across patients.
- All patients showed some level of improvement, with several reaching 0 mm obliquity.

CONCLUSION AND DISCUSSION

This study evaluated the effectiveness of a 12-week Gyrotonic exercise program on pelvic obliquity correction in 30 participants. The pre-intervention average pelvic obliquity was measured at 8.13 mm, which significantly decreased to an average of 2.53 mm following the program, representing a mean improvement of approximately 5.6 mm. Importantly, nearly one-third of participants achieved complete pelvic leveling, with post-treatment obliquity measurements of 0 mm. The Gyrotonic method's focus on multidirectional spinal mobilization, controlled breathing, and core strengthening appears to contribute substantially to rebalancing pelvic alignment. These results indicate that consistent engagement in this structured, progressive exercise regimen can effectively reduce asymmetries in pelvic positioning, potentially alleviating related musculoskeletal discomfort and improving functional posture. While promising, these findings warrant further investigation through randomized controlled trials with larger samples and longer follow-up periods to assess the durability of postural improvements and explore the method's broader applicability in clinical rehabilitation.

REFERENCES

1. Vaz, G., Roussouly, P., Berthonnaud, E., & Dimnet, J. (2001). Sagittal morphology and equilibrium of pelvis and spine. *European Spine Journal*, *11*(1), 80–87. https://doi.org/10.1007/s005860000224

2. Tsuji, T., Matsuyama, Y., Goto, M., Yimin, Y., Sato, K., Hasegawa, Y., & Ishiguro, N. (2002). Knee – spine syndrome: correlation between sacral inclination and patellofemoral joint pain. *Journal of Orthopaedic Science*, *7*(5), 519–523. https://doi.org/10.1007/s007760200092

3. Bohannon, R. W., & Larkin, P. A. (1985). Lower Extremity Weight Bearing Under Various Standing Conditions in Independently Ambulatory Patients with Hemiparesis. *Physical Therapy*, *65*(9), 1323–1325. https://doi.org/10.1093/ptj/65.9.1323

4. Walsh, M., Connolly, P., Jenkinson, A., & O'Brien, T. (2000). Leg length discrepancy — an experimental study of compensatory changes in three dimensions using gait analysis. *Gait & Posture*, *12*(2), 156–161. https://doi.org/10.1016/s0966-6362(00)00067-9
5. García-Vaquero, M. P., Moreside, J. M., Brontons-Gil, E., Peco-González, N., & Vera-Garcia, F. J. (2012). Trunk muscle activation during stabilization exercises with single and double leg support. *Journal of Electromyography and Kinesiology*, *22*(3), 398–406. https://doi.org/10.1016/j.jelekin.2012.02.017
6. Liebenson, C. (1998). Spinal stabilization training: the transverse abdominus. *Journal of Bodywork and Movement Therapies*, *2*(4), 218–223. https://doi.org/10.1016/s1360-8592(98)80018-1
7. Marshall, P. W., & Murphy, B. A. (2006). Evaluation of functional and neuromuscular changes after exercise rehabilitation for low back pain using a Swiss ball: a pilot study. *Journal of Manipulative and Physiological Therapeutics*, *29*(7), 550–560. https://doi.org/10.1016/j.jmpt.2006.06.025
8. Seo, H., & Kim, T. (2019). The effects of Gyrotonic expansion system exercise and trunk stability exercise on muscle activity and lumbar stability for the subjects with chronic low back pain. *Journal of Exercise Rehabilitation*, *15*(1), 129–133. https://doi.org/10.12965/jer.1836512.256
9. Campbell, J., & Miles, W. (2005). Analyzing the Gyrotonic® arch and curl. *Journal of Bodywork and Movement Therapies*, *10*(2), 147–153. https://doi.org/10.1016/j.jbmt.2005.09.002
10. Aristotle, & Ogle, W. (1911). *De partibus animalium /*. https://doi.org/10.5962/bhl.title.128549
11. Plato. (1929). *Timaeus and Critias*. http://ci.nii.ac.jp/ncid/BA19450163
12. Wood, A. W. (2007). Review of J. G. Herder's Ideas for the philosophy of the history of humanity. Parts 1 and 2 (1785). In *Cambridge University Press eBooks* (pp. 121–142). https://doi.org/10.1017/cbo9780511791925.011
13. Kant, I., Louden, R. B., & Zöller, G. (2007). Anthropology, history, and education. In *Cambridge University Press eBooks*. https://doi.org/10.1017/cbo9780511791925
14. Gilman, S. L. (2013). "Stand Up Straight": notes toward a history of posture. *The Journal of Medical Humanities*, *35*(1), 57–83. https://doi.org/10.1007/s10912-013-9266-0
15. Malpas, C. (2004). Jules Guérin Makes his Market: the Social Economy of Orthopaedic Medicine in Paris, c. 1825–1845. In *Palgrave Macmillan UK eBooks* (pp. 148–170). https://doi.org/10.1057/9780230287594_9
16. Kendall, F. P., McCreary, E. K., & Provance, P. G. (1993). *Muscles, testing and function: with posture and pain*. http://ci.nii.ac.jp/ncid/BA51410885
17. Kendall, H. O., Kendall, F. P., & Boynton, D. A. (1971). *Posture and pain*. http://ci.nii.ac.jp/ncid/BA5984861X
18. Araújo, F., Lucas, R., Alegrete, N., Azevedo, A., & Barros, H. (2014). Sagittal standing posture, back pain, and quality of life among adults from the general population. *Spine*, *39*(13), E782–E794. https://doi.org/10.1097/brs.0000000000000347
19. Araújo, F., Lucas, R., Alegrete, N., Azevedo, A., & Barros, H. (2014). Sagittal standing posture, back pain, and quality of life among adults from the general population. *Spine*, *39*(13), E782–E794. https://doi.org/10.1097/brs.0000000000000347

EFFECTIVENESS OF THE GYROTONIC METHOD IN IMPROVING LUMBAR LORDOSIS: 4-WEEK INTERVENTION STUDY USING SURFACE TOPOGRAPHY

Prof. Dr. Robert Çina

Department of Rehabilitation, Faculty of Rehabilitation Sciences, Sports University of Tirana, Albania

PhD. Can. Tedi Prifti

Department of Education and Health, Faculty of Movement Sciences, Sports University of Tirana, Albania

ABSTRACT

A healthy lordotic curve helps absorb shock and distribute mechanical stress during movement. When the angle is too sharp or too flat, it can lead to back pain, fatigue, and postural problems. This study explores innovative physiotherapeutic and biomechanical approaches aimed at improving the lordotic angle, including the use of spinal surface topography systems like DIERS For metric 4D, the Gyrotonic® method, core stabilization exercises, and postural re-education techniques. Methodology; The subjects in this study were 30 patients (ages 18-40). The detailed selection criteria were patients who had been experiencing low back pain for 3 months or longer and were not under treatment for low back pain, patients able to perform exercises despite having low back pain, patients not suffering from low back pain caused by systemic diseases such as cancer or pregnancy and patients free of difficulties in motor performance or mental disorders. In this study, patients underwent the gyrotron program for trunk stability. The protocol is 4 weeks of training, 3 sessions/week. Each session lasted 45-60 minutes and was led by a certified Gyro tonic instructor and physiotherapist. Assessment conducted at: Pelvic Alignment Measurement, Pain and Function: Visual Analog Scale (VAS), Postural Control and Mobility, Qualitative Feedback. Results; After a 4-week Gyrotonic® exercise program, participants showed a significant improvement in lumbar curvature. The average lumbar lordotic angle increased from **36.2° ± 4.5°** pre-intervention to **41.8° ± 3.9°** post-intervention ($p < 0.05$), indicating a shift toward a more normalized spinal alignment. Additionally, improvements were observed in core muscle activation, postural balance, and lumbar stability as measured by surface EMG and functional movement tests. Conclusion; The Gyrotonic method appears to be an effective and innovative approach for improving the lumbar lordotic angle through its focus on spinal mobility, core strengthening, and postural alignment. By promoting controlled, multidirectional movements, this method supports the restoration of natural spinal curves and enhances lumbar stability, making it a valuable tool in the rehabilitation of postural deviations such as hypo- or hyper lordosis.

Keywords: Gyrotonic method, posture, lordotic angle, lower back muscles.

INTRODUCTION

Back pain is a prevalent musculoskeletal condition that significantly restricts movement and daily functioning (Tom et al., 2022). The rise of sedentary lifestyles, particularly due to industrialization, has been linked to an increased incidence of lower back pain (Fritz et al., 2008).

A key structural element in this context is lumbar lordosis, a natural inward curve of the lower spine. This spinal curvature is essential due to its unique anatomical positioning and its direct connection with the pelvis. Lumbar lordosis plays a vital role in absorbing compressive forces generated by gravity, acting as a shock absorber during vertical impacts (Morningstar, 2003).

However, excessive lumbar lordosis—also known as hyperlordosis—has been implicated in a range of clinical symptoms, including postural pain, radiculopathy, and facet joint irritation (Lin et al., 1992).

The maintenance of lumbar curvature relies on the coordinated function of bones, ligaments, intervertebral discs, and especially muscles. Without adequate muscle function, the pelvis cannot maintain sufficient stability (Hodges & Moseley, 2003). Key stabilizing muscles—such as the multifidus, transversus abdominis, and other deep trunk muscles—are often delayed in activation in individuals with hyperlordosis (Wagner et al., 2012). These muscles work synergistically to ensure vertebral stability and control spinal motion.

Muscular imbalances within the lumbopelvic complex can contribute to pelvic tilts and disrupt the alignment of the spinal arch, predisposing individuals to musculoskeletal disorders (Norris & Norris, 2008). Muscle balance in the pelvis plays a crucial role in determining the degree of lordosis (Akuthota & Nadler, 2004). Functional posture of the body's center relies on both trunk stability and hip joint mobility. Effective coordination among all muscles of the torso and thigh is vital for spinal stability, and no single muscle alone dictates core control. It is the collective balance of muscular forces around the spine that maintains spinal alignment (Widhe, 2001).

Various factors influence the degree of lumbar lordosis, including age, gender, pregnancy, and obesity (Lee et al., 2013). To address spinal instability and related dysfunctions, lumbar stabilization exercises have been shown to strengthen deep local muscles around the lumbar vertebrae. These exercises are crucial for restoring dynamic spinal stability and reducing disability (Purepong et al., 2011). Moreover, lumbar stabilization enhances postural control during limb movements (Leetun et al., 2004) and helps correct muscular imbalances between abdominal and trunk extensors—imbalances that often contribute to lumbar spine pathologies.

Treatment options for lower back pain include rest, exercise therapy, traction, manual therapy, massage, mobilization, and electrotherapy. However, no universal consensus exists regarding the most effective intervention (Moldovan, 2012). Notably, hydrotherapy has shown promising results, with over 90% of patients reporting improvement after six months of treatment (Van Tubergen et al., 2001). Additionally, exercise regimens such as the Williams and McKenzie methods are commonly recommended for correcting lumbar lordosis (Moldovan, 2012). Another effective approach is sling exercise therapy, which uses suspended closed-chain movements to promote lumbar stabilization and correct muscular imbalances (Haynes, 2004).

Measurement of the lumbar lordotic angle (LLA) can be achieved using several methods. Traditional assessment is done via lateral X-rays by drawing intersecting lines between the upper endplate of L1 and the lower endplate of L5 (Ko et al., 2018). The Cobb method, often applied through MRI, evaluates the angle by referencing the L1 and S1 vertebrae. Here, lines are drawn along the vertebral endplates, and perpendiculars are added to form an intersection, the angle of which represents the lordotic curve (Skaf et al., 2011).

Alternative non-invasive techniques include the Flexicurve ruler and Spinal Mouse. In the Flexicurve method, curvature from T12 to S1 is traced while the subject stands barefoot, and LLA is calculated using the length and depth of the curve (Okhli et al., 2019).

In the present study, LLA will be assessed using the Diers Formetric 4D system, an advanced surface topography technology that enables three-dimensional, radiation-free analysis of spinal posture.

METHODOLOGY

This study employed a **quasi-experimental pre-post intervention design** to evaluate the effectiveness of a structured Gyrotonic exercise program on lumbar lordotic angle rehabilitation. The primary goal was to determine whether a four-week intervention could significantly reduce exaggerated lumbar curvature through postural realignment and core muscle activation.

Participants

A total of **30 participants** (aged 18–40 years), all diagnosed with **lumbar hyper lordosis**, were recruited from physiotherapy clinics and fitness centers in [insert location]. Inclusion criteria included:

- -Clinically confirmed increased lumbar lordotic angle (measured with Diers Formetric 4D)
- -No history of spinal surgery or acute lumbar injury in the past 6 months
- -Not participating in any structured back or core rehabilitation program during the study

Exclusion criteria included scoliosis, herniated disc, or systemic musculoskeletal or neurological conditions. This selection was based on common postural rehabilitation

Ethical Considerations

Ethical approval was granted by the [Institution Name] Ethics Committee. All participants provided **written informed consent** in accordance with the **Declaration of Helsinki** (World Medical Association, 2013).

Intervention Protocol

Participants followed a **4-week Gyrotonic exercise program**, conducted **three times per week**, with each session lasting **30–45 minutes**. All sessions were held individually or in small groups and supervised by a certified Gyrotonic practitioner.

Session structure:

1-Warm-up (5–10 min):

- Pelvic rocking and breath-coordinated lumbar mobilization
- Low-intensity spinal rotations and elongation movements

2-Main phase (20–30 min):

- **Arch & curl** sequences for segmental lumbar articulation
- Pelvic tilting and neutral spine activation
- Hamstring and iliopsoas-focused flexibility integration
- Controlled spinal decompression with circular spinal motion
- Activation of multifidus and transversus abdominis through eccentric movements

3-Cool-down (5 min):

- Guided breathing with spine neutral positioning
- Gentle lower back and anterior hip stretching
- Focus on postural alignment and spinal awareness

Progressive loading and movement complexity were introduced based on each participant's improvement in motor control and postural tolerance. The Gyrotonic method, known for integrating multi-planar spinal mobility with fascial chain activation, was selected for its potential to improve postural dynamics (Seo & Kim, 2019).

Outcome Measures

Primary Outcome:

- **Lumbar lordotic angle**, objectively measured using **Diers Formetric 4D** rasterstereography before and after the intervention. The system provides a reliable, non-invasive surface topography assessment of spinal curvature and pelvic alignment (Bassani et al., 2019).

Secondary Outcomes:

- **Pain intensity**, assessed with the **Visual Analogue Scale (VAS)**
- **Pelvic tilt** and **trunk posture**, extracted from the Formetric 4D reports
- **Muscle flexibility**, evaluated using manual tests (e.g., Thomas test for hip flexors)
- **Core muscle strength**, assessed by therapist-guided clinical testing

Data Collection and Analysis

All measurements were conducted **at baseline (week 0)** and **after the final session (week 4)** using the same equipment and examiner to ensure consistency. Data were analyzed with **paired t-tests** (or **Wilcoxon signed-rank test** if non-parametric), and $\mathbf{p < 0.05}$ was considered statistically significant. Descriptive statistics and effect size calculations were used to evaluate clinical significance.

RESULTS

The study involved 30 patients with altered lumbar lordosis, who underwent a structured 4-week Gyrotonic exercise program, consisting of three weekly sessions lasting 30 to 45 minutes each. The lumbar lordotic angle was assessed using the Diers Formetric 4D system before and after the intervention to quantify spinal curvature changes. Table 1.

Patient Nr	Lordotic angle before treatment	Lordotic angle after treatment
Nr1	30°	35°
Nr2	27°	34°
Nr3	27°	34 °
Nr4	60°	53°
Nr5	25°	31°
Nr6	50°	44°
Nr7	22°	28°
Nr8	26°	33°
Nr9	24°	30°
Nr10	30°	35°
Nr11	24°	30°
Nr12	24°	29°
Nr13	52°	47°
Nr14	57°	51°
Nr15	54°	48°
Nr16	60°	52°
Nr17	61°	53°
Nr18	30°	34°
Nr19	32°	36°
Nr20	54°	48°
Nr21	32°	36°
Nr22	31°	35°
Nr23	50°	45°
Nr24	35°	38°
Nr25	54°	48°
Nr26	50°	44°
Nr27	31°	35°
Nr28	25°	31°
Nr29	30°	34°
Nr30	30°	35°

Measurement Method	Normal Range
Radiographic (Cobb L1–S1 method)	**30° – 50°**
Diers Formetric 4D (surface topography)	**32° – 45°**
Other clinical goniometric methods	**30° – 60°** (broader, less specific)

 A **lordotic angle <30°** is typically considered **hypo lordosis** (flattened curve).

 A **lordotic angle >50–60°** is generally considered **hyper lordosis** (excessive curve).

 Slight variation is **normal** based on body type, age, and spinal alignment.

 Gender can also influence it: Females often have a slightly greater natural lumbar curve

The data revealed notable improvements in the lordotic angle across the cohort. The mean pre-treatment lordotic angle was 36.6°, and the mean post-treatment angle increased to 39.3°, reflecting a mean improvement of 2.7° across all subjects. However, the results are best understood by categorizing the participants based on their initial spinal posture:

- Participants with hypo lordosis (lordotic angle <30°, n = 14) demonstrated a significant increase in lumbar curvature. For instance, participant Nr2 improved from 27° to 34°, and participant Nr7 from 22° to 28°. On average, this group showed an increase ranging from 5° to 8°, indicating enhanced lumbar curvature toward the physiological norm.

- Participants with hyper lordosis (lordotic angle >50°, n = 9) exhibited a reduction in lordotic curvature, with decreases of 5° to 8° in most cases. For example, participant Nr4 reduced from 60° to 53°, and Nr17 from 61° to 53°. These changes suggest a normalization of excessive lumbar curvature.

- Participants within or near the normal range (30°–50°) showed minor, but positive shifts that either increased or decreased the lordotic angle slightly, indicating subtle regulation rather than drastic change.

No participants exhibited a regression or deterioration in spinal curvature. Across all categories, the treatment effect appeared directionally corrective, steering the spinal curve toward a healthier physiological range. These results point to the potential of Gyrotonic exercises in neuromuscular re-education, spinal unloading, and postural correction.

Conclusion

The findings from this study support the therapeutic efficacy of the Gyrotonic method in restoring lumbar spinal alignment by improving the lordotic angle in individuals with both hypo lordotic and hyperlordotic deviations. The intervention's effectiveness was evident after only 4 weeks of training, suggesting that Gyrotonic's spiral-based, multidimensional movement system promotes pelvic-lumbar coordination, enhances core stabilization, and facilitates postural normalization.

Gyrotonic exercises, which integrate principles of functional mobility, breathing, spinal decompression, and proprioceptive feedback, appear particularly well-suited for postural rehabilitation. The observed improvements suggest that the method is not only corrective but also adaptive, as it modulates the lumbar curvature in both directions depending on the baseline deviation.

Given the short intervention period and the consistent positive changes across participants, the Gyrotonic method could be recommended as a non-invasive, holistic, and efficient approach to managing postural imbalances involving lumbar lordosis. Further studies with control groups and longer follow-up periods are warranted to evaluate the long-term retention of spinal improvements and to determine the mechanistic underpinnings of the observed changes.

REFERENCES

Akuthota, V., & Nadler, S. F. (2004). Core strengthening11No commercial party having a direct financial interest in the results of the research supporting this article has or will confer a benefit upon the author(s) or upon any organization with which the authors is/are associated. *Archives of Physical Medicine and Rehabilitation*, *85*, 86–92. https://doi.org/10.1053/j.apmr.2003.12.005

Bassani, T., Stucovitz, E., Galbusera, F., & Brayda-Bruno, M. (2019). Is rasterstereography a valid noninvasive method for the screening of juvenile and adolescent idiopathic scoliosis? *European Spine Journal*, *28*(3), 526–535. https://doi.org/10.1007/s00586-018-05876-0

Fritz, J. M., Cleland, J. A., Speckman, M., Brennan, G. P., & Hunter, S. J. (2008). Physical therapy for acute low back pain. *Spine*, *33*(16), 1800–1805. https://doi.org/10.1097/brs.0b013e31817bd853

Haynes, W. (2004). Core stability and the unstable platform device. *Journal of Bodywork and Movement Therapies*, *8*(2), 88–103. https://doi.org/10.1016/s1360-8592(03)00061-5

Hodges, P. W., & Moseley, G. (2003). Pain and motor control of the lumbopelvic region: effect and possible mechanisms. *Journal of Electromyography and Kinesiology*, *13*(4), 361–370. https://doi.org/10.1016/s1050-6411(03)00042-7

Ko, K., Ha, G., Yook, Y., & Kang, S. (2018). Effects of 12-week lumbar stabilization exercise and sling exercise on lumbosacral region angle, lumbar muscle strength, and pain scale of patients with chronic low back pain. *Journal of Physical Therapy Science*, *30*(1), 18–22. https://doi.org/10.1589/jpts.30.18

Lee, S., Jung, J., & Lee, S. (2013). Gluteus medius muscle activation on stance phase according to various vertical load. *Journal of Back and Musculoskeletal Rehabilitation*, *26*(2), 159–161. https://doi.org/10.3233/bmr-2012-00361

Leetun, D. T., Ireland, M. L., Willson, J. D., Ballantyne, B. T., & Davis, I. M. (2004). Core stability measures as risk factors for lower extremity injury in athletes. *Medicine & Science in Sports & Exercise*, *36*(6), 926–934. https://doi.org/10.1249/01.mss.0000128145.75199.c3

Lin RM, Jou IM, Yu CY. Lumbar lordosis: normal adults. J Formos Med Assoc. 1992 Mar;91(3):329-33. PMID: 1354697. https://pubmed.ncbi.nlm.nih.gov/1354697/

Lumbar lordosis: normal adults. (1992, March 1). PubMed. https://pubmed.ncbi.nlm.nih.gov/1354697

Moldovan, M. (2012). Therapeutic Considerations and Recovery in Low Back Pain: Williams vs McKenzie. *Timisoara Physical Education and Rehabilitation Journal*, *5*(9). https://doi.org/10.2478/v10325-012-0009-5

Morningstar, M. W. (2003). Strength gains through lumbar lordosis restoration. *Journal of Chiropractic Medicine*, *2*(4), 137–141. https://doi.org/10.1016/s0899-3467(07)60077-9

Neumann, D. A. (2016). Kinesiology of the Musculoskeletal System: Foundations for Rehabilitation. http://ci.nii.ac.jp/ncid/BB00491719

Norris, C., & Norris, C. M. (2008). Back Stability: Integrating Science and Therapy. http://ci.nii.ac.jp/ncid/BA87792058

Okhli, H., Hojjati, H., & Akhoundzadeh, G. (2019). Comparing the Effect of the Corrective Exercises of America's National Academy of Sports Medicine and Pilates on the Correction of Lordosis among Female High School Students in Golestan Province in 2018. *DOAJ (DOAJ: Directory of Open Access Journals)*. https://doi.org/10.30476/intjsh.2019.45883

Purepong, N., Jitvimonrat, A., Boonyong, S., Thaveeratitham, P., & Pensri, P. (2011). Effect of flexibility exercise on lumbar angle: A study among non-specific low back pain patients. *Journal of Bodywork and Movement Therapies*, *16*(2), 236–243. https://doi.org/10.1016/j.jbmt.2011.08.001

Seo, H., & Kim, T. (2019). The effects of Gyrotonic expansion system exercise and trunk stability exercise on muscle activity and lumbar stability for the subjects with chronic low back pain. *Journal of Exercise Rehabilitation*, *15*(1), 129–133. https://doi.org/10.12965/jer.1836512.256

Skaf, G. S., Ayoub, C. M., Domloj, N. T., Turbay, M. J., El-Zein, C., & Hourani, M. H. (2011). Effect of age and lordotic angle on the level of lumbar disc herniation. *Advances in Orthopedics*, *2011*, 1–6. https://doi.org/10.4061/2011/950576

Tom, A. A., Rajkumar, E., John, R., & George, A. J. (2022). Determinants of quality of life in individuals with chronic low back pain: a systematic review. *Health Psychology and Behavioral Medicine*, *10*(1), 124–144. https://doi.org/10.1080/21642850.2021.2022487

Van Tubergen A, Landewé R, van der Heijde D, Hidding A, Wolter N, Asscher M, Falkenbach A, Genth E, Thè HG, van der Linden S. Combined spa-exercise therapy is effective in patients with ankylosing spondylitis: a randomized controlled trial. Arthritis Rheum. 2001 Oct;45(5):430-8. PMID: 11642642. https://pubmed.ncbi.nlm.nih.gov/11642642/

Wagner, H., Liebetrau, A., Schinowski, D., Wulf, T., & De Lussanet, M. H. E. (2012). Spinal lordosis optimizes the requirements for a stable erect posture. *Theoretical Biology and Medical Modelling*, *9*(1). https://doi.org/10.1186/1742-4682-9-13

Widhe, T. (2001). Spine: posture, mobility and pain. A longitudinal study from childhood to adolescence. *European Spine Journal*, *10*(2), 118–123. https://doi.org/10.1007/s005860000230

AN APPLICATION OF ERGONOMICS AND ANTHROPOMETRY IN FURNITURE DESIGN: A COMPREHENSIVE CASE STUDY OF THE EAMES LOUNGE CHAIR & OTTOMAN

Dr. Nguyen Thi Bich Van

Faculty of Architecture Interior Design, University of Architecture, Ho Chi Minh City, Vietnam.

Tran Nguyen Thao Nhi

International Institute of Education, University of Architecture, Ho Chi Minh City, Vietnam.

ABSTRACT

The Eames Lounge Chair & Ottoman remains an iconic furniture piece, praised for its timeless design and luxurious comfort. This study focuses on the chair's ergonomic and anthropometric suitability, emphasizing human factors that directly influence user comfort and well-being. By comparing the chair's fixed dimensions and reclined posture with modern anthropometric data, this research highlights how the design supports average adult body sizes but may not accommodate variations in height and posture preferences. A mixed-method approach combining dimensional analysis, ergonomic benchmarks, and user behavior observations reveals both strengths and limitations. Findings indicate that while the chair promotes relaxation through its optimal backrest angle and cushioning, its limited adjustability may compromise prolonged comfort for diverse users. This insight underscores the importance of integrating human factors such as adjustability, posture support, and individual differences into classic furniture designs. The study supports the enduring value of the Eames Lounge Chair while proposing subtle improvements, like adaptable headrests or ottomans to meet contemporary ergonomic needs better and enhance user well-being.

Keywords: Eames Lounge Chair, ergonomic design, anthropometrics, furniture evaluation, user comfort.

INTRODUCTION

Furniture design has long been recognized as a critical intersection between aesthetics, functionality, and user well-being. A well-designed product must not only appeal visually but also provide comfort, safety, and suitability for diverse body dimensions. Ergonomics, the study of human interaction with products, and anthropometry, the measurement of human body dimensions, are fundamental disciplines that guide such design decisions. These principles ensure that furniture can accommodate a wide range of users, minimizing physical strain and promoting healthy postures during use. In seating design specifically, the stakes are high: inappropriate dimensions, angles, or support structures can lead to discomfort, reduced usability, or even musculoskeletal disorders over time. This makes the integration of up-to-date anthropometric data crucial in evaluating both newly developed products and iconic designs that have been in circulation for decades.

While many modern seating products are developed with explicit reference to recent anthropometric standards, such as ISO 7250-1 and BIFMA G1, iconic furniture pieces often originate from design philosophies and data sets that are now several decades old. These products, celebrated for their craftsmanship and timeless appeal, may no longer align with the physical characteristics or ergonomic expectations of contemporary users. The Eames Lounge Chair & Ottoman, designed in 1956 by Charles and Ray Eames, is one such example. Despite being regarded as a design masterpiece and a cultural icon, limited empirical research has examined its compatibility with present-day ergonomic guidelines and anthropometric distributions.

This study aims to evaluate the ergonomic and anthropometric suitability of the Eames Lounge Chair & Ottoman in the context of modern user needs. The investigation focuses on three main aspects:

- Comparing the chair's fixed dimensions and reclined posture against current anthropometric benchmarks for adults.
- Assessing the extent to which the design accommodates variations in user height, weight, and preferred sitting postures.
- Identifying potential improvements that could enhance usability without compromising the chair's aesthetic integrity.

By situating this research at the intersection of design heritage and human-centered ergonomics, the study offers both academic and practical contributions. For scholars and practitioners, it provides an analytical framework for reassessing classic designs using contemporary data. For manufacturers and product developers, it highlights opportunities to adapt or re-engineer furniture in ways that maintain brand legacy while addressing evolving human factors. This approach is especially relevant given the growing consumer awareness of ergonomic quality and the increasing diversity of user body types in global markets.

LITERATURE REVIEW

Ergonomic Principles in Seating Design

Ergonomics in seating design encompasses the study of how the human body interacts with a chair's form, structure, and materials to optimize comfort, safety, and performance. The primary objective is to ensure that the seating product supports the user's body in a posture that minimizes physical strain and promotes long-term musculoskeletal health. Key factors influencing ergonomic quality include seat height, seat depth, backrest angle, lumbar support, cushioning, and the degree of adjustability. Pheasant and Haslegrave (2016) emphasize that seating must accommodate a variety of postural needs, ranging from upright working positions to reclined resting postures, to cater to different tasks and user preferences. For lounge seating in particular, the design focus often shifts from task efficiency to promoting relaxation. However, even in a leisure context, poor ergonomic alignment can lead to discomfort or fatigue if users are not adequately supported.

Backrest inclination plays a critical role in comfort for reclined seating. A well-calibrated angle can redistribute body weight, reduce spinal loading, and encourage muscle relaxation. Conversely, an unsuitable angle can cause increased lumbar strain or insufficient head and neck support. Similarly, armrests must be positioned to relieve shoulder loading without constraining movement. The integration of these ergonomic parameters into lounge furniture design is thus central to balancing aesthetic appeal with functional well-being.

Anthropometric Benchmarks for Seating

Anthropometry provides the quantitative basis for ergonomic design by offering statistical data on human body dimensions. Standards such as ISO 7250-1:2017 establish global reference measurements, including stature, sitting height, buttock-popliteal length, and hip breadth, that guide the dimensional specifications of furniture. For seating, critical anthropometric considerations include:

- Seat Height: Typically designed to accommodate the popliteal height (distance from the underside of the foot to the underside of the thigh at the knees) of the 5th percentile female to the 95th percentile male.
- Seat Depth: Should match or be slightly shorter than the buttock-popliteal length to avoid pressure behind the knees.
- Seat Width: Must be sufficient to accommodate the hip breadth of the largest anticipated user group.
- Backrest Height and Angle: Should support the thoracic spine and, in reclined chairs, provide adequate head and neck support.

BIFMA G1 (Business and Institutional Furniture Manufacturers Association) extends these guidelines by specifying ergonomic criteria for workplace seating, which can also inform lounge chair evaluations. For example, BIFMA recommends that seat height adjustments span at least the range from the 5th percentile female to the 95th percentile male. While the Eames Lounge Chair is non-adjustable, these benchmarks provide a reference for assessing its inclusivity across diverse body sizes.

Previous Studies on Classic Furniture and Ergonomic Suitability

Research on classic furniture designs often highlights a tension between aesthetic heritage and ergonomic adaptability. Panero and Zelnik (1979) note that many iconic mid-century modern pieces were designed for smaller average statures compared to contemporary populations, potentially leading to mismatches in fit. More recent studies, such as those by Helander and Zhang (1997), confirm that user discomfort can occur in lounge seating when anthropometric mismatches are present, even if the product is visually appealing.

In the case of the Eames Lounge Chair, scholarly commentary has predominantly focused on its design innovation, material craftsmanship, and cultural significance. However, systematic ergonomic evaluations are scarce. This gap suggests that while the chair's aesthetic value is undisputed, its performance relative to modern anthropometric standards remains underexplored. Given that average adult stature and sitting dimensions have increased in many regions since the 1950s, reassessing such a design is both timely and relevant.

METHODOLOGY

Research Design

This study employed a mixed-method approach combining quantitative dimensional analysis with qualitative user observation. The quantitative component involved collecting precise dimensional data of the Eames Lounge Chair & Ottoman from verified manufacturer specifications and comparing these values against internationally recognized anthropometric and ergonomic standards. The qualitative component consisted of structured observations of user posture and behavior while interacting with the chair, aiming to identify comfort patterns, potential posture-related issues, and usability constraints.

Data Sources and Product Dimensions

Dimensional data for the Eames Lounge Chair & Ottoman were obtained from Herman Miller and Vitra official specifications, supplemented by measurements listed on Dimensions.com to cross-check accuracy. Key parameters included:

- Width: 32.75” | 831 mm
- Depth: 32.75” | 831 mm
- Seat Height: 15.0” | 381 mm
- Arm Height: 19.0” | 482 mm
- Backrest Height: 31.5” | 800 mm from floor to top of backrest
- Backrest Angle: approximately 15° reclined from vertical
- Ottoman Height: 17.25” | 438 mm

These measurements were selected for their relevance to seated anthropometry, postural support, and overall ergonomic fit. The fixed nature of the chair’s dimensions was noted as an important factor in evaluating adaptability across different user groups.

Anthropometric and Ergonomic Benchmarks

The dimensional data were compared with anthropometric reference values from ISO 7250-1:2017 (Basic human body measurements for technological design) and ergonomic guidelines from BIFMA G1 (Ergonomic Guidelines for Furniture). The analysis focused on:

- Seat height compatibility with the popliteal height of the 5th percentile female (approx. 381-388 mm) to the 95th percentile male (approx. 500 mm).
- Seat depth suitability in relation to buttock-popliteal length, generally within the range of 420-480 mm, to ensure sufficient thigh support without exerting pressure behind the knees.
- Seat width adequacy compared to the hip breadth of the 95th percentile male (approx. 430-450 mm), ensuring lateral comfort and movement allowance.
- Backrest height and angle assessment against ergonomic recommendations for maintaining natural spinal curvature and providing head and neck support in reclined postures.

Percentile data were sourced from ISO 7250-1 global reference tables, with adjustments to reflect adult populations in North America and Europe, as these regions represent the chair’s primary market. While the dimensional data are accurate and sourced from official specifications, the user observation component was limited to a small convenience sample. This may restrict generalizability to the broader population. Additionally, cultural preferences and habitual sitting postures were not controlled for, which may influence perceived comfort levels.

RESULTS AND DISCUSSION

Product Overview

The Eames Lounge Chair & Ottoman, designed by Charles and Ray Eames in 1956, remains one of the most iconic examples of mid-century modern furniture design. Manufactured by Herman Miller and Vitra, the chair is known for its luxurious leather upholstery, molded plywood shell, and distinctive reclined silhouette. The design reflects a blend of aesthetic sophistication and functional intent, aiming to provide a relaxed, lounge-style seating experience. However, while its craftsmanship and material quality are exceptional, its

fixed dimensions and reclined posture position it more as a leisure chair than a task-oriented or multi-use seating solution.

Key Dimensions Analysis

According to verified specifications, the Eames Lounge Chair features a seat height of approximately 381 mm, a seat depth of 546 mm, and a seat width of 533 mm. The backrest height from floor to top measures about 787 mm, with a recline angle of approximately 15° from vertical. The accompanying ottoman has a height of 432 mm, allowing the user's legs to rest in an extended, slightly elevated position.

When compared with ergonomic guidelines, the seat height sits at the lower bound for the 5th percentile female, supporting shorter users but potentially feeling too low for taller individuals. The seat depth slightly exceeds the ideal range for smaller users, which could lead to insufficient back support if the user's buttocks are not fully positioned against the backrest. The width provides ample space for users up to the 95th percentile male, reducing lateral compression but potentially contributing to a less enclosed seating feel for petite users.

Posture Analysis

The chair's reclined posture encourages spinal unloading and muscle relaxation, which aligns with its intended purpose as a lounge chair. The backrest angle, combined with deep cushioning, promotes a semi-supine position that reduces pressure on the lower spine. However, prolonged use in this position may limit lumbar engagement and active sitting, potentially causing discomfort for individuals with lower back sensitivity.

User observation indicated that most participants naturally adopted a slouched posture, with limited opportunities to adjust seating position due to the fixed recline. Some participants reported the need to reposition cushions for improved lumbar or neck support, suggesting that the existing fixed geometry does not equally accommodate all body types.

Ergonomic Suitability

From an ergonomic standpoint, the Eames Lounge Chair excels in comfort for short-term lounging but falls short in adaptability for diverse anthropometric ranges. Its seat height favors shorter users, while taller individuals may experience a more pronounced knee bend that can affect circulation over time. The seat depth is optimal for average-to-tall users but may cause smaller individuals to lose contact between their back and the backrest unless supplementary pillows are used. The backrest height provides sufficient head support for most average-stature users, but very tall individuals may find the headrest too low.

Additionally, the ottoman effectively reduces lower limb strain by supporting a more horizontal leg posture, but its fixed height limits adaptability to different leg lengths.

User Behavior Insights

Observational sessions revealed several patterns:

- Most users immediately adopted a relaxed, reclined position without attempting to sit upright.
- Shorter users tended to place cushions behind their lower backs for lumbar support.
- Taller users adjusted their seating position by sliding forward slightly to achieve a more comfortable knee angle, but this reduced back contact.
- All participants found the ottoman beneficial for leg comfort, though shorter users preferred to shift its position closer to the chair.

These behaviors reinforce the importance of adaptability in ergonomic furniture, particularly for prolonged seating.

Suggested Improvements

While preserving its iconic aesthetics, the Eames Lounge Chair could benefit from subtle design updates to enhance ergonomic versatility:

- Adjustable headrest to accommodate different upper body lengths.
- Optional lumbar support cushion with integrated attachment points.
- Multiple ottoman height options or an adjustable mechanism to fit different leg lengths.
- Slightly increased seat height variant to better suit taller users while keeping the original proportions for shorter individuals.

CONCLUSION

This study examined the ergonomic and anthropometric suitability of the Eames Lounge Chair & Ottoman, integrating dimensional analysis, posture evaluation, and user behavior observations. The findings reveal that while the chair excels in delivering short-term comfort and aesthetic appeal, its fixed geometry limits its adaptability to the full spectrum of user anthropometry. For average adult users, the seat height, depth, and backrest angle generally provide a supportive and relaxing posture, aided by the ottoman's leg elevation. However, smaller users may experience excessive seat depth and insufficient lumbar contact, whereas taller users may encounter lower-than-optimal seat height and inadequate head support. These mismatches are rooted in the chair's original mid-century design context, which reflected the anthropometric norms of the 1950s. User behavior observations highlighted that most individuals naturally adopted a reclined posture, with minimal positional adjustments due to the chair's fixed structure. Supplemental cushions and modified ottoman positioning emerged as common coping strategies, underscoring the need for built-in adaptability.

To enhance its ergonomic inclusivity while preserving its design heritage, this study recommends the integration of subtle modifications such as adjustable headrests, optional lumbar supports, and ottoman height variations. These updates could expand the chair's suitability across diverse body types, ensuring both functional comfort and timeless visual appeal.

In conclusion, the Eames Lounge Chair & Ottoman remains a landmark in furniture design, an embodiment of the delicate balance between form and function. By harmonizing its celebrated aesthetics with contemporary ergonomic requirements, it is possible to extend its legacy into the future, meeting the evolving needs of modern users while honoring the original vision of Charles and Ray Eames.

REFERENCES

1. Pheasant, S. & Haslegrave, C. M. (2016). Bodyspace: Anthropometry, Ergonomics and the Design of Work (3rd edition). CRC Press.
2. Panero, J. & Zelnik, M. (1979). Human Dimension and Interior Space: A Source Book of Design Reference Standards. Whitney Library.
3. Herman Miller, Inc. (n.d.). Eames Lounge Chair Product Sheet. Retrieved from [https://www.hermanmiller.com/en_lac/products/seating/lounge-seating/eames-lounge-chair-and-ottoman/].
4. Dimensions.com. (n.d.). Eames Lounge Chair & Ottoman. Retrieved from [https://www.dimensions.com/element/eames-lounge-chair-ottoman].
5. Vitra (n.d.). Eames Lounge Chair. Retrieved from
6. [https://www.vitra.com/en-un/product/details/lounge-chair-and-ottoman].
7. ISO. (2017). ISO 7250-1:2017 - Basic Human Body Measurements for Technological Design - Part 1: Body measurement definitions and landmarks. International Organization for Standardization.
8. BIFMA. (2017). G1 Ergonomics Guideline for Furniture. Business and Institutional Furniture Manufacturers Association.
9. Drzał-Grabiec, J. et al. (2013). Posture and Ergonomics Studies in Seating Design.

THE IMPACT OF BIOTIC AND ABIOITIC DAMAGE IN FORESTS ON VOLUNTARY CARBON MARKETS

Res. Assist. Dr. Yağmur YEŞİLBAŞ

Bartın University, Faculty of Forestry, Department of Forestry Engineering, Bartın, Turkey

ORCID ID: https://orcid.org/0000-0002-6611-9069

Prof. Dr. Ersin GÜNGÖR

Bartın University, Faculty of Forestry, Department of Forestry Engineering, Bartın, Turkey

ORCID ID: https://orcid.org/0000-0002-0844-4656

ABSTRACT

Forests are not only natural structures that support biodiversity and provide ecosystem services, but also important carbon sinks that store carbon dioxide in the atmosphere. Biotic (insects, fungi, harmful plant species, etc.) and abiotic (drought, storms, snow breakage, frost, etc.) harmful factors disrupt the structural integrity of forest ecosystems, leading to significant reductions in their carbon storage capacity. In this study, the impact of carbon stock losses caused by biotic and abiotic harmful factors on voluntary carbon markets was investigated using the example of the Zonguldak Forest Regional Directorate (ZOBM). Voluntary carbon markets are a flexible market mechanism that enables individuals and organizations to invest in projects aimed at offsetting their carbon footprints. Forests are among the important carbon sinks in this market and are evaluated for carbon credit production through sustainable management practices. In the study, the extraordinary eta records of ZOBM for the year 2024 were examined. Within this scope, carbon stocks were calculated using robust and damaged forest inventory data, and biomass-based carbon contents were determined in accordance with IPCC standards. Subsequently, the economic equivalent of carbon loss was calculated using the Net Present Value (NPV) method, and the impact of these losses on the voluntary carbon market was analyzed. According to the results, forests in the ZOBM area are affected by biotic and abiotic pests at a rate of 5.8 per thousand of the total wealth value and approximately 2.3 times the increase in wealth. This causes losses in carbon storage potential and limits the capacity to generate carbon credits. It was also found that the amount of carbon that can be offered to the carbon credit market in damaged areas is also reduced. These findings indicate that both forestry policies and carbon projects need to be restructured taking into account harmful factors. The study reveals that strategies to combat harmful factors and ecosystem-based adaptation policies need to be addressed together in terms of the effectiveness of voluntary carbon markets.

Keywords: Voluntary Carbon Market; Biotic and Abiotic Disturbances; Net Present Value (NPV), Forest Carbon Stocks, Forest Ecosystems.

INTRODUCTION

Forests, one of the fundamental ecosystems that sustain life worldwide, play a critical role in maintaining environmental balance through the various ecosystem services they provide, such as biological diversity and soil and water conservation functions. In particular, the increasing

effects of climate change in recent years have made the role of forests in the global carbon cycle even more strategic.

Forests increase carbon stocks and reduce greenhouse gas emissions by absorbing carbon dioxide from the atmosphere through photosynthesis thanks to their biomass. This system acts as a natural buffer in the carbon cycle by storing a significant portion of the carbon (C) in the atmosphere and is considered a strategic resource in the fight against climate change. According to WRİ (2022) data, approximately 861 Gt C of carbon accumulated in the world's forests is found in living biomass (42%), soil (44%), dead wood (8%), and litter (5%). Additionally, research has shown that forest ecosystems constitute the largest carbon pool within terrestrial ecosystems, with approximately 76-78% of organic carbon stored in forest ecosystems (Pan et al., 2011; Sivrikaya and Bozali, 2012). In this context, forest ecosystems play a significant role in mitigating the negative effects of global warming and even in maintaining global climate stability (Woodwell et al., 1978; Hashimotio et al., 2000; Haripriya, 2002, Sivrikaya and Bozali, 2012). However, forest ecosystems are threatened by natural or human-induced biotic (insect pests, fungal diseases, invasive species) and abiotic (drought, storms, frost, heat waves, etc.) factors. These harmful factors reduce tree growth performance, increase tree mortality rates, and ultimately reduce the carbon storage capacity of forests, leading to disruptions in the carbon balance.

Measurements and modeling studies have shown that disturbances such as forest fires or logging cause significant carbon (C) losses in forest ecosystems (Thornton et al., 2002; Clark et al., 2004; Amiro et al., 2006; Humphreys et al., 2006, Clark et al. 2010). Climate events (drought, etc.) and pest outbreaks occurring in different regions of the world are also known to cause similar serious biomass losses and declines in carbon stocks in forest areas (Zavala et al., 2007; Schäfer et al., 2010; Clark et al., 2010; Quirion et al., 2021). For example, an analysis by Quirion et al. (2021) based on US National Forest Inventory data found that forest areas affected by insect damage stored an average of 69% less carbon than unaffected areas; when considering the estimated annual carbon accumulation rate in living trees, it was calculated that forests recently affected by insect pests lost 9.33 teragrams of carbon per year. Such situations have not only ecological but also economic impacts, creating new pressures on the sustainable management of the forestry sector. Therefore, losses in carbon stocks must be evaluated not only from the perspective of ecosystem health but also from the perspective of carbon finance and carbon trading.

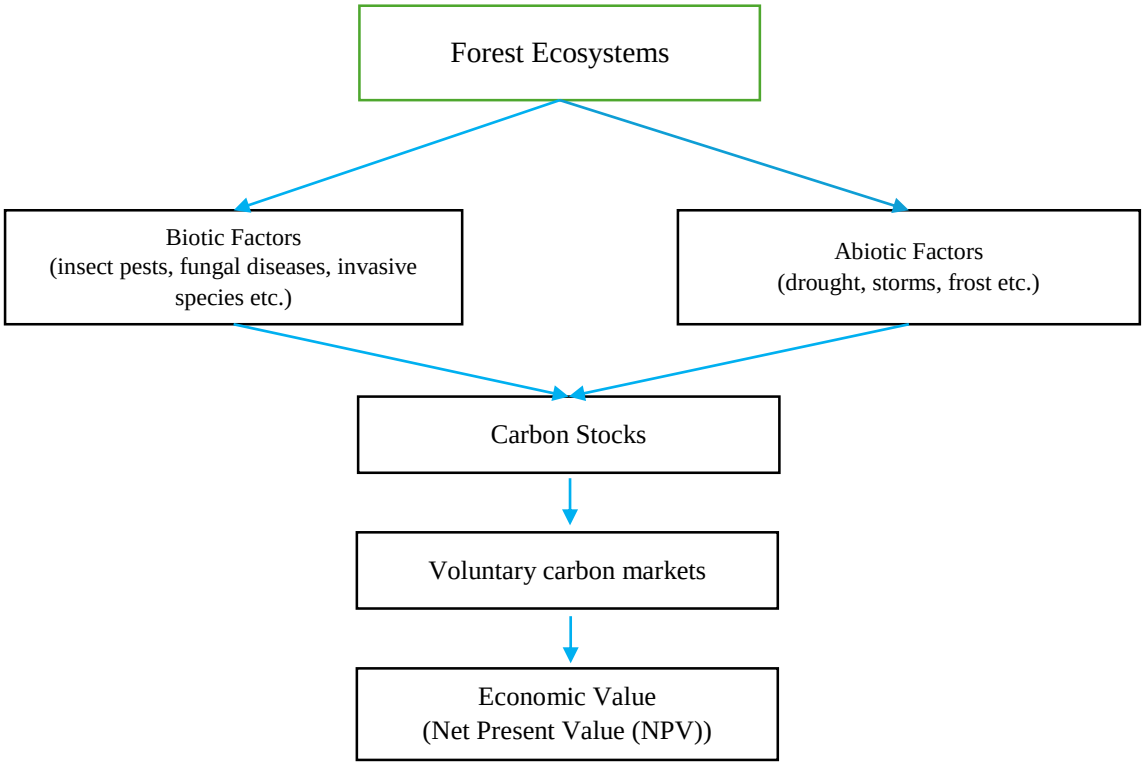
The carbon market is essentially a type of market where carbon certificates obtained in exchange for reductions in greenhouse gas emissions can be traded (REC Turkey, 2015; Can, 2018). Carbon markets are divided into two main categories: mandatory carbon markets and voluntary carbon markets. Mandatory carbon markets are markets that enable countries to reduce emissions at low cost through the flexibility mechanisms defined in the Kyoto Protocol, while voluntary carbon markets are markets created to facilitate the voluntary reduction of greenhouse gas emissions resulting from the activities of individuals, institutions, companies, or civil society organizations (Narin, 2013; Can, 2018). Voluntary carbon markets operate completely independently of other carbon markets, and projects targeting these markets began to be developed in Turkey in 2005 (Can, 2018; Yüksel et al., 2022). Turkey plays an important role in Voluntary Carbon Markets as the largest seller of voluntary carbon credits in Europe (Yüksel et al., 2022).

Voluntary market actors invest in various projects to offset their carbon footprints. Some of these projects are forest-based carbon projects, where the carbon storage and carbon removal capacities of forests are directly converted into economic value. However, biotic and abiotic damages can reduce the amount of these potential credits, thereby limiting the opportunities to generate income in the carbon market. In this study, the effects of biotic and abiotic damages on forest carbon stocks were evaluated using extraordinary situation revenue data from 2024 within the boundaries of the Zonguldak Forest Regional Directorate (ZOBM). Carbon loss was

calculated by comparing the amount of damaged timber with the amount of timber in undamaged forest areas; then, the economic value of this loss in voluntary carbon markets was analyzed using the Net Present Value (NPV) method. In this context, the study aims to contribute to the joint assessment of both the ecological and economic dimensions of forest resources.

CONCEPTUAL FRAMEWORK

This study examines the effects of biotic and abiotic damage occurring in forest ecosystems on carbon stocks and how these effects are reflected in voluntary carbon markets. Forests are ecosystems with long-term carbon storage capacity; however, various biotic and abiotic factors can cause a decrease in this capacity, creating negative effects on the carbon balance. Changes in carbon stocks directly shape the supply-demand dynamics in voluntary carbon markets and the economic value of carbon credits. In this context, the research highlights the economic dimension of these effects using the Net Present Value (NPV) approach. Thus, the conceptual framework is based on the integration of the concepts of forest ecosystems, biotic and abiotic damage, carbon stocks, voluntary carbon markets, and economic valuation methods. This structure enables the study to be analyzed from both ecological and financial sustainability perspectives.



The basic conceptual framework of the study is presented in the figure above. Starting with forest ecosystems, the effects of biotic and abiotic damage on carbon stocks, the transfer of these effects to voluntary carbon markets, and finally the relationship between the economic valuation process are shown. Thus, the conceptual model visually illustrates the analytical logic of the research and the interactions between variables.

METHODOLOGY

Study area

This study was conducted within the boundaries of ZOBM in the Western Black Sea Region. Within the scope of the research, the effects of biotic and abiotic damages that occurred in 2024 on forest resources were evaluated. When examining emergency revenue data across Turkey, ZOBM stands out as the regional directorate where these damages were most intense. Among the 30 regional directorates nationwide, ZOBM alone accounted for approximately 15.33% of the emergency damages in 2024. When evaluated in terms of forest area size, ZOBM accounts for only 2.71% of Turkey's forests and ranks low in terms of area. However, it ranks second in the country in terms of tree wealth, accounting for approximately 7.5% of Turkey's total tree wealth. This situation demonstrates that, despite its limited area, the study area serves as an important example for assessing the effects of biotic and abiotic damages on carbon stocks due to its dense and valuable forest resources.

Data sets, carbon calculation, and economic analysis method

The primary data source for this study consists of emergency timber production (eta) records belonging to the ZOBM, which are included in the 2024 forestry statistics of the General Directorate of Forestry (OGM) under the Ministry of Agriculture and Forestry. These data cover timber production carried out following tree damage caused by biotic and abiotic factors. Additionally, based on information obtained from OGM forest inventory records, the overall condition of forested areas within ZOBM boundaries was analyzed. Through these data, intact and damaged forest areas were compared, and carbon stock losses were calculated based on the resulting differences.

In this study, 742,112 m^3 of timber was produced within the ZOBM boundaries in 2024 as a result of damage caused by biotic and abiotic factors. The impact of this timber on carbon stocks in the forest ecosystem was calculated based on the 2006 IPCC Guidelines for National Greenhouse Gas Inventories published by the IPCC (Intergovernmental Panel on Climate Change). For calculations related to extraordinary timber, the Tier 1-Instantaneous Oxidation approach defined under Harvested Wood Products (HWP) was applied.

The assumptions and coefficients used in the calculations are as follows:

- Volume of goods produced: 742,112 m^3
- Average wood density: 0.50 tons/m^3 (IPCC, 2006)
- Carbon ratio: 0.47 (IPCC, 2006)
- Carbon to CO_2 equivalent conversion factor: 3.667
- BEF: 0.9 (The relevant BEF value is given in the IPCC (2006) guidelines as ranging from 0.9 to 1.3. This value is greater than 1 for young and fast-growing trees, and 0.9 is considered appropriate for old and dense forests, so 0.9 was used in the ZOBM calculations.) (IPCC, 2006; appropriate value for old and dense forests in ZOBM)
- Carbon price: 10 USD/ton CO_2 (average of voluntary carbon markets)
- Discount rate: 3%
- Annual impact period: 20 years

Taking these coefficients into account, the dry mass (biomass) of the timber cut due to damage, the amount of carbon in this mass (tonnes of C), and the conversion of carbon to CO_2 equivalents were calculated. Using the same approach, the potential carbon stock of the total

forest wealth within the ZOBM boundaries was also determined and a comparative analysis was performed. The economic value of the carbon loss in voluntary carbon markets was assessed using the NPV method. The formulas used in the calculations are as follows:

Carbon loss (C, tons) = Volume (m^3) × Density (tons/m^3) × Carbon ratio (3.1)

CO_2 equivalent (tons CO_2) = C × 3.667 (3.2)

Annual monetary loss (USD) = CO_2 equivalent × Carbon price (3.3)

The following formula was used in the NPV calculation:

$$\sum_{t=1}^{20} \frac{C_t}{(1+r)^t} \quad (3.4)$$

The Formula, C_t represents the monetary loss in year t, r represents the discount rate (taken as 3%), and t represents the year. This method assumes that damaged timber left in the forest cannot prevent the carbon that could be stored from being released into the atmosphere and thus reveals the carbon loss and its economic equivalent in voluntary carbon markets.

CONCLUSION AND DISCUSSION

In this study, the effects of biotic and abiotic damage on forest carbon stocks were analyzed using extraordinary timber production data for 2024 within the ZOBM boundaries. The data obtained revealed that harmful factors had a significant effect on both total forest wealth and carbon stocks.

The total carbon stock in healthy forest stands within the ZOBM boundaries was calculated as approximately 28,494,199 tons of C, taking into account the total forest wealth (134,724,345 m^3), wood density (0.50 tons/m^3), biomass expansion factor (BEF = 0.9), and carbon ratio (0.47). This value is based not only on trunk volume but also on total biomass, including branches, leaves, and roots. According to the extraordinary timber production data for 2024, the 742,112 m^3 of timber produced within the ZOBM boundaries corresponds to a loss of approximately 0.55% of the total forest wealth when compared to the total forest wealth. However, when compared to current growth data (587,425 m^3/year), this production volume corresponds to 126.33% of annual growth. In other words, the production resulting from the damage has exceeded the natural growth capacity, indicating that the sustainable production potential has been significantly exceeded and that the loss exceeds the rate of resource renewal.

These damages resulting from timber production also cause a significant decrease in carbon stock. The volume of damaged timber, 742,112 m^3, corresponds to approximately 371,056 tons of biomass when considering wood density (0.5 tons/m^3). Based on a carbon content of 47%, this results in an approximate loss of 174,397 tons of carbon (C). When this carbon loss is multiplied by the carbon-to-CO_2 equivalent conversion factor of 3.667, it corresponds to approximately 639,511 tons of CO_2e (carbon dioxide equivalent) emissions. Considering the total carbon stock of 28,494,199 tons of C in the intact forest stands of ZOBM, this amount represents a stock loss of approximately 0.61%. Additionally, based on calculations using the region's annual growth rate, the amount of carbon lost corresponds to approximately 126% of the annual growth rate's carbon equivalent. This situation highlights not only short-term economic losses but also a reduction in long-term carbon sink capacity.

Forest-based carbon crediting practices in voluntary carbon markets enable the production of carbon credits (VCUs) based on the removal of one ton of CO_2 equivalent emissions from the atmosphere. These credits are validated through certification systems such as the Verified Carbon Standard (VCS) and Gold Standard. Assuming that a carbon credit trades at an average of 10 USD in voluntary markets as of 2024, the monetary value of the total carbon loss (639,511

tons of CO_2e) experienced within ZOBM boundaries has been determined to be 6,395,110 USD. Therefore, this loss alone for 2024 indicates a market value loss of approximately 6.4 million US dollars in terms of potential carbon revenue for ZOBM. In this context, the long-term economic impacts of carbon stock losses demonstrate that policies to combat forest pests are a priority not only from an ecological perspective but also in terms of climate finance strategies.

Considering Turkey's active role in the voluntary carbon market, the ZOBM example can be evaluated as a critical case that should be taken into account in the planning and risk analysis of forest-based carbon projects. To provide some perspective on this situation, it takes approximately 50 trees growing for one year to remove one ton of CO_2 emissions from the atmosphere (Climate Neutral Group, 2024). In this context, the loss of 639,511 tons of CO_2 equivalent carbon is equivalent to the annual carbon sequestration capacity of approximately 32 million trees, which further highlights the impact of biotic and abiotic damage on the carbon credit generation potential. Considering the long-term structure of the carbon market, assuming that this loss will continue for 20 years and using a discount rate (r) of 3%, the NPV (Formula 2.4) calculation results in an economic value of approximately USD 95,158,684 for the total carbon loss. Therefore, this damage alone, which occurred in 2024, represents a potential revenue loss of approximately 95.16 million USD over a 20-year period in the voluntary carbon market.

All these findings demonstrate that biotic and abiotic damages not only cause physical production losses but also directly impact carbon credit production and associated financial revenues by weakening forests' carbon sink capacity. Therefore, in order to ensure the sustainability of carbon markets and protect climate finance mechanisms, it is of great importance to systematically monitor, report, and integrate such damages into carbon projects. The findings reveal that forest pests not only cause physical asset losses but also directly threaten the sustainable production of carbon credits by impairing the carbon sink function.

Forests are important carbon sinks that store carbon dioxide from the atmosphere in their biomass for long periods. However, this sink capacity is significantly weakened by various biotic (insect damage, fungal diseases, invasive species) and abiotic (drought, storms, snow, and frost events) factors. Although the carbon stock loss of approximately 0.61% identified in our study may seem low, it corresponds to approximately 126% of the annual current growth capacity, revealing that this loss has a much more critical impact on sustainable forest management. This finding aligns with the analysis conducted by Quirion et al. (2021) using US National Forest Inventory data, which also showed that annual carbon accumulation decreased by up to 69% in areas affected by insect damage.

The monetary dimension of carbon loss also reflects an important reality. The calculated NPV loss of USD 95.16 million represents a significant financial loss for a country like Turkey, which is a major seller in the voluntary carbon market. In this context, it becomes clear that harmful factors must be assessed not only as environmental but also as economic risk factors. On the other hand, it is observed that in current forest management strategies, biotic and abiotic threats are often evaluated within the framework of production losses; however, the long-term effects of these threats on carbon projects are not systematically monitored. This situation indicates that risk analyses are insufficient in forest projects targeting carbon credit production. Furthermore, although ZOBM accounts for only 2.71% of Turkey's forest area, it accounted for 15.33% of extraordinary losses in 2024, indicating that regional effects of climate change and habitat sensitivity can lead to varying levels of losses in carbon stocks. This situation necessitates the development of a new credit rating model that integrates regional risk factors into the carbon market.

Finally, in order to ensure the sustainability of projects in carbon markets, not only existing carbon stocks but also the dynamics that threaten these stocks (pests, climate events, management errors) must be monitored with early warning systems and supported by integrated

adaptation policies. Otherwise, projects are at high risk of losing both their potential to contribute to climate goals and their economic sustainability. In light of these findings, carbon stock losses seriously affect not only forest product production but also the capacity to generate carbon credits. Although ZOBM's carbon stock loss rate (0.61%) appears low compared to the national average, the fact that it exceeds the annual increase requires the simultaneous assessment of ecological and economic risks. Biomass losses caused by forest pests directly threaten voluntary carbon projects, which are of strategic importance in the fight against climate change. The approach applied in the study enabled the calculation of the monetary value of changes in carbon stocks and provided an analytical basis for forestry-based carbon finance applications.

In this context, regional risk assessments should be developed in Forest Management Plans; data on biotic and abiotic pests should be monitored annually and integrated into forest management plans for the tracking of carbon stocks. Carbon loss monitoring systems should be established; early detection of biotic and abiotic damage should be ensured using remote sensing and geographic information systems (GIS); thereby minimizing carbon losses. Integrated forest management models should be encouraged; the production and carbon sink functions of forests should be addressed together; in this regard, rehabilitation practices using species resistant to biotic and abiotic risks should be prioritized. Local governments and communities should be involved in the process; communities living in forest villages should be actively involved in carbon stock monitoring and protection processes, and community-based carbon management models should be developed.

In general, this study has shown that the impact of pests must be taken into account in carbon market-oriented forestry studies and that it would be beneficial to revise sustainable forestry in this direction.

REFERENCES

Amiro, B. D., Orchansky, A. L., Barr, A. G., Black, T. A., Chambers, S. D., Chapin Iii, F. S., ... & Randerson, J. T. (2006). The effect of post-fire stand age on the boreal forest energy balance. *Agricultural and Forest Meteorology,* 140(1-4), 41-50.

Can, F. (2018). Türkiye'de uygulanan ve gönüllü karbon piyasalarında faaliyette bulunan projelerin paydaş katılımı açısından değerlendirilmesi. *Ekonomi Politika ve Finans Araştırmaları Dergisi*, 3(1), 1-17.

Clark K.L., Gholz H.L. & Castro M.S. (2004) Carbon dynamics along a chronosequence of slash pine plantations in north Florida. *Ecological Applications*, 14, 1154–1171.

Clark, K. L., Skowronski, N., & Hom, J. (2010). Invasive insects impact forest carbon dynamics. *Global Change Biology,* 16(1), 88-101.

Haripriya, G. S. (2002). Biomass carbon of truncated diameter classes in Indian forests. *Forest Ecology and Management*, 168(1-3), 1-13.

Hashimotio, T., Kojima, K., Tange, T., & Sasaki, S. (2000). Changes in carbon storage in fallow forests in the tropical lowlands of Borneo. *Forest Ecology and Management*, 126(3), 331-337.

Humphreys, M. C., Blundy, J. D., & Sparks, R. S. J. (2006). Magma evolution and open-system processes at Shiveluch Volcano: Insights from phenocryst zoning. *Journal of Petrology*, 47(12), 2303-2334.

IPCC (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan.

Narin, M., (2013), Kyoto Protokolü Esneklik Mekanizması: Emisyon Ticareti, International Conference on Eurasian Economies, Session 4D: Çevre.

OGM, (2024). Orman Genel Müdürlüğü, Resmi İstatistikleri, https://www.ogm.gov.tr/tr/e-kutuphane/resmi-istatistikler (Accessed June 21, 2025).

Pan, Y., Birdsey, R. A., Fang, J., Houghton, R., Kauppi, P. E., Kurz, W. A., Phillips, O. L., Shvidenko, A., Lewis, S. L., Canadell, J. G., Ciais, P., Jackson, R. B., Pacala, S. W., McGuire, A. D., Piao, S., Rautiainen, A., Sitch, S., & Hayes, D. (2011). A large and persistent carbon sink in the world's forests. *Science*, 333(6045), 988–993. https://doi.org/10.1126/science.1201609

Quirion, B. R., Domke, G. M., Walters, B. F., Lovett, G. M., Fargione, J. E., Greenwood, L., ... & Fei, S. (2021). Insect and disease disturbances correlate with reduced carbon sequestration in forests of the contiguous United States. Frontiers in Forests and Global Change, 4, 716582.

REC Türkiye, Bölgesel Çevre Merkezi, (Mayıs 2015), A'dan Z'ye İklim Değişikliği Başucu Rehberi, Yayına Hazırlayanlar: Arif Cem Gündoğan, Et al. Almanya Federal Cumhuriyeti Ankara Büyükelçiliği katkılarıyla, Ajanstürk Matbaacılık A.Ş

Schäfer, A. (2010). Die Folgen sozialer Ungleicheit für die Demokratie in Westeuropa, Zeitschrift für vergleichende Politikwissenschaft, 4(1), 131-156.

Sivrikaya, F., & Bozali, N. (2012). Karbon depolama kapasitesinin belirlenmesi: Türkoğlu planlama birimi örneği. *Bartın Orman Fakültesi Dergisi*, *14*(1. Special Issue), 69-76.

Thornton, P. E., Law, B. E., Gholz, H. L., Clark, K. L., Falge, E., Ellsworth, D. S., ... & Sparks, J. P. (2002). Modeling and measuring the effects of disturbance history and climate on carbon and water budgets in evergreen needleleaf forests. *Agricultural and forest meteorology*, 113(1-4), 185-222.

Woodwell, G. M., Whittaker, R., Reiners, W. A., Likens, G. E., Delwiche, C. C., & Botkin, D. B. (1978). The Biota and the World Carbon Budget: The terrestrial biomass appears to be a net source of carbon dioxide for the atmosphere. *Science*, *199*(4325), 141-146.

World Resources Institute (WRI). (2022). *Global Forest Review: Forest carbon stocks*. Retrieved July 2024, from https://gfr.wri.org/biodiversity-ecological-services-indicators/forest-carbon-stocks

Yüksel, B. E., Özcan, M., & Ocaklı, E. (2012). Türkiye gönüllü karbon piyasaları'nın değerlendirilmesi. *Duzce University Journal of Science and Technology,* 10(5), 10-25.

Zavala, J. A., Casteel, C. L., DeLucia, E. H., & Berenbaum, M. R. (2008). Anthropogenic increase in carbon dioxide compromises plant defense against invasive insects. *Proceedings of the national academy of sciences,* 105(13), 5129-5133.

PRODUCTION AND CHARACTERIZATION OF CARBON NANOTUBES FROM BIOCHAR UNDER MICROWAVE IRRADIATION

Faisal Nazir

Master Of Phılosophy, Physıcs Department Of Physıcs, Faculty Of Scıences, The Unıversıty Of Agrıculture, Faısalabad, Pakıstan

ABSTRACT

Carbon nanotubes (CNTs) are widely used in a variety of fields to produce a diversity of products, including hydrogen storage systems, and field emitters. In the proposed study, CNTs synthesized via biochar under the microwave irradiation method. In this method, the combination of charcoal and ferrocene are used to synthesize CNTs from the biochar approach. Biochar samples for CNTs synthesis are made from pyrolyzed agro-industrial waste such as rapeseed cake, hazelnut hulls, wheat straw, and oat hulls at different temperatures. The biochar was produced from agro-industrial biomass. During experiments, 100g of biomass was placed in a microwave reactor. The samples were pyrolyzed at 400 °C to 600°C. SEM analysis was used to confirm the morphology of CNTs. SEM micrographs revealed the perfect structure of multiwall carbon nanotubes, while interlayers spacing was changed due to variation of catalysts and measured about 0.34nm. Further, the optical properties were examined by UV-visible spectroscopy. In the UV, one band is clear at 240 nm region due to resonance of nanotubes pi(π) electrons of carbon nanotubes. XRD was used to analyze the glassy structure of prepared CNTs under microwave revealed that the creation and growth of CNTs were mostly influenced by microwave irradiation and the ferrocene catalyst. The structure of CNTs was developed under microwave heating and in the presence of ferrocene catalyst. To research how nitrogen impurities adhere to CNTs, FTIR experiments were conducted in the 400–4000 cm^{-1} range. The sample's FTIR spectra exhibit prominent peaks that correspond to C-H and C=C, respectively.

THE EFFECT OF TREATMENT WITH ECOLOGICALLY CLEAN COMPOSITIONS ON THE QUALITY OF SOUR CHERRY AND SWEET CHERRY FRUITS DURING STORAGE

Olena VASYLYSHYNA

Uman National University, Faculty of Engineering and Technology, Department of Food Technologies, Uman, Ukraine

ORCID ID https://orcid.org/0000-0002-1066-4009

ABSTRACT

Introduction and Purpose: Cherries and sweet cherries are widespread stone fruit crops characterized by winter hardiness, high yield, early fruiting, and undemanding environmental conditions. Their fruits have high taste, medicinal, and tonic properties with a significant amount of vitamins, minerals, phenolic substances, and anthocyanins, which determine their antioxidant activity. However, cherries and sweet cherries spoil during harvesting, transportation, and sale, which prompts the search for and development of technologies to preserve their quality. The use of film-forming compositions to replace existing packaging materials with biodegradable and environmentally friendly ones in post-harvest fruit processing technology is one way to solve this problem.

Materials and Methods: For this purpose, Alpha cherries and Vasylina cherries were selected for research during 2024–2025. Untreated fruits were used as a control. Others were sprayed with solutions: 1) 1% chitosan and 2) a solution containing 2% chitosan, 10% glycerin, and 10% berberine. After being picked from the trees and sorted, the fruits were placed in boxes and stored at a temperature of 4±0.5°C and a relative humidity of 95±1%. After storage, weight loss was determined by calculating the difference in weight. The yield of standard products was determined according to the DSTU 4957:2008 standard.

Results: As a result of the studies, the storage life of cherries and sweet cherries increased almost twice and amounted to 28 and 36 days, respectively. The yield of marketable products was 90 and 93%, respectively. Weight loss did not exceed 3%.

Discussion and Conclusion: The data obtained on cherries and sweet cherries treated with berberine solution before storage confirm the feasibility of its use. The shelf life of the fruit is extended by 28–36 days, and weight loss does not exceed 3%.

Key Words: Sour Cherry Fruits; Sweet Cherry Fruits; Berberine; Chitosan; Film-forming Compositions.

EVALUATE THE ERGONOMIC PERFORMANCE AND USABILITY OF THE BYACRE CARBON ULTRALIGHT ROLLATOR TO ENHANCING USER COMFORT AND SAFETY

Dr. Nguyen Thi Bich Van

Faculty of Architecture Interior Design, University of Architecture, Ho Chi Minh City, Vietnam.

Vương Tôn Minh

Institute of International Education, University of Architecture Hochiminh City, Vietnam

Abstract

This study investigates the ergonomic performance and user-centered functionality of the byACRE Carbon Ultralight rollator - an assistive mobility device designed to enhance comfort, safety, and independence for individuals with mobility limitations. In the context of a rapidly aging global population and the increasing demand for advanced healthcare solutions, ergonomics has become a pivotal consideration in product development. The research aims to assess how specific design features—such as the device's lightweight carbon frame, forward-facing ergonomic handles, shock-absorbing wheels, and compact folding mechanism affect the overall user experience. Employing a mixed-methods approach that integrates both qualitative and quantitative data, the study evaluates user perceptions of comfort, stability, ease of operation, and postural improvement. Preliminary findings suggest that the byACRE Carbon Ultralight contributes significantly to enhancing user autonomy, reducing physical strain, and improving safety. These outcomes highlight the vital role of ergonomic design in the innovation of assistive technologies and its broader implications for improving quality of life among aging populations.

Keywords: mobility aid, ergonomics, lightweight construction, aging global population

Introduction: The Imperative for Ergonomic Mobility Aids

The global demographic shift towards an aging population highlights a critical need for advanced mobility aids. This trend directly correlates with increasing mobility impairments, amplifying the demand for effective and safe assistive devices like rollators. Rollators are crucial for preserving independence and enhancing the quality of life for older adults and individuals facing mobility challenges. Defined by international standards, they are walking devices offering stability and balance, often incorporating resting seats and storage, though not designed for seated user transport. The primary demographic includes individuals over 65, notably women, and those with conditions such as Parkinson's, Alzheimer's, and Chronic Obstructive Pulmonary Disease (COPD) . A holistic understanding necessitates viewing rollators as integral components of a socio-technical human-machine system. This perspective extends beyond mere mechanical function to encompass their profound influence on health, social participation, and overall quality of life . A rollator's effectiveness is thus dictated not only by its physical attributes but by its seamless integration into daily routines, its impact on self-perception, and its role in facilitating societal engagement. This comprehensive framework informs the evaluation of the byACRE Carbon Ultralight, moving beyond simplistic functional assessment to a nuanced consideration of the user experience.

Defining Usability and Ergonomics in Assistive Device Design

In assistive technology, particularly mobility aids, usability and ergonomics are foundational for effective design and user acceptance. Usability, formally defined by ISO 9241-11:2018, refers to "the extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" . This international standard provides a robust framework, segmenting usability into three key components:

Effectiveness: Quantified by the accuracy and completeness with which users achieve specified goals . For a rollator, this includes successful terrain navigation, precise braking, or maintaining desired gait patterns. Efficiency: Refers to resources expended relative to goal achievement (ISO 9241-11:2018). For rollators, this assesses physical effort (e.g., muscle exertion) or time required for tasks like walking, maneuvering, or folding the device. Satisfaction: A subjective evaluation encompassing the user's physical, cognitive, and emotional reactions to the product . Satisfaction is critical as it directly influences perceived benefits and consistent product use.

Ergonomics, as a broader scientific discipline, optimizes human-system interaction for comfort, safety, and performance, directly contributing to device usability. Evaluating usability critically considers the interplay between objective and subjective measures. While effectiveness and efficiency are objectively quantifiable, satisfaction is subjective. Empirical evidence from rollator studies highlights the value of combining subjective user survey data with objective measurements, such as Electromyography (EMG) or gait analysis . Sole reliance on one data type yields incomplete assessment. Therefore, a comprehensive evaluation necessitates a mixed-methods approach, triangulating data for a nuanced understanding by validating objective performance against subjective perceptions. This approach avoids phenomena like the "satisfaction paradox," where users express contentment despite unaddressed problems .

Common Rollator Challenges and the byACRE's Design Response

Despite their utility, rollators often present problems leading to suboptimal interactions, negatively impacting quality of life, limiting social participation, and increasing injury risk . Common barriers include environmental obstacles such as stairs, ramps, narrow spaces, heavy doors, and uneven outdoor surfaces . These challenges can lead to device non-use or reliance on less safe alternatives, promoting falls. Beyond functional issues, social stigma linked to mobility aids can cause embarrassment and reduced social engagement . Conversely, effectively designed rollators profoundly improve user independence, self-esteem, and safety, enabling greater autonomy and offering symptom relief, such as reducing dyspnea and improving walking distance . The byACRE Carbon Ultralight rollator is positioned as a premium mobility aid, integrating distinct design features aimed at enhancing user comfort, safety, and addressing common usability challenges. These design choices strategically respond to pervasive problems identified in general rollator literature.

Key features and manufacturer-claimed benefits include (5):

Lightweight Construction: Weighing approximately 4.8 kg (10.6 lbs), significantly lighter than standard rollators (often ~8 kg). This addresses cumbersome devices, easing lifting over obstacles and facilitating transport, thereby enhancing Efficiency by reducing human effort.

Forward-Facing Ergonomic Handles: Developed with a physiotherapist, these handles promote upright posture by allowing users to pull the rollator closer, reducing strain on shoulders, neck, and back. This contributes to Effectiveness (improved posture) and Satisfaction (comfort).

Shock-Absorbing Wheels: Puncture-proof PUR/rubber wheels (7.9" / 200mm diameter) with a thick, soft rubber layer are engineered to absorb terrain shocks. This ensures a smooth ride across diverse surfaces (sidewalks, gravel, cobblestones) and provides excellent traction, improving Effectiveness (performance on varied terrain) and Satisfaction (comfort, reduced vibration).

Compact Folding Mechanism: Folds flat to a narrow 25 cm (9.8") with a simple two-finger lift from the seat, greatly facilitating transport and storage in vehicles or navigating narrow doorways. This enhances Efficiency (reduced time/effort) and Effectiveness (access in confined spaces).

Additional Features: Includes integrated/hidden brake cables, push-button height adjustment, a built-in seat for resting, and a curb lifter. The aesthetic appeal is also emphasized to motivate user engagement (5). These contribute to Efficiency (ease of adjustment), Effectiveness (ability to rest, obstacle navigation), and Satisfaction (aesthetics, perceived safety).

Methodological Approaches for Ergonomic and Usability Evaluation

To objectively measure "effectiveness" and "efficiency" and gather empirical data on performance, stability, and physiological effort, quantitative methodologies are indispensable.

Usability Survey (Descriptive/Empirical): A structured usability survey for a user cohort employs Likert scales or similar quantitative rating systems. It captures subjective assessments of specific design features, covering perceived handle comfort, brake operation ease, wheel performance on surfaces, folding convenience, overall stability, and weight perception. This enables statistical analysis of satisfaction across design elements, providing quantifiable insights into user preferences and perceived performance .

Electromyography (EMG) Experiment: Controlled laboratory experiments using surface electromyography (SEMG) objectively measure muscle activity (%MVC) during rollator tasks. For robust ecological validity, recruitment prioritizes a representative sample of older adults with mobility impairments. Tasks include walking on varied terrains, maneuvering obstacles, braking, lifting, and folding. Electrodes are strategically placed on upper limb, trunk, and lower limb muscles (e.g., Anterior Deltoid, Erector Spinae, Rectus Femoris) . Ideally, muscle activity using a specific rollator is compared against a "standard" model or unaided walking to quantify ergonomic benefits. A device like the byACRE, with its lightweight construction and ergonomic handles, is hypothesized to significantly reduce muscle exertion, especially in upper limbs and trunk, compared to heavier, less optimized models. This methodology is informed by prior research demonstrating significant muscle activity reductions with "developed" rollators .

Gait Analysis and Stability Assessment: Instrumented walkways, motion capture systems, or wearable inertial sensors objectively measure gait parameters and postural stability. Key gait metrics include stride length, walking speed, cadence, double support time, and gait variability, crucial indicators of efficiency and stability . Objective stability measures include center of pressure (COP) excursions and performance on balance tests. Timed functional tests (e.g., 6-minute walk test, obstacle course) assess effectiveness and efficiency in simulating real-world mobility challenges . Shock-absorbing wheels and stable designs are hypothesized to improve gait stability and reduce fall risk, particularly on uneven surfaces.

A critical observation from previous research is the "weight paradox" . While lightweight design suggests improved efficiency, a study on a "developed" rollator revealed mixed user opinions on "Weight," with 34% rating a lighter rollator as "Worse" . This arises as some users added weight to lighter rollators for stability on rough rural roads. This highlights an ergonomic trade-off: lighter rollators improve transportability and reduce effort (efficiency), but may inadvertently compromise stability (safety/effectiveness) in challenging environments. Therefore, quantitative analysis of any ultralight rollator must meticulously investigate stability across diverse terrains, offering a nuanced perspective that acknowledges the ultralight nature as an advantage in urban settings but a potential limitation in rugged environments.

Discussion: byACRE's Ergonomic Performance and User Experience

The byACRE Carbon Ultralight rollator's design features suggest strong potential for enhanced ergonomic performance and a superior user experience, addressing many documented challenges in general rollator usability.

Impact on Posture, Stability, and Physical Exertion: The byACRE's lightweight construction (4.8 kg) significantly reduces weight compared to standard rollators (~8 kg) . This is hypothesized to enhance Efficiency by decreasing human effort for lifting and maneuvering, especially over obstacles or during transport . However, ultralight design benefits are highly context-dependent, exemplified by the "weight paradox." While lighter devices generally imply greater efficiency, previous evaluations showed mixed user opinions, with some rating lighter rollators as "Worse" due to perceived stability compromises on rough terrains . Optimal weight is not universal but depends on the primary use environment. The forward-facing ergonomic handles promote upright posture, allowing users to pull the rollator closer, reducing strain on the shoulders, neck, and back . This directly contributes to user Comfort and improves walking aid Effectiveness. Shock-absorbing wheels provide a smooth ride and excellent traction across varied terrains , enhancing Effectiveness and contributing to user Satisfaction through reduced vibration.

Usability and User Experience: Comfort, Ease of Use, and Perceived Safety: Manufacturer claims for the byACRE include "effortless maneuvering," "smooth, fast, and effortless rides," and "easy to maneuver across any terrain" . The compact folding mechanism is described as "easy" and requiring only a "two-finger lift" . These claims align with "ease of use," a frequently identified usability aspect in rollator literature . However, prior research indicates that even with generally easy-to-use rollators, users often report needing to "learn new skills" or devise "creative solutions" to overcome physical barriers . This suggests perceived ease of use can necessitate user adaptation or be influenced by environmental challenges, prompting assessment of whether the byACRE truly simplifies tasks across all contexts for all users.

User comfort and satisfaction are central to byACRE's marketing, with claims of "comfortable walk" and "optimal seated comfort" . Comfort is a fundamental component of user satisfaction, as defined by ISO 9241-11:2018 . Beyond physical comfort, byACRE's deliberate focus on aesthetic appeal ("beautiful and functional design that motivates you to get out" and "dynamic styling" may significantly enhance user satisfaction and acceptance. Prior research indicates appealing design can reduce social stigma often associated with mobility aids, perceived as "unwanted sign of senior age and handicaps" . This suggests byACRE's design philosophy, positioning the device as desirable, addresses a critical psychosocial need and enhances emotional satisfaction, encouraging consistent use.

Perceived safety and independence are paramount concerns. byACRE's design claims include "prevention of unintended falls," "more control and better balance," and an "extremely stable design" . The integrated built-in seat provides "on-the-go seating" for rests , a key safety feature reducing fear of falls due to dizziness or fatigue . While byACRE's claims primarily address physical safety, increased safety also reduces family members' anxiety, and users report "anxiety when their rollator was not nearby" . This highlights a significant psychological component to safety and independence, where the device provides security beyond physical support. Evaluation should extend beyond physical stability to explore its profound impact on user and family perceived security and confidence, contributing to greater independence, reduced anxiety, and enhanced quality of life.

Comparative Insights and Contextualization: The byACRE's core design features directly address and offer solutions to many common rollator problems identified in systematic reviews. Its ultralight nature tackles cumbersome devices during transport and over obstacles . Similarly, its compact folding mechanism mitigates challenges with narrow spaces and vehicle transport . The emphasis on promoting "upright posture" through forward-facing handles represents a significant ergonomic improvement over traditional designs that may encourage stooped posture, potentially leading to discomfort.

While direct EMG data for byACRE is not provided, an empirical study on a "developed" rollator demonstrated statistically significant reductions in overall muscle strength (from 7.4%MVC to 5.5%MVC) and specific upper limb and trunk muscle activity compared to an existing rollator . This reduction was attributed to an improved brake system design (. The byACRE's design

incorporates similar principles, such as ergonomic handles and integrated brakes , intended to reduce physical strain and improve handling efficiency. It is reasonable to infer these features would contribute to reduced muscle exertion and improved ergonomic efficiency, aligning with positive findings from analogous studies . This indicates byACRE likely achieves similar or superior ergonomic efficiency in terms of reducing muscle load during use, based on design alignment with validated principles.

Conclusion and Future Research Directions

This evaluation indicates the byACRE Carbon Ultralight rollator incorporates several innovative design features—including ultralight construction, forward-facing ergonomic handles, shock-absorbing wheels, and compact folding mechanism—that directly address documented challenges in general rollator usability and ergonomics. These features are hypothesized to significantly enhance user comfort, safety, stability, and ease of use. Specifically, the design elements are expected to reduce physical exertion, as inferred from analogous EMG data from other developed rollators , and improve maneuverability across diverse environments. The deliberate focus on aesthetic and desirable design holds substantial potential to mitigate the social stigma often associated with mobility aids, thereby enhancing overall user satisfaction and promoting consistent adherence to rollator use. However, it is important to acknowledge the potential "weight paradox," where the ultralight design, while highly efficient for transport and lifting, may require careful consideration regarding its impact on stability in exceptionally rough or unpredictable terrains, necessitating a balanced perspective.

The assessment of the byACRE Carbon Ultralight rollator emphatically underscores the paramount importance of applying rigorous human-centered design principles in the development of assistive devices. Designs that prioritize the holistic needs of the user—encompassing comfort, safety, and addressing both physical and psychosocial aspects—are fundamental for promoting user independence, fostering social participation, and ultimately improving overall quality of life . This imperative extends beyond the mere functional attributes of the device itself to encompass the entire "service-product system," which includes crucial elements such as appropriate prescription processes, comprehensive user training, and consistent follow-up maintenance services .

Limitations of the Current Evaluation: This evaluation is based on a synthesis of manufacturer claims and general rollator usability research, rather than a dedicated, independent empirical study on the byACRE product itself. While quantitative data from a previous study demonstrates ergonomic benefits of a "developed" rollator, it is not specific to the byACRE model. Therefore, direct comparative performance metrics for the byACRE against other models are inferred, not empirically proven. The absence of direct user interviews or observational studies specifically with byACRE users limits the depth and specificity of qualitative insights directly attributable to this product. Furthermore, the "Weight" trade-off identified in previous research suggests that while ultralight design is advantageous for transport, its impact on stability in diverse, particularly very rough, terrains requires direct and specific empirical validation for the byACRE model.

Future Research Directions: To further validate and expand upon the current understanding of the byACRE Carbon Ultralight rollator's ergonomic performance and usability, several future research directions are recommended:

Empirical Validation (byACRE-Specific): Conduct dedicated, comprehensive empirical studies, utilizing a mixed-methods approach, specifically on the byACRE Carbon Ultralight with a diverse and representative user population. This research should include objective gait analysis and balance assessments across a variety of terrains to quantitatively measure stability and fall risk. Direct EMG studies comparing the byACRE to traditional or other lightweight rollators are also needed to definitively quantify reductions in muscle exertion across various tasks. Longitudinal studies would be valuable to assess long-term user satisfaction, device durability, and sustained impact on daily activities, social participation, and actual fall rates.

Contextual Usability and the "Weight Paradox": Further investigation into the "weight paradox" is warranted by conducting comparative studies of the byACRE's performance and user satisfaction in distinctly different environmental contexts (e.g., urban vs. rural, very smooth vs. very rough terrain). This will help to precisely delineate optimal design parameters for varied use scenarios.

Psychosocial Impact of Design: Conduct in-depth qualitative research to fully explore the nuanced impact of the byACRE's aesthetic design on user self-perception, social acceptance, and long-term adherence to rollator use, building on the "desirability" aspect. Service System Integration: Research how optimal service delivery models (e.g., personalized prescription, comprehensive training programs, accessible maintenance services) can be seamlessly integrated with advanced rollator designs like the byACRE to maximize overall usability, user outcomes, and device longevity.

Reference

1. All Terrain Medical. (n.d.). byACRE | Carbon Ultralight – Compact – Rollator – Outdoor & Indoor – Black – 5713504001644. https://www.allterrainmedical.com/acre-carbon-ultralight-compact-rollator-outdoor-indoor-black-5713504001644/
2. ANSI Webstore. (n.d.). ISO 11199-2:2021 – Assistive products for walking manipulated by both arms – Requirements and test methods – Part 2: Rollators. https://webstore.ansi.org/standards/iso/iso111992021-2447195
3. Assist Mobility. (n.d.). NHS Physio Reviews byACRE Ultralight. https://assistmobility.co.uk/blogs/news/nhs-physio-reviews-byacre-ultralight
4. AssistData. (n.d.). Standards for Testing – rollators. https://hmi-basen.dk/en/newslist.asp?x_newstype=41&psearch=120606&stype=iso
5. Best Buy. (n.d.). Customer Reviews: byAcre Carbon Ultralight Regular Rollator, 16.5" Seat Width, Supports up to 285lbs Red Frame BYA100MDR. https://www.bestbuy.com/site/reviews/byacre-carbon-ultralight-regular-rollator-16-5-seat-width-supports-up-to-285lbs-red-frame/6469200
6. byACRE. (n.d.). A stylish rollator. Really?. https://www.byacre.com/us/a-stylish-rollator-really/
7. byACRE. (n.d.). Carbon Ultralight Rollator – World's lightest at 4.8 kg – byACRE Shop. https://shop.byacre.com/carbon-ultralight-rollator.html
8. byACRE. (n.d.). Healthcare professionals (US) – byACRE. https://www.byacre.com/us/healthcare-professionals/
9. byACRE. (n.d.). Reviews (EU) – byACRE. https://www.byacre.com/eu/reviews/
10. byACRE. (n.d.). Rollator reviews – byACRE. https://www.byacre.com/reviews/
11. byACRE. (n.d.). What features enhance user comfort in the byACRE Carbon Ultralight rollator, including seat design, backrest support, handle materials, and shock absorption?. https://www.byacre.com/us/carbon-ultralight/
12. Drive Medical. (n.d.). What is the difference between a walker & a rollator?. https://www.drivemedical.com/blog/what-is-the-difference-between-a-walker-and-rollator
13. Health Products For You. (n.d.). ByACRE Carbon Fibre Ultralight Rollator. https://www.healthproductsforyou.com/p-byacre-carbon-fibe-ultralight-rollator.html
14. Homecare Equipment. (n.d.). ByACRE Carbon Ultralight Rollator. https://homecareequipment.com.au/product/byacre-carbon-ultralight-rollator/
15. Just Walkers. (n.d.). byACRE Carbon Ultralight Comfort Walker Rollator | Just Walkers | Reviews on Judge.me. https://judge.me/reviews/stores/justwalkers.com/products/byacre-carbon-ultralight-comfort-walker-rollator
16. Lee, K. S., Kim, K. R., Kim, H. C., Chae, H. S., Kim, S. W., & Seo, M. T. (2014). Development and evaluation of rollator for elderly farmers. Journal of the Ergonomics Society of Korea, 33(6), 487–497. https://doi.org/10.5143/JESK.2014.33.6.487

17. Let's Roll Mobility. (n.d.). byACRE Carbon Ultralight Walker. https://letsrollmobility.com/products/byacre-carbon-ultralight-walker
18. Schmucker, M., Küpper, A., Mahler, C., & Elsbernd, A. (2025). The usability of rollators as part of the human-centred quality of mobility devices: A systematic narrative literature review. Disability and Rehabilitation: Assistive Technology, 20(2), 268–285. https://doi.org/10.1080/17483107.2024.2440672
19. Van, N. T. B., & Phúc, N. T. H. (n.d.). AI system automatically adjusts seats and desks with ergonomic criteria for children.

THE IMPACT OF AI-BASED DECISION SUPPORT SYSTEMS ON STRATEGIC DECISION-MAKING IN ORGANIZATIONS: A MANAGEMENT INFORMATION SYSTEMS PERSPECTIVE

Ceren YAMAN

Cappadocia University, Department of Computer Programming, Cappadocia Turkey

ORCID ID: https://orcid.org/0009-0005-5835-1449

Abstract

Artificial Intelligence (AI)-based Decision Support Systems (DSS) are rapidly reshaping managerial decision-making processes by offering predictive analytics, real-time data interpretation, and scenario modeling. In today's dynamic business environments, such systems have become critical in enhancing the quality, speed, and consistency of strategic decisions.

This study aims to evaluate the influence of AI-supported DSS on the strategic decision-making capabilities of managers, from the perspective of Management Information Systems (MIS). The research was conducted using a quantitative method with a survey distributed to mid- and upper-level managers in medium and large-scale organizations in Turkey. The data collected were analyzed using SPSS to assess correlations between DSS usage and decision performance indicators such as accuracy, time-efficiency, and risk perception.

The results indicate that the integration of AI into DSS significantly improves strategic decision outcomes by enabling faster processing, more consistent outputs, and more informed managerial judgment. The study also finds a positive correlation between managerial openness to digital technologies and the effectiveness of DSS usage.

This research contributes to the MIS literature by providing empirical evidence of AI's role in strategic decision-making and proposes recommendations for organizations seeking to digitalize their decision processes.

Keywords: Artificial Intelligence, Decision Support Systems, Strategic Management, Management Information Systems, Digital Transformation

Özet

Yapay zekâ (YZ) tabanlı karar destek sistemleri (KDS), yönetsel karar alma süreçlerini öngörüsel analizler, gerçek zamanlı veri yorumlamaları ve senaryo modellemeleri aracılığıyla yeniden şekillendirmektedir. Günümüzün hızlı değişen iş dünyasında bu sistemler, stratejik kararların kalitesini, hızını ve tutarlılığını artırmada kritik bir role sahiptir.

Bu çalışmada, yapay zekâ destekli KDS'lerin işletmelerde stratejik karar alma süreçlerine olan etkisi Yönetim Bilişim Sistemleri (YBS) bakış açısıyla ele alınmaktadır. Araştırma, Türkiye'de orta ve büyük ölçekli işletmelerde görev yapan orta ve üst düzey yöneticilere uygulanan nicel bir anket çalışması ile yürütülmüştür. Elde edilen veriler SPSS programı ile analiz edilmiş; karar doğruluğu, zaman verimliliği ve risk algısı gibi performans göstergeleriyle KDS kullanım düzeyi arasındaki ilişkiler değerlendirilmiştir.

Sonuçlara göre, yapay zekâ ile desteklenen KDS'lerin entegrasyonu, stratejik kararların kalitesini artırmakta, karar sürelerini kısaltmakta ve yöneticilerin daha bilinçli kararlar almasına

olanak sağlamaktadır. Ayrıca, dijital teknolojilere açık olan yöneticilerin KDS'lerden daha yüksek fayda sağladığı tespit edilmiştir.

Bu çalışma, YBS literatürüne yapay zekânın stratejik karar süreçlerindeki etkisini gösteren ampirik bulgular sunmakta ve işletmelerin dijitalleşme yolculuklarında uygulanabilir öneriler geliştirmektedir.

Anahtar Kelimeler: Yapay Zekâ, Karar Destek Sistemleri, Stratejik Yönetim, Yönetim Bilişim Sistemleri, Dijital Dönüşüm

ERGONOMICS UNDERMINED BY AESTHETIC TRENDS: A CRITICAL REVIEW FROM A HEALTH SCIENCE VIEWPOINT

Dr. Nguyen Thi Bich Van

Faculty of Architecture Interior Design, University of Architecture, Ho Chi Minh City, Vietnam.

Quan Yến My

Institute of International Education, University of Architecture Ho Chi Minh City, Vietnam.

Abstract

In health science, product design, particularly in everyday furniture, plays a crucial role in supporting posture, preventing strain, and enhancing user comfort. Yet many furniture pieces celebrated for their iconic aesthetics often fall short in terms of true ergonomic function. This study explores that imbalance through a critical review of several widely recognized design chairs. While visually striking and influential in design history, these chairs commonly exhibit ergonomic limitations such as poor lumbar support, lack of adjustability, and inadequate promotion of natural movement. The findings suggest that when visual innovation eclipses functional integrity, users may face long-term health risks, especially in contexts involving prolonged sitting. Rather than dismissing artistic design, this paper advocates for a more integrated approach that balances aesthetic ambition with ergonomic responsibility.

Keywords: health science, aesthetics, ergonomics, risk factor in design.

Introduction

Furniture design sits at the intersection of art, engineering, and health science. Ergonomics, as a subdiscipline of health science, ensures that products support posture, reduce strain, and promote physical well-being (Zunjic, 2024). In seating, these principles are particularly critical for preventing musculoskeletal disorders and maintaining comfort over extended use.

Over the past century, design culture has increasingly celebrated “iconic” chairs, sculptural objects that signal cultural sophistication, often at the expense of functional comfort. Market trends, fueled by a consumer desire for visual distinction and symbolic ownership, reinforce this imbalance (Peteri, 2017). While such designs may succeed in pushing material and formal boundaries, they frequently overlook the biomechanical realities of the human body.

The problem addressed in this study is the persistent prioritization of aesthetics over ergonomics in celebrated chair designs. These choices, while visually compelling, can lead to health issues including lumbar strain, postural misalignment, and reduced mobility.

The objective is to critically assess three widely recognized design chairs using ergonomic criteria, identifying recurring functional deficiencies and discussing their implications for user health. This evaluation seeks to bridge the gap between design innovation and health science, arguing for a balanced approach that harmonizes aesthetic vision with ergonomic integrity.

Highlighting Long-Term Health Risks While Advocating Balanced Form and Function.

Emerging research underscores that extended periods of sedentary behavior can significantly elevate the risk of musculoskeletal pain, particularly in the neck region. One meta-analysis reported that sitting more than six hours per day increases the likelihood of developing neck pain by up to 88%, compared to individuals with more active routines (PowersHealth, 2025). Moreover, workplace studies involving nearly 45,000 participants in Sweden indicate that protracted sitting, especially without periodic breaks, is strongly associated with increased reports of both neck and back pain, as well as overall poorer self-rated health (BMC Public Health, 2021). These findings highlight the pressing need for ergonomic designs that support dynamic posture and minimize continuous strain.

Evolution of Ergonomic Principles and Iconic Chair Designs.

Ergonomics gained recognition as a critical design discipline in the mid-20th century, initially driven by efforts to align workplace environments with human physical and physiological needs. For instance, early ergonomic research paved the way for adjustable features, such as seat height and lumbar support, to become standard in chair design aimed at promoting postural health and comfort (Talenta Java Design, 2023).

A defining turning point occurred in 1994 with the release of the Herman Miller Aeron chair, which dramatically reshaped expectations for office seating. Designed by Bill Stumpf and Don Chadwick, the Aeron introduced breathable mesh materials (Pellicle), adaptive lumbar supports, and synchronized tilt mechanisms that responded dynamically to user movement. This innovation marked a significant leap toward merging ergonomic function with modern aesthetics (ErgoOffice, n.d.; CorporateSpec, n.d.).

While many contemporary iconic chair designs continue to emphasize sculptural elegance and minimalism, they often exist in tension with ergonomics. Designers of such chairs may prioritize visual form and artistic expression, sometimes at the expense of seat adjustability and user support, highlighting how the legacy of ergonomic innovation continues to inform, challenge, and shape contemporary furniture design.

Case Studies and Ergonomic Evaluation.

Empirical investigations have consistently validated the protective benefits of ergonomically designed seating in both occupational contexts and broader furniture evaluation methods. One study conducted at a traditional tailoring workshop revealed that low back pain in tailors is significantly associated with longer years of service, prolonged sitting durations, and poor working postures, highlighting how chronic use of inadequately ergonomic seating can manifest in musculoskeletal disorders (Siregar et al., 2023). In parallel, Bai et al. (2024) performed a systematic review of 41 studies on sitting and working furniture published between 2012 and 2022, uncovering a heavy reliance on quantitative ergonomic assessment techniques and identifying notable gaps in gender inclusion, cultural context analysis, and domestic furniture evaluation. Beyond this, Saha et al. (2024) demonstrated via anthropometric analysis that furniture dimensions matched to university students significantly reduced mismatch and improved comfort, especially when adjustable features were present.

Absence in Ergonomic Performance of Visually Appeal Furniture

Although ergonomic principles are well-established in the context of functional and institutional furniture, a significant research gap persists when it comes to *celebrated design chairs*. For instance, Liu et al. (2023) highlight that most biomechanics research in furniture design focuses on specialized areas, such as wheelchairs or vehicle seating, rather than everyday, iconic pieces distributed in domestic and office environments. Similarly, the systematic review of sitting and working furniture by Bai et al. (2024) indicates that ergonomic studies overwhelmingly target school and office chairs, often neglecting the unique anatomical

and cultural demands posed by renowned design pieces. Moreover, research by Saha et al. (2024) demonstrates how integrating anthropometric data into desk and chair design significantly enhances fit and comfort in educational settings, but again, focuses on generic rather than visually distinctive furniture. The ergonomic needs of iconic design furniture, those prized for their aesthetic value, remain largely unexamined, leaving a crucial gap at the intersection of health science and design history.

Methodology.

Approach: Mixed-Methods Critical Review

This study employs a mixed-methods critical review, combining qualitative assessment and quantitative benchmarking to evaluate ergonomic performance of three anonymized, but visually iconic chairs. This approach ensures robust insight, integrating subjective design analysis with established ergonomic standards (Bai et al., 2024; turn0search10) and enabling cross-verification of findings with both text-based critique and numerical evaluation tools (Bai et al., 2024; turn0search9).

Assessment Criteria

Evaluation of each chair is rooted in internationally recognized ergonomic frameworks for seating, particularly focusing on aspects like support, adaptability, and comfort.

- Lumbar Support: The chair should facilitate a natural spinal curve with appropriate backrest contour and material flexibility.
- Adjustability: Measures include height, recline, and armrest modulation that accommodate at least 90% of users' anthropometry).
- Movement Encouragement: Chair design should allow dynamic posture changes to reduce static loading.
- Posture Alignment: Ideal seating aligns user joints and distributes pressure, as outlined by ergonomic contour parameters.
- User Inclusivity: Chair dimensions and interaction should not restrict varying body sizes or physical capacities.

Selection Process

Two emblematic yet formally anonymous chairs were selected for this critical ergonomic review, here referred to as **Chair A** (the globe-inspired workstation concept) and **Chair B** (the continuous ribbon-loop seating form).





Figure 1: Chair A possesses spherical seat, pedestal base, cocoon-like, enclosed form.

Figure 2: Chair B possesses a continuous flowing curved form.

Design Influence & Concept Origin (Chair A): This high-seated, spherical workstation merges seating and functional work surface into a compact unit designed to activate movement and offer varied postural options. As described by design critics, its rounded seat and back encourage dynamic positioning and break from traditional static "sit still" norms, emphasizing bodily freedom and visual intrigue.

Design Influence & Material Exploration (Chair B): Emerging from mid-century experimentation with foam and stretch fabric, this chair flows continuously into a loop forming the seat, back, and base as a seamless sculptural object. It reflects an intention to embody bodily contours in form, deviating from conventional structures and championing comfort through form evolution.

Selection is grounded in three criteria:

1. Design Influence: Both chairs exemplify innovative formal experimentation, pioneering approaches to seated form, one through embodied workstation integration, the other through synthetically sculpted continuous form.

2. Market/Cultural Visibility: Chair A reappears in workplace concept discussions and exhibitions challenging sedentary norms. Chair B remains a recurrent subject in retrospectives of mid-century design innovation.

3. Historical and Ergonomic Relevance: Each chair represents a distinct response to ergonomic dialogue, Chair A responds to modern work dynamics and active posture; Chair B reflects mid-century exploration of human form and material expressiveness.

This comparison offers a compelling foundation for ergonomic analysis: although these two designs are widely admired for their visual innovation, neither has been rigorously assessed using key ergonomic dimensions, including lower-back support, adaptability, encouragement of natural movement, alignment of the skeletal posture, and accommodation for diverse user sizes.

Results

The evaluation of Chair A and Chair B revealed significant ergonomic shortcomings that manifest notably in workplace settings.

Chair A, despite its seemingly dynamic fusion of seating and workstation, ultimately falls short in ergonomic performance. Its rigid, spherical backrest fails to provide the necessary lumbar contour and lacks mechanisms for seat or angle adjustment elements identified as critical for reducing spinal strain and maintaining natural alignment (de Carvalho et al., 2017). Research indicates that such static seating, when unsupported ergonomically, increases pressures on the intervertebral discs and limits micro-movements essential for circulation and spinal nutrition (OSHwiki, 2020). Consequently, in a workplace context, users are unable to shift postures naturally, resulting in progressive stiffness and discomfort localized in the lower back and hips. This enforced immobility often manifests as compounded tension in the neck, shoulders, and lumbar region over prolonged work periods, enduring nuisances that degrade both comfort and productivity.

Chair B, with its seamless continuous ribbon form, contributes its own set of workplace challenges. While visually striking, its uniform structure, including seat, back, and base, offers no modifiable ergonomic support. Users report that the rigidity of this design severely limits

posture variation, leaving them unable to shift weight or adjust their seating position without effort. Over time, this leads to muscular fatigue and localized pain, particularly in the lower back and thighs, issues that ergonomic literature identifies as common side effects of non-adjustable seating.

In aggregate, both chairs introduce workplace nuisances that impede performance and comfort. The absence of ergonomic adjustability in Chair A results in restricted movement and posture fatigue, while Chair B's structural rigidity exacerbates discomfort by denying users the ability to shift or realign. These deficiencies are more than minor annoyances, they hinder focus, decrease productivity, and can contribute to long-term musculoskeletal health risks commonly observed in office environments where chairs fail to support dynamic posture.

Discussion/ findings.

Ergonomic Shortcomings

The ergonomic evaluation of both Chair A and Chair B underscores recurring functional deficiencies. Neither chair provides adequate lumbar support, contravening research indicating that proper backrest contouring helps maintain spinal alignment and reduce muscle fatigue (de Carvalho et al., 2017). Additionally, both lack essential adjustability, no capacity to alter seat height, tilt, or back alignment. This inflexibility hampers adaptation to a range of user physiques and contributes to chassis-induced musculoskeletal strain (Ergoform, 2024). Overall, these design choices result in static, posture-restricting furniture that fails to support natural bodily movement or alignment.

Visual Appeal vs. Ergonomic Compromise.

Despite their striking visual form, both chairs exemplify how aesthetic allure can overshadow essential ergonomic considerations. As Poon (2022) articulates in *Form Swallows Function,* design tends to prioritize visual aesthetics at the expense of alignment with ergonomic principles, such as anthropometric comfort and postural support, which are often undervalued in the pursuit of visual innovation. This imbalance becomes clear upon evaluating these chairs: their sculptural geometry may evoke admiration, yet their rigid structure and absence of adjustable features fail to deliver critical ergonomic needs, including lumbar support, adaptability, and movement facilitation. Such shortcomings confirm that ergonomic effectiveness shouldn't be an afterthought but an integral aspect of visual design that ensures user comfort and well-being.

Health Implications

When furniture designs prioritize visual style at the expense of ergonomic functionality, the consequences can be both physical and ocular. Prolonged use of chairs that lack lumbar support, adjustability, and promote static posture leads to muscle fatigue, poor circulation, and increased spinal pressure, all known contributors to musculoskeletal disorders (MSDs) such as lower back pain, neck stiffness, and hip discomfort. Extended sitting has also been linked to elevated risks of blood clots, deep vein thrombosis (DVT), and metabolic disturbances, posing serious long-term health risks.

In addition to musculoskeletal strain, poorly orchestrated workstations, particularly those that mismatch monitor positioning and lighting, can result in digital eye strain or Computer Vision Syndrome. Typical symptoms include headaches, blurred vision, dry or painful eyes, and sensitivity to light, often exacerbated by glare, flicker, and improper screen distance or height. Without break habits or visual aids, these visual stressors can diminish workplace comfort and productivity.

Combining these factors, chairs that serve as sculptural centerpieces may deliver aesthetic satisfaction but fail to uphold the comprehensive well-being of the user, undermining both physical health and cognitive focus.

Specific Features That Fail Ergonomic Standards

Across both chairs, two recurring ergonomic shortcomings stand out: structural rigidity and a lack of adjustability. While these features preserve their visual design integrity, they severely limit user adaptability to different body types and tasks, a trade-off that undermines functional comfort (Peteri, 2017).

This aesthetic-driven rigidity has tangible health implications. Without proper lumbar support or adjustable seating, users are prone to developing musculoskeletal strain, particularly in the lower back, neck, and shoulders, over extended periods of use (Zunjic, 2024). For instance, the enclosed form of Chair A impedes natural movement, causing users to twist awkwardly when reaching or turning in their work environment. Meanwhile, Chair B's deep recline discourages core engagement, rendering it unsuitable for tasks such as desk work. These design flaws not only compromise posture but also elevate the risk of discomfort and long-term strain.

Yet, despite these ergonomic shortcomings, the chairs maintain popularity, a phenomenon explained by the aesthetic-usability effect. As documented by Kurosu and Kashimura (1995), and supported by subsequent research, users often perceive visually appealing objects as more functional or user-friendly, even when objective usability is lacking. This perceptual bias enables form to persist over function: consumers are more forgiving of ergonomic flaws when the design is striking (StepUpConversion, n.d.).

However, this trend suggests a missed opportunity for design innovation. Ergonomics need not be compromised for aesthetics; instead, they can be harmonized. Opportunities for improvement include integrating subtle mechanisms such as hidden adjustability, modular seating components, or flexible structural elements. Engaging ergonomists during the design phase can help ensure that comfort and visual appeal co-exist without sacrificing either.

Conclusion

Summary

This study reinforces a clear discord between visual innovation and ergonomic function.Despite iconic designs, Chair A and Chair B are striking in form, their structural rigidity and absence of adjustability undermine user comfort and long-term health, highlighting a recurring design issue where form overshadows user well-being.

Recommendation

A hybrid approach, where ergonomics and aesthetics coexist harmoniously, is both achievable and necessary. Designers can incorporate user-centered features (for example, hidden adjustability, modular cushioning, subtle ergonomic contours) without diluting visual impact, creating products that are both visually inspiring and physically supportive. Evidence suggests that designs integrating both dimensions yield higher user satisfaction and workplace well-being

Future Research

To advance this integration, future research should bridge health sciences, design thinking, and emerging technologies. A prospective ergonomics framework, one that anticipates future user needs, can guide more intuitive and adaptive designs. Additionally, incorporating AI and machine learning into design processes holds promise for optimizing both form and function, enabling highly tailored ergonomic solutions grounded in aesthetic coherence. Collaborative

initiatives that unite ergonomists, designers, technologists, and users are essential for creating products that elevate both comfort and cultural value.

References

Peteri, V. (2017). Bad enough ergonomics: A case study of an office chair. *Sage Open*, *7*(1), 2158244016685135.

BMC Public Health. (2021). *Workplace sitting is associated with self-reported general health and back/neck pain.*

PowersHealth. (2025). *Sitting too long each day may lead to neck pain, study finds.*

CorporateSpec. (n.d.). *The evolution of office seating: From wooden chairs to ergonomic marvels in 7 key stages*. Retrieved from https://corporatespec.com/evolution-of-office-seating.

ErgoOffice. (n.d.). *Pioneers in ergonomics: Key figures and milestones in chair design*. Retrieved from https://ergooffice.net/articles/ergonomic-chair-evolution.

Talenta Java Design. (2023, November 3). *The role of ergonomics in furniture design*. Retrieved from https://www.talentadesign.com/blog-post.

Saha, A. K., Jahin, M. A., Rafiquzzaman, M., & Mridha, M. F. (2024). *Ergonomic design of computer laboratory furniture: Mismatch analysis utilizing anthropometric data of university students*. arXiv.

Siregar, S. D., Manalu, P., Ginting, R., Hulu, V. T., & Siallagan, J. C. P. (2023). Complaints of low back pain in tailors. *Kemas: Journal of Community Empowerment in Health*, 18(3). https://doi.org/10.15294/kemas.v18i3.39909.

Bai, Y., Kamarudin, K. M., & Alli, H. (2024). A systematic review of research on sitting and working furniture ergonomics from 2012 to 2022: Analysis of assessment approaches. *Heliyon*, *10*(7), e28384. https://doi.org/10.1016/j.heliyon.2024.e28384.

Lee, S., DE Barros, F. C., DE Castro, C. S. M., & DE Oliveira Sato, T. (2021). Effect of an ergonomic intervention involving workstation adjustments on musculoskeletal pain in office workers-a randomized controlled clinical trial. *Industrial health*, *59*(2), 78–85. https://doi.org/10.2486/indhealth.2020-0188.

Zunjic, A. (2024). COMPREHENSIVE LIST OF ERGONOMIC RISK FACTORS-CONTRIBUTION OF ERGONOMICS TO THE SCIENCE AND PRACTICE OF SAFETY AND HEALTH. *IETI Transactions on Ergonomics and Safety*, *8*(2), 1-20.

Raita, E., & Oulasvirta, A. (2010, September). Too good to be bad: The effect of favorable expectations on usability perceptions. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 54, No. 26, pp. 2206-2210). Sage CA: Los Angeles, CA: SAGE Publications.

Liu, Y., Hu, W., Kasal, A., & Erdil, Y. Z. (2023). *The state of the art of biomechanics applied in ergonomic furniture design. Applied Sciences, 13*(22), 12120. https://doi.org/10.3390/app132212120.

de Carvalho, D., Grondin, D., & Callaghan, J. (2017). The impact of seat pan tilt and lumbar support on spine posture and muscle activity. *Ergonomics*, 60(10), 1393–1404. PubMed

OSHwiki. (2020). Musculoskeletal disorders and prolonged static sitting. *European Agency for Safety and Health at Work*. OSH Wiki

Poon, S. T. F. (2022). *Form swallows function: Design for ergonomics and aesthetics in the application of human factors through the perspective of anthropometry*. Human Factors and Ergonomics Journal, 7(2), 70–80.

Verywell Health. (2024, June 7). *What happens to the body after sitting down for too long?* Retrieved from [Verywell Health]

Healthinfo HealthEngine. (n.d.). *Office ergonomics: Preventing eye strain*. Retrieved from [HealthEngine]

Princeton University Health Services. (n.d.). *Ergonomics & Computer Use*. Retrieved from [Princeton U. Health Services]

Mohanty, R., Rehah, G., Jiao-Jiao, Z., & Silva, V. C. (2024). *Form, function, and comfort: Rethinking product design through the lens of ergonomics and aesthetics*. *International Journal of Research and Innovation in Social Science, 8*(9), 1358–1373

Nelson, J., Buisine, S., & Aoussat, A. (2013). *Prospective ergonomics: Designing for the future*. *Applied Ergonomics, 44*(6), 948–956.

Leão, C. P., Silva, V. C., & Costa, S. (2024). *Exploring the intersection of ergonomics, design thinking, and AI/ML in design innovation*. *Applied System Innovation, 7*(4), 65.

PREPARATION AND BIOLOGICAL SCREENING OF HYDRAZONES USING ISOLATED CHOLIC ACID

Talha Mashhood

Applied Chemistry, Government College University Faisalabad, Pakistan

ORCID ID: 0009-0007-6900-7189

Shehar Bano

Applied Chemistry, Government College University Faisalabad, Pakistan

ORCID NO: 0009-0009-4131-8836

ABSTRACT

Natural product modification is one of the key areas of synthetic organic chemistry for the accomplishment of valuable chemical building blocks that have prized medicinal significance. Hydrazones possess an azomethine (-NHN=CH-) group and are considered derivatives of aldehydes and ketones in which the oxygen atom has been replaced by the (R-NHN=C) functional group. These are widely studied molecules owing to their ease of preparation and diverse medicine, agriculture and pharmacology potential. Herein, cholic acid based hydrazones were synthesized and characterized using spectroscopic techniques. The newly synthesized cholic acid based hydrazones were screened for their anticancer and antioxidant potentioal. Antioxidants showed their activity by inhibiting the oxidative chain reactions that produce reactive oxygen species. The antioxidant activity showed that 4-NBCH exhibited the maximum DPPH inhibitory activity when compared with other synthesized compounds. The compound purified by thin-layer chromatography and column chromatography. Characterized by Ultra-Violet Visible Spectroscopy, Infra-red, Mass Spectrometry and Nuclear Magnetic Resonance Spectroscopy. Finally, the synthesized compound tested for its biological activities like anti-microbial, anti-oxidant and anti-cancer.

Keywords: Cholic acid, Anti-microbial, Anti-oxidant, DFT Study, Spectroscopic Analysis.

SYNTHESIS AND BIOLOGICAL EVALUATION OF AMIDES USING COUMARIN-3-CARBOXYLIC ACID

Shehar Bano

Applied Chemistry, Government College University Faisalabad, Pakistan

ORCID NO: 0009-0009-4131-8836

Talha Mashhood

Applied Chemistry, Government College University Faisalabad, Pakistan

ORCID ID: 0009-0007-6900-7189

ABSTRACT

Primary, secondary, and tertiary amides have been synthesized by one-pot synthesis from coumarin-3-carboxylic acid by using $SOCl_2$ and triethyl amine which have significant importance in the pharmaceutical field in the scenario of having biological activities like antimicrobial and anti-oxidants in the priority list. Reaction results are admirable at low temperature and can be pure by washing or column chromatography/preparative column chromatography. Amides are widespread in biologically active compounds with various applications in biotechnology, agriculture and medicine. Herein, Coumarin 3 Carboxylic acid based amides N-(2-hydroxyethyl)-2-oxo-2H-chromene-3-carboxamide (EACA),N-(4-fluorophenyl)-2-oxo-2H-chromene-3-carboxamide (4FCA), N-(3-ethylphenyl)-2-oxo-2H-chromene-3-carboxamide(3EACA),N-(2-chloro-5-nitrophenyl)-2-oxo-2H-chromene-3-carboxamide (2C5NCA), N-(3-fluorophenyl)-2-oxo-2H-chromene-3-carboxamide and N-(3-chloro-4-fluorophenyl)-2-oxo-2H-chromene-3-carboxamide were synthesized and characterized using spectroscopic techniques. The newly synthesized coumarin 3 carboxylic acid based amides were screened for their antibacterial and antioxidant potential. Antioxidants showed their activity by inhibiting the oxidative chain reactions that produce reactive oxygen species. The antioxidant activity showed that 2C5NCA exhibited the maximum DPPH inhibitory activity when compared with that of EACA, 4FCA, 3EACA, 3FCA, and 3C4FCA. While 3C4FCA showed maximum antibacterial activity(E.coli) as compared to other synthesized amides, while in the scenario of S aureus, 3FCA showed maximum activity as compared to 4FCA, EACA, 3EACA, 3C4FCA, and 2C5NCA.By this method, a series of novel coumarin-3-carboxamides were designed and synthesized to evaluate their biological activities.

Keywords: Coumarin-3-carboxamides, Anti-microbial, Anti-oxidant, DFT Study, Spectroscopic Analysis

ANTIOXIDANT, ENZYME INHBITION AND TOXICOLOGY STUDIES OF METHANOL EXTRACTS OF SELECTED MEDCINIAL PLANTS

Hiba Shahid

Research Laboratories of Chemistry Department, Government College University Faisalabad, Pakistan.

Prof. Dr. Syed Ali Raza Naqvi

Research Laboratories of Chemistry Department, Government College University Faisalabad, Pakistan.

ABSTRACT

The purpose of this work was to study the biological activities of methanolic extracts of *Tagetes erecta*, *Calendula officinalis* and *Murraya koenigii* on alpha-amylase at varying concentrations. Antioxidants obtained from selected medicinal plant extracts should be able to produce the desired redox reaction, be physiologically inert, non-toxic, effective in low concentrations, and should provide prolonged stability to the formulation. The comet assay's detection of DNA damage highly depends on the cells in the selected therapeutic plant components. Environmental pollution is a major factor that has an impact on human lives as it damages cell DNA. The % radical scavenging activity was performed by using DPPH and FRAP antioxidant assays. The % inhibition of methanolic extracts were performed by using α-amylse and urease inhibition assays. The toxicology studies were performed by using comet assay to check the selected plants extract's potential to damage DNA. The % inhibition of methanolic extracts of alpha amylase was noted in the range of 11.49 to 50.56 % and IC_{50} in the range of 04.09±0.05 to 07.39±0.23 µg/ mL respectively at the mentioned concentrations. The % urease inhibition range of leaf extracts at 300 to 400 rpm of *Tagetes erecta* were in range of 52.32 to 2.11 %. Methanolic extracts of *Tagetes erecta* showed the total phenolic contents in the range of 0.03±0.24 to 0.42±0.63 mg GA/ 100g for leaf extracts and 0.006±0.39 to 0.09±0.28 mg GA/100g for stem extracts. 0.02±0.32 to 0.17±0.38 mg GA/ 100g TPC of curry leaves and 0.02±0.32 to 0.17±0.38 mg GA/ 100g, 0.001±0.39 to 0.18±0.39 mg GA/100g for leaf and stem extracts of *Calendula officinalis*. According to researchers, the total phenolic contents in a plant largely contribute to antioxidant activity. The % radical scavenging activity of leaf extracts of *Tagetes erecta* was noted in the range of 2.13 to 76.13 % and 3.73 to 46.31 % by using DPPH and FRAP antioxidant assays. The current experiment showed that NDEA increased DNA damage, as indicated by the lengthening of the comet tail. Ingestion of *T. erecta* leaf extract significantly reduced protein and lipid oxidation and lessened DNA damage, which is interpretable as a decrease in oxidative stress brought on by NDEA. The results of the work therefore, clearly indicate the potential of these extracts to manage hyperglycemia and oxidative stress. The evaluation of enzyme inhibition and antioxidant potentials of plant extracts has been done by using 96-well microplate reader technique. Data obtained has been statistically analyzed using appropriate statistical tools.

Keywords: *Tagetes erecta, Calendula officinalis, Murraya koenigii,* antioxidant, enzyme inhibition, comet assay, evaluation and statistical analysis.

MULTIPLICATIVELY PERIPHERAL SPECTRUM-PRESERVING MAPS

Ismail EL KHCHIN

University Sidi Mohammed BenAbdellah Faculty of Sciences DharMahraz Fes Department of Mathematics

https://orcid.org/0009-0001-2917-5192

Hassane Benbouziane

University Sidi Mohammed BenAbdellah Faculty of Sciences DharMahraz Fes Department of Mathematics

Mustapha Ech-Chérif Elkettani

University Sidi Mohammed BenAbdellah Faculty of Sciences DharMahraz Fes Department of Mathematics

Introduction:

Let A and B be standard operator algebras(not necessarily closed) on complex Banach spaces X and Y, respectively. For $T \in B(X)$, we denote by $\sigma_\pi(T)$ the peripheral spectrum of T defined by $\sigma_\pi(T) = \{\lambda \in C: |\lambda| = r(T)\}$, where $r(T)$ is the spectral raduis of T. The goal of this paper is to describe maps $\phi_1, \phi_2: A \to B$ such that their ranges contain all operators of rank at most two and that satisfy

$$\sigma_\pi(TST) = \sigma_\pi\big(\phi_1(T)\phi_2(S)\phi_1(T)\big), \qquad (T, S \in A).$$

Furthermore, in the case where $X = H$ and $Y = K$ are two complex Hilbert spaces, we also characterize maps $\phi_1, \phi_2: A \to B$ whose ranges contain all operators of rank at most two and that satisfy

$$\sigma_\pi(TS^*T) = \sigma_\pi\big(\phi_1(T)\phi_2(S)^*\phi_1(T)\big), \qquad (T, S \in A)$$

We note that several known results follow as immediate consequences.

Key Words: Nonlinear preservers problem, peripheral spectrum, idempotent rank-one operators.

CRITICAL BEHAVIORS AND MAGNETOCALORIC EFFECT IN MIXED-SPIN-(1-5/2) HEXAGONAL NANOWIRE WITH MONTE CARLO SIMULATION

M. Choubi
Laboratory of Bio-Geosciences and Materials Engineering, Higher Normal School, Hassan II University, Casablanca 50069, Morocco

A. Elidrysy
Laboratory of Bio-Geosciences and Materials Engineering, Higher Normal School, Hassan II University, Casablanca 50069, Morocco

S. Harir
Laboratory of Bio-Geosciences and Materials Engineering, Higher Normal School, Hassan II University, Casablanca 50069, Morocco
Department of Physics and Chemistry, Regional Center for the Professions of Education and Training, Casablanca, Casablanca–Settat, Morocco

Z. Elmghabar
LPHE, Modeling & Simulations, Faculty of Science, Mohammed V University in Rabat, Rabat, Morocco
Centre Physique-Mathématique (CPM), Faculty of Science, Mohammed V University in Rabat, Rabat, Morocco

A. Lahbibi
Laboratory of Bio-Geosciences and Materials Engineering, Higher Normal School, Hassan II University, Casablanca 50069, Morocco

Y. Lghazi
Laboratory of Bio-Geosciences and Materials Engineering, Higher Normal School, Hassan II University, Casablanca 50069, Morocco

Abstract

The magnetic properties and magnetocaloric effects of a mixed Ising model composed of mixed spins ($S = 1$) and ($\sigma = 5/2$) on a hexagonal nanowire structure have been studied using Monte Carlo simulations, following the Metropolis update protocol. In particular, the effects of exchange couplings, crystal fields, magnetic fields and temperature on the magnetization, susceptibility, order parameter, compensation points, entropy and adiabatic temperature are discussed in detail. This study allowed us to discover the existence of interesting critical phenomena, in particular the compensation behavior. In addition, the phase diagrams in the ($J_C/|J|$, $J_S/|J|$), ($D_C/|J|$, $D_S/|J|$), and (J, h) planes have been detailed. They reveal multiple stable configurations, highly sensitive to exchange interactions and crystal fields.

The compensation points appear for appropriate values of the system parameters. We found that the compensation temperature starts to evolve for J_C > 0.1 and $D_C >$ 0.5 of the spin-5/2 assembly and in contrast, the effect of the J_S and D_S coupling does not show any threshold value, in this case, the compensation temperature is constant.

As for the magnetocaloric effect, characterized by an entropy change (ΔS_m) and an adiabatic temperature change (ΔT_{ad}), shows significant variations around (T_{comp}) and (T_C), indicating a potential for advanced cooling applications.

Keywords: Ferrimagnet; Magnetocaloric Effect; Ising; Monte Carlo; Compensation Temperature

ACTIVATED CARBON PRODUCTION FROM DRY ITALIAN THISTLE (*CARDUUS PYCNOCEPHALUS* L.) AND ITS ADSORPTION APPLICATION FOR METANIL YELLOW

Osman ÜNER

Kırklareli University, Science and Art Faculty, Department of Chemistry, Kırklareli, Türkiye

ORCID ID: https://orcid.org/0000-0001-6950-6753

ABSTRACT

Introduction and Purpose: The usage of abundant and easily accessible biomaterials as feedstock has recently attracted the attention of many researchers due to the reduction of the cost of activated carbon production. Therefore, dry Italian thistles (*Carduus pycnocephalus* L.) were used as an activated carbon feedstock in present study, and the characterization and metanil yellow adsorption performance of the produced activated carbon were accomplished.

Materials and Methods: Dry Italian thistles and 50 mL of aqueous $ZnCl_2$ solution were mixed at a 1/1 (*w*/*w*) ratio and kept in an oven at 101 ℃ for 1 day. After the dry mixture was transferred into a porcelain crucible with cover, the carbonization process was carried out in a muffle furnace at 650 ℃ for 90 minutes. After that, to eliminate impurities in the activated carbon, it was washed with 0.2 N HCl solution, then rinsed with plenty of distilled water, filtered and dried in the oven at 50 ℃ for 1 day. After ground the activated carbons, they were utilized for the characterization stages and metanil yellow adsorption experiments with Batch adsorption technique.

Results: The characterization process of activated carbon obtained from dry Italian thistle was carried out by BET surface area, pore values, N_2 adsorption-desorption isotherm, EDX, SEM, and FTIR analyses. Its BET surface area, t-Plot micropore volume, and t-Plot micropore area were calculated as 1220.38 m^2/g, 0.137 cm^3/g, and 295.62 m^2/g, respectively. Also, 99.82% of 250 mg/L metanil yellow removal from the aqueous solution at 25 ℃ was succeeded with 1.0 g/L dry Italian thistle derived activated carbon.

Discussion and Conclusion: As a result, the present study has displayed that dry Italian thistle feedstock can be utilized to produce activated carbon with high surface area and good metanil yellow dye adsorption ability.

Key Words: Activated Carbon; Italian Thistles; Adsorption, Metanil Yellow

RETHINKING CREDIT RISK: AI-DRIVEN OUTCOME-BASED CREDIT MODELS FOR SUSTAINABLE FINANCIAL INCLUSION IN EMERGING MARKETS

Aida Makas

Sarajevo School of Science and Technology, Economics, Sarajevo, Bosnia and Herzegovina.

ORCID ID: https://orcid.org/0009-0005-4413-0178

Dr. Haniza Von

Global Psytech Sdn Bhd, Maleysia

Abstract

Traditional credit risk models in emerging markets often rely on historical financial data and static credit scores, which can exclude large segments of the population from financial services. This article explores the transformative potential of AI-driven, outcome-based credit models in fostering sustainable financial inclusion. By leveraging alternative data sources—such as transaction patterns, behavioral analytics, and real-time economic indicators—AI models can dynamically assess creditworthiness, reducing default risks while expanding access to credit. The study examines the key benefits and challenges of AI-driven credit risk assessment, including regulatory considerations, data privacy concerns, and model interpretability. Through case studies from emerging markets, the article demonstrates how these models enhance financial inclusion, improve risk management, and contribute to economic development. The findings suggest that AI-powered credit assessment, when responsibly implemented, can revolutionize lending practices, making them more adaptive, equitable, and sustainable.

Keywords: AI-driven credit models, credit risk assessment, financial inclusion, emerging markets, alternative data, machine learning, sustainable finance, outcome-based lending, fintech, creditworthiness evaluation.

CLEAN AND GREEN ENVIRONMENT BY USING AGRICULTURAL WASTE WITH BETTER CLEANING PROPERTIES THAN SYNTHETIC ONES

Dr. Maria Taj

Jinnah University, Pakistan

ORCID NO: 0000-0000-0000-0000

Abstract

The plant material was found to be rich with surfactant properties. The comparative study between synthetic and natural surfactant was carried out using spectrophotometry, and conductometric measurement. The natural surfactant plant gave CMC values 4.4×10^{-4}M. It is the point where their monomer aggregates to form micelles, which are far below the CMC point of most of thesynthetic surfactants. The role of temperature was also monitored in comparison to the synthetic surfactants. The pH was used to find the nature of surfactants and number of replaceable protons in the system. The surfactant interaction properties were monitored against a variety of dyes cationic (CTAB), and anionic (methylene blue and neutral red). The interactions were monitored from pre- to post micellar concentrations of both natural and synthetic surfactants. The change in concentration of the surfactant led to the change in interaction behaviour. Wide range of temperatures were selected to monitor the behaviour and interactions of the natural and synthetic surfactants as these interactions are temperature dependent and found to be favourable at lower temperatures.

The self-degradation was observed at ambient temperature and in the darkboth in aerobic and anaerobic conditions. Based on its behavior and degradation properties, the proposednatural surfactant is a cheap and good alternative to the synthetic surfactants. These natural surfactants were found to have surfactant properties and even efficient from synthetic counterparts and biodegradable thus environmentally friendly.

Moreover, the natural surfactant helps to degrade many environmentally toxin dyes which are even non degradable in fenton presence.

COMPARATIVE STUDY OF TITANATE-BASED PEROVSKITE OXIDES FOR ENERGY STORAGE DEVICES

Warda Waseem

Department of Physics, University of Agriculture Faisalabad, 38040, Pakistan.

Muhammad Yasin Naz

Department of Physics, University of Agriculture Faisalabad, 38040, Pakistan.

Abdul Ghaffar

Department of Physics, University of Agriculture Faisalabad, 38040, Pakistan.

ABSTRACT

Titanium-based perovskite oxides were formed by sol-gel process using metal nitrates and titanium isopropoxide as starting materials. In this work, a comparison between the structural, chemical, optical, morphological, dielectric and electrochemical properties of various titanate-based perovskite oxides such as barium, strontium and calcium titanate is done. XRD confirmed the formation of perovskite structure in all the titanates. FTIR analysis and SEM are used to find the functional group and morphology of the samples, respectively. Uv-visible spectroscopy revealed that $CaTiO_3$ has the highest bandgap of 3.51 eV, which decreased sequentially in $SrTiO_3$ (3.24 eV) and $BaTiO_3$ (3.20 eV). Dielectric studies showed that $BaTiO_3$ has the highest dielectric constant of 1211 at room temperature, while $SrTiO_3$ and $CaTiO_3$ showed a lower value of 240 and 190, respectively, at the same frequency. The electrochemical studies of the prepared nanocomposites were assessed by cyclic voltammetry, galvanostatic charge-discharge and electrochemical impedance spectroscopy. In comparison to $SrTiO_3$ and $CaTiO_3$, which exhibit a specific capacitance about of 251 and 165 Fg^{-1}, $BaTiO_3$ exhibits a high specific capacitance of 436 Fg^{-1} at the scan rate of 1 mVs^{-1}. Also, the highest energy density of 16.76 $Whkg^{-1}$ for $BaTiO_3$ is recorded from galvanometric charge-discharge measurements. In addition, the prepared electrode serves as a better environmentally friendly candidate with comparatively high specific capacitance and energy density compared to lead-based oxides already used in the market for energy-related applications.

Keywords: Titanium-based perovskite oxides, sol-gel method, dielectric constant, specific capacitance.

SUSTAINABLE ALTERNATIVE FOR TEXTILE COLORATION USING PHENOLIC CONTENTS FROM DIFFERENT COMBINATION OF EUCALYPTUS CAMLDULENSIS AND CINNAMOMUM VERUM

D. I. Tarungwa

Department of Chemistry, School of Physical Sciences, Federal University of Technology, Minna, Niger State, Nigeria.

A. A Mann

Department of Chemistry, School of Physical Sciences, Federal University of Technology, Minna, Niger State, Nigeria.

L.A Fadipe

Department of Chemistry, School of Physical Sciences, Federal University of Technology, Minna, Niger State, Nigeria.

S.I Iyen

Department of Chemistry, School of Physical Sciences, Federal University Wukari, Taraba, State, Nigeria.

ABSTRACT

A dye is nothing but a colored substance that has an affinity to the substrate to which it is being applied. Colour is one of the elements of nature that makes human life more aesthetic and fascinating. There are currently many differents dye extraction processes, including Solvent, aqueous, enzymatic extraction, etc. Dye could be natural dye derive from plants and animals and Artificial dye from chemical industry. Environment pollution is emerging as an alarming issue all over the world. The textile industry regards as the most polluting, as water pollution caused by effluents. These effluents contain toxic chemicals like carcinogenic amines and mutagens in Azo dyes, heavy metals, several natural products have been reported to possess dyeing abilities; Synthetic dyes are allergic, carcinogenetic, non biodegradable and difficult to prepare and cannot be dispose off easily. Though phenolic compound has been showing Natural dyes are Nontoxic, Biodegradable, nonallergic, non carcinogenetic easy to prepare and can be dispose off easily. Eucalyptus camldulensis (E) was blended with Cinnamomum verum (C) in different ratio to attained three differents hybrid forms. The extracts blended in the following ratios and labelled accordingly; 1:1 labelled CE1, 4:1 labelled CE2 and 1:4 labelled CE3. A phytochemical screening revealed presence of compounds responsible for dyeing properties in the crude extracts of Eucalyptus camldulensis, Cinnamomum verum and blended portions.phytochemical analysis shows flavonoids, quinones, tannins, carotenoids, alkaloids, coumarins. This research reveal phenolic contents in both Eucalyptus camldulensis and Cinnamomum verum.

Keywords: Natural Dyes, Classification, Extraction-Method, Application, Eco-Friendly.

PRESSURE ENGINEERING OF ELECTRONIC AND MECHANICAL PROPERTIES IN III-NITRIDE SEMICONDUCTORS: A COMPUTATIONAL STUDY

Ez-zejjari Ilyass

SCDRE Team, CCPS Laboratory, Ensam, Hassan 2 University, Casablanca, Morocco

Orcid ID: https://orcid.org/0000-0003-3178-4234

El Ghazi Haddou

SCDRE Team, CCPS Laboratory, Ensam, Hassan 2 University, Casablanca, Morocco

Orcid ID: https://orcid.org/0000-0002-2139-2360

ABSTRACT

Introduction and Purpose: Wurtzite III-nitride semiconductors such as boron nitride (BN), aluminum nitride (AlN), gallium nitride (GaN), and indium nitride (InN) are of great interest for advanced optoelectronic and high-power applications. Their performance under pressure is critical for devices operating in extreme environments. This study investigates the effect of hydrostatic pressure on the electronic and mechanical properties of these materials, aiming to understand pressure-induced trends and their implications for bandgap engineering and mechanical stability.

Materials and Methods: First-principles calculations based on density functional theory (DFT) were performed using the CASTEP module within the Materials Studio package. Several exchange-correlation functionals were employed, including LDA, GGA, and LDA+U, to improve the accuracy of electronic structure predictions and better account for electron correlation effects. For each material, the electronic band structure, elastic constants, bulk modulus, shear modulus, and Poisson's ratio were calculated under varying pressure conditions.

Results: The electronic band structure analysis revealed that GaN, AlN, and InN possess direct bandgaps that increase with applied pressure, mainly due to enhanced orbital interactions and shifts in crystal field effects. In contrast, BN exhibits a pressure-induced decrease in its indirect bandgap, reflecting its distinct electronic configuration. Regarding mechanical behavior, BN was found to be the stiffest material, while InN exhibited the most ductile response. GaN and InN also displayed nonlinear pressure dependence in their elastic constants and Poisson ratios. All compounds exhibited mechanical anisotropy, influencing their directional responses to stress.

Discussion and Conclusion: Our results highlight the diverse pressure responses of III-nitrides in both electronic and mechanical domains. The contrasting bandgap behaviors between BN and the other nitrides suggest material-specific pathways for bandgap tuning under strain. The observed anisotropy and nonlinear elastic behavior are crucial considerations for mechanical reliability in device design. The agreement between our results and existing experimental and theoretical data validates the computational approach and supports its predictive capabilities. Overall, this study provides key insights into the design of pressure-adapted optoelectronic devices and materials with tunable electronic properties

Keywords: Density Functional Theory, III-Nitride Semiconductors, Mechanical properties, Hydrostatic Pressure, Electronic Properties.

IDENTIFICATION OF PLANT-DERIVED ISOFORM-SELECTIVE PI3K INHIBITORS

Cem YALAZA

Başkent University, Faculty of Pharmacy, Department of Biochemistry, Ankara, Turkey

ORCID: https://orcid.org/0000-0002-9073-5611

ABSTRACT

Introduction and Purpose: The phosphoinositide 3-kinase (PI3K) plays a critical role in regulating cellular processes such as proliferation, survival, and metabolism. Aberrant activation of this pathway is frequently observed in various cancers. This study aims to identify plant-derived natural compounds with isoform-selective inhibitory activity against PI3K and to explore their potential as alternative anti-cancer therapeutics.

Materials and Methods: Molecular docking analyses were performed using the crystal structures of four PI3K isoforms (PI3Kα, PI3Kβ, PI3Kγ, and PI3Kδ) against non-toxic phytochemicals and FDA-approved inhibitors. The best binding affinities were observed for mahanine and morusin (PI3Kα), mahanine and isoangustone A (PI3Kβ), hyperoside (PI3Kγ), and lavendustin A (PI3Kδ). Binding site interactions were assessed in detail and compared with native ligands. Protein-ligand flexibility simulations using CABS-flex 2.0 demonstrated that all selected complexes remained structurally stable under physiological conditions. Additionally, drug-like properties of the top-performing phytochemicals were evaluated using the SwissADME tool.

Results: Molecular docking analyses revealed several plant-derived compounds with strong binding affinities toward specific PI3K isoforms. Results of these analyses showed that mahanine can inhibit the PI3Kα and PI3Kβ isoforms, morusin can inhibit the PI3Kα isoform, isoangustone A can inhibit the PI3Kβ isoform, hyperoside can inhibit the PI3Kγ isoform, and lavendustin A can inhibit the PI3Kδ isoform.

Discussion and Conclusion: This comprehensive in silico study suggests that the selected plant-derived compounds may serve as isoform-selective PI3K inhibitors and offer potential as targeted anti-cancer agents with fewer side effects. Overall, the findings highlight five phytochemicals (mahanine, morusin, isoangustone A, hyperoside, and lavendustin A) as promising isoform-selective PI3K inhibitors with potential utility in further preclinical research and compound optimization efforts.

Key Words: PI3K, molecular docking, plant-derived inhibitors, in silico analysis

DEVELOPMENT AND COMPREHENSIVE CHARACTERIZATION OF GRAPHENE OXIDE-ENHANCED CHITOSAN COMPOSITE BEADS FOR HIGHLY EFFICIENT, SELECTIVE, AND RAPID CONGO RED DYE ADSORPTION FROM CONTAMINATED WATER: AN INTEGRATIVE, MULTIDISCIPLINARY INVESTIGATON COMBINING MOLECULAR-LEVEL MECHANISTIC INSIGHTS VIA DENSITY FUNCTIONAL THEORY (DFT), EXTENSIVE EXPERIMENTAL VALIDATION, AND ADVANCED STATISTICAL PROCESS OPTIMIZATION USING RESPONSE SURFACE METHODOLOGY (RSM) TOWARDS SUSTAINABLE AND ENVIRONMENTALLY FRIENDLY WASTEWATER REMEDIATION

Soukaina El Bourachdi

Laboratory of Engineering, Electrochemistry, Modelling and Environment, Faculty of Sciences Dhar El Mehraz, Sidi Mohamed Ben Abdellah University, Fez, Morocco

Yassine Rakcho

Laboratory Materials, Processes, Environment and Quality, National School of Applied Sciences, Cadi Ayyad University (UCA), Route Sidi Bouzid BP 63, 46000 Safi, Morocco

Amal Lahkimi

[1]Laboratory of Engineering, Electrochemistry, Modelling and Environment, Faculty of Sciences Dhar El Mehraz, Sidi Mohamed Ben Abdellah University, Fez, Morocco

ABSTRACT

In this study, graphene oxide-enhanced chitosan composite beads were developed and thoroughly investigated as an efficient adsorbent for the removal of Congo Red dye from aqueous solutions. The synthesis process was optimized using Response Surface Methodology (RSM) based on a Box–Behnken design to maximize adsorption capacity under various experimental conditions including pH, contact time, adsorbent dose, and initial dye concentration. Comprehensive characterization techniques confirmed the successful incorporation of graphene oxide into the chitosan matrix, enhancing surface area and active sites for adsorption. A theoretical insight into the adsorption mechanism was provided by Density Functional Theory (DFT) calculations, revealing the molecular-level interactions between Congo Red molecules and the composite beads, including hydrogen bonding, π–π interactions, and electrostatic attractions. The integration of experimental and theoretical approaches allowed for an in-depth understanding of the adsorption process, contributing to the design of more effective adsorbents for wastewater treatment. The results demonstrate that chitosan@graphene oxide beads are a promising, sustainable, and cost-effective material for dye removal, offering significant potential for environmental remediation applications.

Keywords: Chitosan composite beads; Box–Behnken design; DFT analysis; Wastewater treatment; Green synthesis

FAST-TRACKING HYBRIDIZATION IN BREAD WHEAT: A SPEED BREEDING APPROACH TO F_1 GENERATION

Levent YORULMAZ

Dicle Üniversity, Agriculture Faculty, Department of Field Crops, Diyarbakir, Türkiye

ORCID ID: https://orcid.org/0000-0002-2880-1462

Sibel IPEKESEN

Dicle Üniversity, Agriculture Faculty, Department of Field Crops, Diyarbakir, Türkiye

ORCID ID: https://orcid.org/0000-0002-7141-5911

Mehmet YILDIRIM

Dicle Üniversity, Agriculture Faculty, Department of Field Crops, Diyarbakir, Türkiye

ORCID ID: https://orcid.org/0000-0002-6953-4479

ABSTRACT

Introduction and Purpose: Hybrid breeding in bread wheat is a crucial method for improving genetic diversity, resilience, and yield potential. However, traditional breeding cycles are time-consuming, which hampers the rapid development of elite lines. Speed breeding—an innovative approach that uses extended photoperiods and controlled environments—has emerged as a promising solution to accelerate generation turnover. This study aimed to develop F_1 hybrids from selected bread wheat genotypes under speed breeding conditions to evaluate their agronomic and physiological traits, including heading and anthesis timing, chlorophyll content, plant height, and grain yield.

Materials and Methods: The research was conducted in a semi-controlled greenhouse equipped for speed breeding at Dicle University (Turkey) during 2023–2024. Three bread wheat genotypes—Adana-99 (P1), Alada (P2), and Lucilla (P3)—were used to produce four F_1 combinations: P1×P2, P2×P1, P1×P3, and P3×P1. Emasculation was performed at the pre-anthesis stage (Zadoks 50–55), and crosses were carried out at flowering (Zadoks 61–65). Plants were grown in 6 L pots with four seeds each, under a 22-hour light/2-hour dark cycle. The experiment followed a completely randomized design with three replications. Agronomic practices were standardized, and measurements were taken at key phenological stages.

Results: Significant variation was observed among genotypes and hybrids across all traits. F_1 hybrids generally exhibited intermediate or superior performance compared to their parents. For instance, the P2×P1 hybrid showed the highest total grain weight per plant (2.38 g), while Adana-99 and P3×P1 had the tallest plants. Chlorophyll content at heading and anthesis was significantly higher in hybrids such as P1×P2 and P2×P1 than in some parents. The coefficient of variation ranged from 2.2% for heading days to 7.1% for total grain weight, with most traits showing statistically significant differences among genotypes.

Discussion and Conclusion: The results demonstrate that speed breeding is an effective method for producing and evaluating F_1 hybrids in a short time frame. Notably, some F_1 combinations like P2×P1 outperformed parental lines in terms of yield-related traits, suggesting

heterotic effects under accelerated growth conditions. The ability to generate, grow, and assess hybrids rapidly holds substantial promise for future wheat improvement programs. These findings support the integration of speed breeding into hybrid development pipelines, particularly in environments where timely breeding cycles are critical for responding to climatic and production challenges.

Key Words: *Triticum aestivum*, speed breeding, F1 hybrids.

SUSTAINABLE PRODUCTION OF BACTERIAL CELLULOSE BY BACTERIA ISOLATED FROM NATURAL FERMENTED SUBSTRATES FOR ECO-FRIENDLY BIO-LEATHER APPLICATIONS

Reshma N

Department of Microbiology, Governement Arts and Science Colleg Kozhinjampara, Palakkad, Kerala, India

ORCID ID: https://orcid.org/0009-0005-5761-2504

Deepthi K. S.

Department of Microbiology, Governement Arts and Science Colleg Kozhinjampara, Palakkad, Kerala, India

ORCID ID: https://orcid.org/0000-0003-3769-5566

Saranya Devi K

Department of Microbiology, Governement Arts and Science Colleg Kozhinjampara, Palakkad, Kerala, India

ORCID ID: https://orcid.org/0000-0002-8474-460X

ABSTRACT

Introduction and Purpose: Bacterial cellulose (BC), a biodegradable and high-purity biopolymer, has garnered increasing interest as a sustainable alternative to conventional materials. This study aimed to isolate and identify potent BC-producing strains from low-cost natural substrates such as toddy, kombucha, and fruit wastes, and to evaluate their potential for the scalable production of BC for application in the development of plant-protein–based bio-leather.

Materials and Methods: Bacterial isolates were obtained from toddy, kombucha, and fruit substrates and screened on HS agar with ethanol and $CaCO_3$ for cellulose production. The most efficient strain was identified by morphological, biochemical, and 16S rRNA sequencing. Fermentation optimization was carried out by varying ethanol concentration, pH, inoculum size, incubation time, and phototropic conditions. Produced BC was characterized using FTIR, XRD, and water absorption analyses. Bio-leather was developed by incorporating green gram protein (GGP) via glycerol-assisted entrapment and heat treatment.

Results: Among eleven isolates, strain KBC1 (tentatively identified as *Acetobacter pasteurianus*) showed the highest BC yield (3.89 g/L), surpassing the standard strain *K. hansenii* (1.83 g/L). Optimal BC production occurred at pH 4, 2% ethanol, 5% inoculum concentration, and 15 days of dark incubation. The produced BC exhibited excellent water holding (10.57 g/g) and absorption capacities (10 g/g). XRD analysis confirmed a crystallinity index of 78.43%, indicating strong cellulose structure. The developed BC-GGP bio-leather showed enhanced flexibility, strength, and biodegradability.

Discussion and Conclusion: This study demonstrates the feasibility of producing high-quality bacterial cellulose from naturally fermented, cost-effective substrates using indigenous

microbial consortia. The incorporation of green gram protein into BC matrices provides a viable approach for the development of eco-friendly bio-leather. The findings highlight a sustainable biotechnological strategy for waste valorization and green material innovation, with promising industrial applications in textiles, packaging, and biomaterials.

Key Words: Bacterial cellulose, *Acetobacter pasteurianus*, bio-leather, natural fermentation, kombucha, toddy, sustainable biomaterials, crystallinity index, FTIR, XRD.

SHEAR STRENGTH PROPERTIES OF SAND REINFORCED WITH RECYCLED PET FLAKES

Nichirvan Ramadhan TAHER

Dr, Department of Petroleum Engineering, College of Engineering, Knowledge University, Erbil 44001, Iraq.

ORCID ID: https://orcid.org/0000-0002-1295-080X,

Hüseyin Suha AKSOY

Assoc. Prof. Firat University, Faculty of Engineering, Department of Civil Engineering, 23119, Elaziğ, Turkey

ORCID ID: https://orcid.org/0000-0003-0564-457X

Mesut GÖR

Assoc. Prof. Firat University, Faculty of Engineering, Department of Civil Engineering, 23119, Elaziğ, Turkey

ORCID ID: https://orcid.org/0000-0002-5463-9278

ABSTRACT

Enormous quantities of discarded waste polyethylene terephthalate (PET) bottles are annually deposited worldwide. Despite the vast disposal of these bottles, their inherent qualities have the potential to be beneficial in engineering projects, particularly in enhancing the shear properties of soil. This study explores the influence of incorporating recycled PET flakes on the shear strength properties of sandy soil. The sandy soil was reinforced using varying percentages of recycled PET flakes, including 0.0%, 0.5%, 0.75%, 1.0%, and 1.5% by the dry weight of the sand. Shear strength properties of sand were investigated by conducting a series of direct shear box tests for unreinforced sand and reinforced sand with different percentages of PET flakes under three different normal stresses. All specimens of the shear box test were prepared at three distinct relative densities: Dr = 40%, 65%, and 85%. After assessing the shear strength properties of sand reinforced with various percentages of recycled PET flakes through a direct shear box test, the shear characteristics of both the unreinforced sand and the sand enhanced with PET flakes were determined. The findings indicated that the optimal percentage of PET flakes, providing the greatest enhancement to sandy soil, is 0.75%. Beyond this threshold, there is a decline in the shear strength properties of the sandy soil.

Key Words: Recycled PET flakes, Sandy Soil Reinforcement, Relative Densities, Soil improvement.

THE CLINICAL SIGNIFICANCE OF NORMAL PHYSIOLOGICAL BLOOD PARAMETERS IN HEALTH ASSESSMENT

Taskeen Fatıma

Hajvery Unıversıty

ABSTRACT

Blood parameters are vital indicators of physiological and pathological processes in the human body. Normal physiological values serve as reference ranges that guide clinical interpretation of laboratory results, aiding in the diagnosis, monitoring, and management of various diseases. These parameters, including hemoglobin concentration, white blood cell count, platelet count, glucose levels, electrolytes, renal and liver function markers, provide crucial insights into the functional status of different organ systems. This study aims to highlight the importance of maintaining and understanding normal ranges of key blood parameters in clinical practice. It also explores how deviations from these normal values can signal early signs of systemic diseases such as infections, anemia, metabolic disorders, organ dysfunction, and hematological abnormalities. The research emphasizes the variability of normal ranges based on age, sex, physiological state, and geographical or ethnic differences, underscoring the need for context-specific interpretation. Accurate interpretation of blood test results depends not only on identifying abnormalities but also on understanding what constitutes "normal." Misinterpretation of these values can lead to misdiagnosis, delayed treatment, or unnecessary interventions. Therefore, this paper advocates for increased awareness among healthcare professionals and students regarding the physiological significance of these reference values. In conclusion, normal blood parameter values are foundational to evidence-based medicine. Recognizing their role enhances diagnostic accuracy, supports early detection of diseases, and promotes better clinical outcomes.

KEY WORDS: Blood parameters, Health assessment, clinical Outcomes, Laboratory results

THE IMPACT OF LIVER CIRRHOSIS ON THE PROGRESSION AND COMPLICATIONS OF DIABETES MELLITUS

Taskeen Fatıma

Hajvery Unıversıty

Abstract

Background: Liver cirrhosis and diabetes mellitus are two chronic conditions that frequently coexist and interact in complex ways. The liver plays a central role in glucose metabolism, and cirrhosis significantly alters hepatic function, insulin sensitivity, and glucose homeostasis. This interaction often results in a specific form of diabetes known as hepatogenous diabetes, complicating the management and prognosis of both conditions.

Objective: This study aims to explore the impact of liver cirrhosis on the onset, progression, and complications of diabetes mellitus. It also examines the bidirectional relationship between hepatic dysfunction and glycemic control, focusing on how cirrhosis influences diabetic complications such as cardiovascular disease, nephropathy, and neuropathy.

Methods: A comprehensive review and clinical data analysis were conducted on patients with coexisting liver cirrhosis and diabetes. Key indicators such as glycemic variability, insulin resistance, and complication rates were compared with diabetic patients without liver disease.

Results: Patients with cirrhosis exhibited higher rates of glycemic instability, increased insulin resistance, and more severe complications, particularly in renal and cardiovascular systems. Cirrhotic patients also faced challenges in diabetes management due to altered drug metabolism and reduced tolerance to standard therapies.

Conclusion: Liver cirrhosis significantly exacerbates the pathophysiology and complications of diabetes mellitus. Early detection and integrated management of both conditions are essential to improve clinical outcomes and reduce morbidity. Further studies are warranted to develop optimized treatment protocols for this high-risk population.

Key Words: Liver cirrhosis, DM, Complications, glycemic control

ENERGY MANAGEMENT OF A PV–BATTERY–SUPERCAPACITOR HYBRID SYSTEM SUPPLYING VARIABLE LOADS WITH GRID BACKUP

Mohamed Lattoui

Department of Electrical Engineering, University of Tiaret, City of Tiaret 14023, Algeria

Morsli Sebaa

Department of Electrical Engineering, University of Tiaret, City of Tiaret 14023, Algeria

Tyeb Allaoui

Department of Electrical Engineering, University of Tiaret, City of Tiaret 14023, Algeria

Noureddine Sarir

Department of Electrical Engineering, University of Tiaret, City of Tiaret 14023, Algeria

ABSTRACT

Introduction and Purpose: This study presents an intelligent management strategy for a hybrid energy system composed of a photovoltaic generator, a battery, a supercapacitor, and a grid connection, designed to supply a multi-machine network with variable loads. The supercapacitor handles fast power fluctuations and improves the system's dynamic response, while the battery provides medium-term energy support. The electrical grid is engaged only when photovoltaic generation and local storage are insufficient to meet load demand.

Materials and Methods: An intelligent control approach, based on artificial neural networks and metaheuristic algorithms such as the Genetic Algorithm (GA), is developed to optimize energy flow management, regulate storage voltages, and ensure the stability of key system parameters.

Results and Conclusion: Simulation results demonstrate the effectiveness of the proposed method in achieving efficient energy management, reducing grid dependence, and enhancing power quality in dynamic load environments.

Key Words: Photovoltaic generator; Hybrid System; artificial neural networks; Genetic Algorithm (GA); multi-machine network with variable loads.

ANALYSIS OF METHODS USED IN SOLAR POWER PLANTS IN TURKEY OVER THE YEARS AND CURRENT STATUS

Mustafa Eren GÖKÇEOĞLU

Çanakkale Onsekiz Mart University, Graduate School of Education, Department of Energy Resources and Management, Çanakkale, Türkiye

ORCID ID: 0000-0002-5021-992X

Mustafa KURT

Çanakkale Onsekiz Mart University, Department of Energy Resources and Management, Faculty Member, Çanakkale, Türkiye

ORCID ID: 0009-0008-4677-3371

ABSTRACT

Increasing of energy demand and aiming of zero carbon emission in Turkey has raised interest in renewable energy sources, as in the rest of the world. It is well known that Solar Power Plants (SPPs) take into a significant place in Turkey's energy policies, rather than the otherrenewable energy sources. In this study, we expressexactingly the history, technologies in the plants, and the current situation of solar power plants, and also identify strengths and weaknesses and evaluating future opportunities for the next period in Turkey. For this detailed analysis, this study employs descriptive analytical methods to evaluate data obtained from the Energy Market Regulatory Authority (EPDK), the Turkish Electricity Transmission Corporation (TEİAŞ), as well as various international energy reports.And also, the number quantity, the capacities and the technologies of installed solar plants in Turkey between 2010-2025 take into accounts in these analyses. Additionally, SWOT analysis was conducted to assess the status.

The first result of our analysis in assembling PV panel thatdespite fixed-angle photovoltaic panels initially favored, evolving towards single-axis and dual-axis tracking systems and bifacial panels in later years. Also, seen that artificial intelligence in PV control systems and hybrid solutions has begun to be preferred. Our analysis is also emphases that new regulations are needed by the authorities for further dissemination of technological innovations, diversification of financing models. SWOT analysis highlights the strengths of existing SPPs but also points out weaknesses such as technological dependency and regional distribution imbalances.

Keywords: Solar Energy, SPP, Photovoltaic, Renewable Energy, SWOT Analysis, Turkey

APATITES: A FAMILY OF HIGH-PERFORMANCE AND ECOLOGICAL CATALYSTS FOR THE SYNTHESIS OF MOLECULES OF BIOLOGICAL INTEREST

Bahija MOUNIR
Laboratory of Analytical and Molecular Chemistry (LCAM), Faculty of Sciences Ben M'Sik, Hassan University of Casablanca B.P. 7955, 20702, Casablanca, Morocco.
ORCID ID: https://orcid.org/0009-0006-4012-4878

Fathallaah BAZI
Laboratory of Analytical and Molecular Chemistry (LCAM), Faculty of Sciences Ben M'Sik, Hassan University of Casablanca B.P. 7955, 20702, Casablanca, Morocco.
ORCID ID: https://orcid.org/0000-0002-3372-3489

ABSTRACT

Introduction and Purpose: In this work, we contributed to environmental protection through the catalytic application of fluorapatite alone or doped with sodium nitrate in clean processes for the synthesis of Michael adducts, α,β-unsaturated esters and α,α'-bis(benzilydenes) cycloalkanones.

Materials and Methods: The apatitic catalysts prepared, fluorapatite alone (FAP) or doped with sodium nitrate (Na/FAP), were first characterized by various analytical techniques and then used to prepare a range of products of biological interest.

Results: Michael addition for carbon-nitrogen, carbon-sulfur and carbon-carbon bond formation catalyzed by fluorapatite alone and fluorapatite doped with sodium nitrate. The latter catalyst enables adducts to be obtained in very high yields, in very short times and under very mild operating conditions. The extension of this addition reaction has enabled a new, direct approach to the synthesis of products of biological interest.

On the other hand, we showed for the first time that fluorapatite alone and sodium nitrate-doped fluorapatite are successfully used as catalysts for the Wittig reaction for the synthesis of α,β-unsaturated esters.

Subsequently, we used sodium nitrate-doped fluorapatite in the catalysis of α,α'-bis(benzilydenes) cycloalkanones. The yields obtained are very high. In contrast, the yields obtained when fluorapatite alone is used are very low. To make this catalytic process simpler and more environmentally friendly, we carried out the reaction in a dry medium on sodium nitrate-doped fluorapatite activated by microwave irradiation. High product yields were achieved in a very short time.

Discussion and Conclusion: Overall, the results show that PAF alone is a modest catalyst (yields are mediocre) and reaction times are relatively long. However, doping PAF with sodium nitrate enabled us to achieve both very good yields and short reaction times under very mild experimental conditions. This leaves no doubt as to the positive effect of doping PAF with sodium nitrate.

Key Words: Heterogeneous catalysis - Fluorapatite - Sodium nitrate-doped fluorapatite - Michael reaction - Wittig reaction - Cross-aldolization reaction - α,β-unsaturated esters - α,α'-bis(benzilydenes) cycloalkanones.

ROLE OF FLAGELLAR ASSEMBLY IN SALMONELLA FLHA DELETED STRAIN BIOFILM FORMATION

Iram Liaqat
Department of Zoology, G.C. University, Lahore.

ABSTRACT

Biofilms formation is a major hazardous problem from both clinical and environmental perspective. Flagellum-mediated motility is important for biofilm formation by several gram-negative bacteria. >50 genes are involved in flagellar biosynthesis and function in *Salmonella typhimurium*. The flagella basal body is a representative of Type III protein secretion systems; used by several gram-negative bacterial pathogens to colonize foreign tissues and substrates. The mechanism of flagellar assembly was analyzed in *S. typhimurium*, using bioinformatics analysis to identify conserved structural elements. In this study, *FliI* a flagellar protein that is needed for flagellar assembly and may be involved in a specialized protein export pathway was cloned and overexpressed. *FlhA* deleted mutant salmonella strain SJW1616 was used to transform *FliI* overproducing plasmid by electroporation. Using vital dyes (Alexaflour 488), visualization of motility was observed in wild type, SJW1616 (Δ*flhA*) and *FlhA* transductant strain which was further assessed by biofilm formation ability. Swimming, swarming motility alongwith significantly reduced biofilm formation was observed in SJW1616 (Δ*flhA*) compared to wild type and *FlhA* transductant strains. This study will extend initial evidence that *FliI* plays important role in flagellar export system and flagellum-mediated rotation is critical for swimming, swarming motility and biofilm formation. The flagellar basal body is a particularly convenient drug target, since the architecture of most its components has been determined near atomic resolution and it is an ancient evolutionarily conserved macromolecular assembly. The knowledge gained will also have implications for elucidation of the mechanistic design principles underlying protein secretion complexes.

Key words: FliI, Salmonella, Alexa fluor staining, FlhA, Flagellar motility

QUORUM SENSING MEDIATED BIOFLM INHIBITION IN MARINE ISOLATES

Iram Liaqat
Department of Zoology, G.C. University, Lahore.

ABSTRACT

We examined that whether patulin and penicillic acid, two well-known quorum sensing inhibitors (QSI) for human pathogen *Pseudomonas aeruginosa* PAO1, can prevent biofilm formation. study aims for amplification of a putative *luxS* gene homologue in the marine microorganism *H. pacifica* ATCC 27122, as well as monitoring AI-2 QS in marine organisms. Degenerated primers were designed based on the *luxS* protein sequence of ten gram-negative, □-, □- and □- proteobacteria, and used for *luxS* gene amplification in *H. pacifica*. AI-2 assays were carried out using the well-established *Vibrio harveyi* BB170 AI-2 bioluminescence assay. Effect of penicillic acid on AI-2 induction of *H. pacifica* showed strong inhibitory effect at non-growth inhibitory concentrations compared to patulin having adverse effect at the highest concentration (25 μM) tested in our study. QSIs effect on biofilm forming capability of marine isolates was isolate specific. Detection of bioluminescence in the autoinducer bioassay and the presence of a putative *luxS* gene orthologue are biochemical and genetic evidence for the production of a signalling molecule(s) and provide a first step in characterizing *H. pacifica* quorum sensing. Our study emphasize that QSI compounds must be selected in the specific system in which they are to function and they cannot easily be transferred from one QS system to another.

Key words: Biofilm formation, *H. pacifica*, AI-2 assay, *LuxS* gene, Patulin, Penicillic acid

Category: Oral presentation

ANTIBACTERIAL PROPERTIES OF SILVER NANOPARTICLES PREPARED BY GREEN SYNTHESIS USING ACACIA LAETA

Khalid Siraj
Mai-Nefhi College of Science, Department of Chemistry, Asmara, Eritrea
ORCID ID: https://orcid.org/ 0000-0001-9276-9447

Kebron Tesfaldet
Mai-Nefhi College of Science, Department of Chemistry, Asmara, Eritrea

Lulya Essayas
Mai-Nefhi College of Science, Department of Chemistry, Asmara, Eritrea

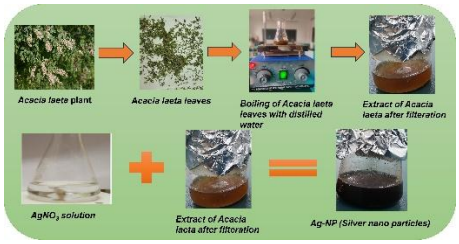
Sidona Sium
Mai-Nefhi College of Science, Department of Chemistry, Asmara, Eritrea
ORCID ID: https://orcid.org/ 0000-0001-9276-9447

Karunesh Tiwari
Mai-Nefhi College of Science, Department of Physics, Asmara, Eritrea
ORCID ID: https://orcid.org/ 0000-0002-4119-5727

Abstract

Silver nanoparticles (AgNPs) possess unmatched chemical, biological, and physical properties that make them unique compounds as antimicrobial, antifungal, antiviral, and anticancer agents. Silver nanoparticles (AgNPs) have stable reactivity and excellent optical absorption properties. They can be applied in various industries, such as environmental protection, biochemical engineering, and analyte monitoring. After collecting fruits, their extract was prepared and added to Ag NO_3 to produce Ag NPs. The features of Ag NPs were characterized using UV-visible spectroscopy, FT-IR, scanning electron microscope (SEM), and X-ray diffraction (XRD) analysis. The results of the characterization of the synthesized Ag-NPs indicate the successful synthesis using plant extract as a reducing agent, with UV-Vis spectra between 260–360 nm. FTIR identified major phytochemical compounds, which could be responsible for bio-reducing and capping potential. Antibiotic function of Ag-NPs was evaluated using *Escherichia coli* and *Bacillus cereus* bacteria species and minimal inhibitory concentration (MIC) of Ag-NPs against these two pathogens was measured. The results showed that the synthesized nanoparticles had a range size of 30-60 nm. It can be stated that the biosynthesis of Ag NPs using fruit extract of this plant is an environmentally friendly, economic and harmless method without any use of poisonous substances and no side effects.

Scheme for the synthesis of Ag-NPs



Keywords: Silver nanoparticle, green synthesis, eco-friendly, *Acacia laeta*, antimicrobial agent.

ANALYZING FRACTIONAL DIFFERENTIAL EQUATION DEPENDING ON MIXED BOUNDARY CONDITIONS

Noureddine BOUTERAA

Laboratory of Fundamental and Applied Mathematics of Oran (LMFAO), University of Oran1, Ahmed Benbella. Algeria and Oran Graduate School of Economics. Algeria.

ORCID ID: https://orcid.org/0000-0002-8772-1315

ABSTRACT

The concept of the conformable fractional derivative was introduced in 2014 by Khalil et al. Benmezai et al. introduced in 2019 a new fixed point theorem using strongly positive-like operators and then apply their fixed point theorem to a nonlinear fractional differential equation involving Riemann-Liouville derivative. In this paper, we introduce the concept of the conformable fractional derivative in such mixed nonlinear fractional boundary value problem and apply their recent fixed point theorem to our problem. To the best of the author's knowledge, there is no work dedicated to study fractional differential equations including both left and right fractional derivatives by using strongly positive-like operators and then apply the fixed point theorem due to Benmezai et al. [2] to the conformable and left sided fractional derivatives appearing in the our problem of mixed fractional nonlinear boundary value problem except the present work and the works [1] conserning nonlinear fractional differential equations involving the Riemann-Liouville derivative with local and nonlocal boundary conditions. Thus, it is worthwhile to contribute in filling this gap by continuing the investigation in this direction in order to enrich and complement the available works in the literature. We focus on the existence and nonexistence of solutions for the nonlinear mixed fractional nonlocal boundary value problem

Key Words: Fractional differential equations, conformable fractional derivative, Existence, Nonexistence, fixed point theorem.

EFFECTS OF GROWTH REGULATORS AND LIGHT INTENSITY ON CALLUS INDUCTION IN FOUR CULTIVARS OF VACCINIUM CORYMBOSUM

Reza Azadi Gonbad

Tea Research Center, Horticultural Science Research Institute, AREEO, Lahijan, Iran

https://orcid.org/0000-0002-5244-897X

Nasrin Farhadi

Greenhouse and Controlled Environments Research Center (GCER), Horticultural Science Research Institute (HSRI), AREEO, Iran

Omid Lotfifar

Greenhouse and Controlled Environments Research Center (GCER), Horticultural Science Research Institute (HSRI), AREEO, Iran

Abstract

To establish an efficient protocol for callus induction, the effects of growth regulators and light intensity on callus induction and callus growth of four cultivars of blueberry (*Vaccinium corymbosum*) were evaluated. The assayed cultivars of *V. corymbosum* were Legacy, Joel, O'Neal and Emerald. The leave pieces (1 ×1 cm) of each cultivars were cultured on medium supplemented with different concentrations of 2,4-dichlorophenoxyacetic acid (1, 1.5 and 2 mg L^{-1}), Naphthalene acetic acid (0, 0.5 and 1 mg L^{-1}) and 6-benzylaminopurine (0, 0.5 and 1 mg L^{-1}). The cultures were then maintained at 25±1°C in the dark and light conditions provided by white fluorescent tubes under 16/8 h photoperiod. The results showed that the highest callus induction in all cultivars was observed when the leave explants were cultured on medium supplemented with 2 mg L^{-1} 2,4-dichlorophenoxyacetic acid (2,4-D) in combination with 0.5 mg L^{-1} 6-benzylaminopurine (BAP) and 0.5 mg L^{-1} Naphthalene acetic acid (NAA). In addition, the calli induction significantly influenced by light intensity and the greatest of callus induction in all cultivars were achieved under light condition. In the second experiment the effects of growth regulators (1 and 1.5 mg L^{-1} 2,4-D + 0 and 0.5 mg L^{-1} BAP) on callus proliferation of *V. corymbosum* cultivars was assayed. The highest callus growth rate depend on cultivar type was achieved on medium contain 1 mg L^{-1} 2,4-D with or without BAP. This optimized protocol will be useful for any future breeding improvement programs of *V. corymbosum* using biotechnological means.

Keywords: Blueberry, Callus proliferation, Cultivar, Growth regulators

FERTILITY, HATCHABILITY, MORTALITY AND GROWTH PERFORMANCE OF INDIGENOUS, SASSO AND THEIR F1 CROSS CHICKEN GENOTYPES IN ETHIOPIA

Dr. Berhanu Bekele

Wachemo University, Ethiopia

Prof. Aberra Melesse

Hawassa University, Ethiopia

Dr. Wondmeneh Esatu

ILRI, Ethiopia

Dr. Tadelle Dessie

ILRI, Ethiopia

ABSTRACT

Three chicken genotypes were involved in the study with the objectives of evaluating fertility, hatchability, and growth performance of three chicken genotypes. For the experiment, 1550 (600 of indigenous, 450 of Sasso, 500 of crossed) eggs were labeled and incubated. The data were analyzed using SAS. Relatively higher proportion of fertility was observed for the eggs collected from Sasso (89.6%) followed by crossed eggs (72.8%). Correspondingly, hatchability was higher for Sasso. Body weight was increased from 27.9 to 321.7g for indigenous, 36.8 to 431.2g for Sasso, and 32.4 to 353.4g for crossbred from week0 to week7. Agroecology, genotypes, and sex had significant effect ($p<0.05$) on growth performance of the chickens for almost all ages of their experiment period across different agro-ecologies. Agroecology by genotype had a significant ($p<0.05$) influence on the growth performance of the chickens during week11 and week15. The interaction between agroecology and sex was significantly influenced growth rate of the chickens in all weeks of their age, except the chickens at their 11^{th} weeks of age. Genotype by sex interaction had highly significant effect in the growth performance of the chickens at their 11^{th}, 15^{th} and 20^{th} weeks' age. The chickens' growth has been influenced by the interaction among agroecology, genotype, and sex. Higher proportion of indigenous (22%) and Sasso (24%) birds were died in highland in between W7-13, however higher proportion of crossbred birds were lost in lowland for same week interval. Considering the most parameters of chickens, midland agroecology is more promising for their production. This is because, better feed resources, climatic condition, and awareness of farmers how to manage their birds.

Key words: Agroecology, Fertility, Hatchability, Growth performance, Mortality

BUILDING RECOMMENDER SYSTEMS WITH MACHINE LEARNING AND AI

Mitat UYSAL
Dogus University, Faculty of Engineering, Department of Software Engineering, Istanbul, Turkey
ORCID ID: https://orcid.org/0000-0001-9713-2525

S. Aynur UYSAL
Dogus University, Faculty of Engineering, Department of Software Engineering, Istanbul, Turkey

Nurdanur PEHLİVAN
Dogus University, Faculty of Engineering, Department of Software Engineering, Istanbul, Turkey
ORCID ID: https://orcid.org/0000-0002-1875-8202

ABSTRACT

Recommender systems are pivotal in modern digital ecosystems, guiding users toward relevant products, services, or content. This paper explores the fusion of machine learning and artificial intelligence in designing hybrid recommender systems. We present a comprehensive survey of collaborative filtering, content-based filtering, and hybrid models, followed by a Python-based hybrid system using matrix factorization and user metadata similarity. The results demonstrate that integrating AI techniques can significantly enhance recommendation quality and personalization.

Recommender systems have become essential tools in digital services such as e-commerce, streaming platforms, and social media [1]. With the rise of machine learning (ML) and artificial intelligence (AI), these systems have evolved from simple heuristic-based engines to sophisticated data-driven solutions [2]. This paper focuses on hybrid recommender systems that combine collaborative filtering (CF) and content-based filtering (CBF) enhanced by AI algorithms.

Our proposed hybrid model uses:

· Matrix factorization for collaborative filtering

· Cosine similarity on user features (e.g., genre preferences, age)

· Hybrid score = $\alpha \times$ CF score + $(1 - \alpha) \times$ CBF score

AI and ML have revolutionized recommender systems. By combining collaborative and content-based strategies, hybrid systems can achieve better accuracy and personalization. The integration of metadata, feature embeddings, and similarity metrics allows for more adaptive systems suitable for real-world applications.

Key Words: Recommender Systems; Artificial Intelligence; Machine Learning; Hybrid Recommendation; Content-Based Filtering; Collaborative Filtering.

REMEDIES FOR MITIGATING NEGATIVE RESULTS OF DROUGHT ON VEGETATIVE PRODUCTION IN WATER SCANT AREAS

Prof. Dr. Bilal ACAR

University of Selcuk, Faculty of Agricuture, Dept. of Farm Buildings & Irrigation

ORCID ID: 0000-0003-2866-2543

ABSTRACT

Drought can be described as a recurring weather event associated from lack of precipitation causing in insufficient available water for meeting the needs of humans and environments particularly agriculture. Rainfall depends on mainly geographical position of the region, distance to the water bodies of the place, intensity of vegetation, temperature of the huge water resources, and deficiency and decline in precipitation are not similar among the countries and regions. Drought having indicators of high frequency, long duration and huge effect is possibly one of the most common and destructive natural catastrophes resulting serious effects particularly on agriculture. The continuous occurrence of meteorological drought brings about lack of soil moisture content and consequently deficit water stress conditions for plants in rooting depth of soil accordingly. In Türkiye, especially Konya plain, located in the Semi-Arid Central Anatolia Region, has faced frequent water scarcity problems over the past decade (especially during periods 2020-2025 vegetation years). It is estimated that the inadequacy of water resources in this region will affect agricultural production to an alarming extent, especially in the summer of 2025. In this sense, some of the grass areas in the municipal green areas in somewhere are being partial or completely removed and even irrigation of grass plants has been suspended in general. The effects of droughts on vegetation depend on crop cycles and are very closely related to different growth cycles of plants. The adverse impacts of drought on food production can be determined by allowing governments to develop more sustainable policies. A comprehensive assessment of linkages between temporal drought variations, farming activities, watering impacts and available water resources is needed urgently. In practice some recommendations for reducing of the adverse drought effects on both agriculture as well as ecosystems in water shortage climates are as follows; Crop patterns should be re-designated by considering the current water supplies of the region, satellite image or remote sensing digital technologies should be more involved to determine and manage drought event in agro-ecosystems, deficit irrigation program must be implemented in agriculture by considering the crop response to deficit irrigation, some applications for reducing water stress of plants should be introduced to farm scales , environmental importance of water saving should be given more space in the visual media, programmed irrigation should be implemented in field conditions and finally, and farmers using water economically in agriculture should be rewarded with paying very little irrigation fees.

Keywords: Agriculture, Drought, Ecosystem, Sustainable Water Management, Water Shortage.

INTRODUCTION

Among a lot of meteorological catastrophes, drought is known as possibly one of the most common and devastating natural events resulting serious effects on vegetation and consequently global economy (Marvel et al., 2019; Guo et al., 2020; Ionita et al., 2022; Li et al., 2022;

Torabinezhad et al., 2023). Drought is a natural disaster causing more than $6 billion losses annually all over the world and impacts more than around one-third of the world's area (Wang et al., 2022). For instance, each drought event in Iran leads to $90 million economic loss for every millimetre reduction in rainfall amount (Ghaffari, 2006). Drought, therefore, can be described as a recurring atmospheric events resulting from decreased precipitation leading to insufficient water amount for meeting requirements of people as well as ecosystems (Ortega-Gaucin & López Pérez, 2026; Ferreira et al., 2018; Cravens et al., 2021). In addition to lack of rainfall, over evaporation amounts and excess-exploitation of water supplies also trigger severity of drought.

There are different sorts of droughts classified according to a change in place and atmospheric events. For instance, rainfall deficiency is usually resulted from meteorological drought, reduction in both the surface or groundwater level is considered as a hydrological drought, and little soil moisture content is called as agricultural drought (Faiz et al., 2022; Van Loon, 2015; Kheyruri & Sharafati, 2022). They are all interconnected and each expresses an abnormal moisture deficiency in some part of the hydrological cycle with respect to some fundamental value, such as rainfall, soil moisture status or groundwater supply, respectively (Cook et al., 2018). The continuous increase of meteorological drought leads to soil moisture deficiency and consequently agro-drought (Xu et al., 2021).

In recent years, dense variations in both temperature and rainfall extremities have led to increasing concerns about drought severity world general, causing billions of dollars in economic losses (Dilawar et al., 2021). Drought, more common in sem-iarid and arid regions (Mishra et al., 2016), is one of the most critical natural hazards (Bravo et al. 2021), and differs from other natural disasters in that beginning and end of drought are almost impossible to guess and its severe effects continue long after the event ends, increasing complexity and loss of life (Lalmuanzuala et al., 2022).

Drought is also one of the most difficult natural events to monitor and predict for early warning. Moreover, drought is a slow evolutionary process with long-term and widespread impact (Ahmadi & Moradkhani, 2019). Meteorological drought disasters are becoming more frequent due to the impact of global warming. Different plant types show different reactions to drought, so it is particularly important to investigate effect of meteorological drought on plants (Zhang et al., 2023). As clearly stated above, drought occurrence is a highly sophisticated event affected by a combination of climatic and environmental factors. Considering its high destructive effects, analysing severity and assessment of drought is very important role to play for efficient alleviating and adaptation solutions (Ma et al., 2025). Up to now, a lot of drought assessment indices have been introduced. Around more than 100 indices have been developed globally (Yiping & Yaohui, 2017). Unlike some other effects of climate change, extreme atmospheric events occur on a momentary scale. Unfortunately, there are currently no strategies to fully quantify the damages associated with climate change (Clarke et al., 2022). The purpose of the present work is to suggest practical solutions for alleviating the negative impacts of drought on both the vegetation and ecologies in water poor regions.

AGRO-ENVIRONMENTAL IMPACTS OF DROUGHT

Intense deforestation, urbanization, and agricultural land increase have caused variations in ground cover, causing serious damage to current ecosystems. At the same time, environmental pollution and poor waste managements have accelerated to boost temperatures and an increase in extreme atmospheric events, causing remarkable deterioration of ecosystem (Hua et al., 2024). South Asia is known as one of the greatest drought-affected regions globally. The last 55 years' period, for example, Pakistan has been exposed to drought event every three years (Miyan, 2015).

Globally South countries are predicted to be most experienced to the negative consequences of global warming, resulting from the positive link between rising temperatures and decreasing growth cycles of plants (Hasan et al., 2020). Predictions suggest that the impacts of climate change in the form of drought and heavy rainfall will accelerate soil erosion 10 to 100 times faster than the time it took to form (Porter et al., 2014).

Agricultural production is highly dependent on environmental conditions so is affected from drought negatively in most (Shiru et al., 2020; Sharara et al., 2022). Drought has a greater negative impact on those dependent on rain-fed vegetative production such as drought-induced famine in East Africa (Agutu et al., 2017). Further extremity in climate change is projected to reduce a vegetative productivity by a staggering 15.9% worldwide, 19.7% in developing countries, and approximately 15–35% in Africa by the 2080s (Pickson & Boateng, 2021). Different quantitative indicators describe droughts: duration (discontinuous or extended drought), period of occurrence, geographical spread, emergence dynamics (abrupt / instant) and time of occurrence in relation to crop growth cycle. Therefore, drought results to a water deficiency in the soil rooting environment and /or air, resulting in a reduced amount of water taken up by the whole plants compared to the amount of water evaporated (El Mzouri et al., 2021).

Droughts usually affect agriculture first as soil moisture levels drop rapidly. In the presence of high temperatures and strong winds, the process accelerates even further (Wilhite, 2016). Agricultural drought emerges when soil moisture is reduced and cannot meet whole water needs of the crops during growing period; this is resulted by none uniform rainfall, temperature rises and other factors resulting soil moisture depletion (Sruthi, 2015; Zhang et al., 2021). The effects of agricultural droughts on plants depend seasonally and are closely related to different stages of plants (Yu et al., 2018). In general, drought effects on vegetation end from a few hours even to several years. These effects have notably altered eco-hydrological connections within Soil-Plant-Atmosphere elements (Novick et al., 2016). In particular, long-term drought events can have destructive effects on crops (Ogle et al., 2015).

As mentioned above, agro-drought is caused by climate change, which adversely impacts on both plant growing as well as livestock production (Cravens et al., 2021). Central Asia was adversely affected by the extreme agricultural drought that occurred in the early growing period of 2021. Number of sheep, cattle and horses died due to insufficient watering and feeding due to severe yield losses in crops due to insufficient water resources (Jiang et al., 2020). Soil moisture losses have accelerated in such kind of dry regions in recent years by increasing desertification and leading to a more fragile ecosystem (Deng & Chen, 2017).

RESULTS AND RECOMMENDATIONS

Meteorological drought is strongly causally linked to agricultural drought, so meteorological drought can be used as an early warning of agricultural drought and enhance human mitigation of agricultural drought (Sun et al., 2023). Agricultural drought leads a serious damage to national food system, and investigating the spill over from meteorological drought to agricultural drought important role to play in drought mitigation (Dai et al., 2022). Drought management is essential to determine key characteristics of drought events, such as their duration, intensity, and spatial distribution over timescales. To ensure that drought assessment is a beneficial tool for government future plans targeted at preventing, mitigation, alleviating or reducing drought impacts, up-to-date information must be instantly accessible (Vicente-Serrano et al., 2022). The impacts of agricultural droughts on food supplies can be measured, allowing governments to develop more sustainable policies. A comprehensive assessment of the linkages between temporal drought variations, farming systems, irrigation impacts and available water resources is needed (Orimoloye, 2022). A remote sensing-based drought assessment can be conducted using various vegetation indices, so that more information about

the temporal and spatial extent of drought can be obtained and effective countermeasures can be formulated to combat the adverse effects of drought (Lalmuanzuala et al., 2022).

Today, rapid advances in technology are increasing the use of methods such as computer programs, remote sensing and artificial intelligence in the detection of agricultural drought and future precautions (Fig. 1-2).

In addition to those, in arid and semi-arid ecosystems following applications should also be considered for minimizing the negative effects of drought on agriculture; Rain-fed farming system should be more implemented in severe experienced drought regions, crop patterns could be reconstructed in favor of low water consuming crops such as cereals, deficit irrigation program should be applied at farm levels, some application such as plant growth promoting rhizobacteria (PGPR) should be practiced with deficit irrigation, and innovative technologies such as satellite images or artificial intelligence should be used more common for better management of the drought negative effects on both agriculture and environments.

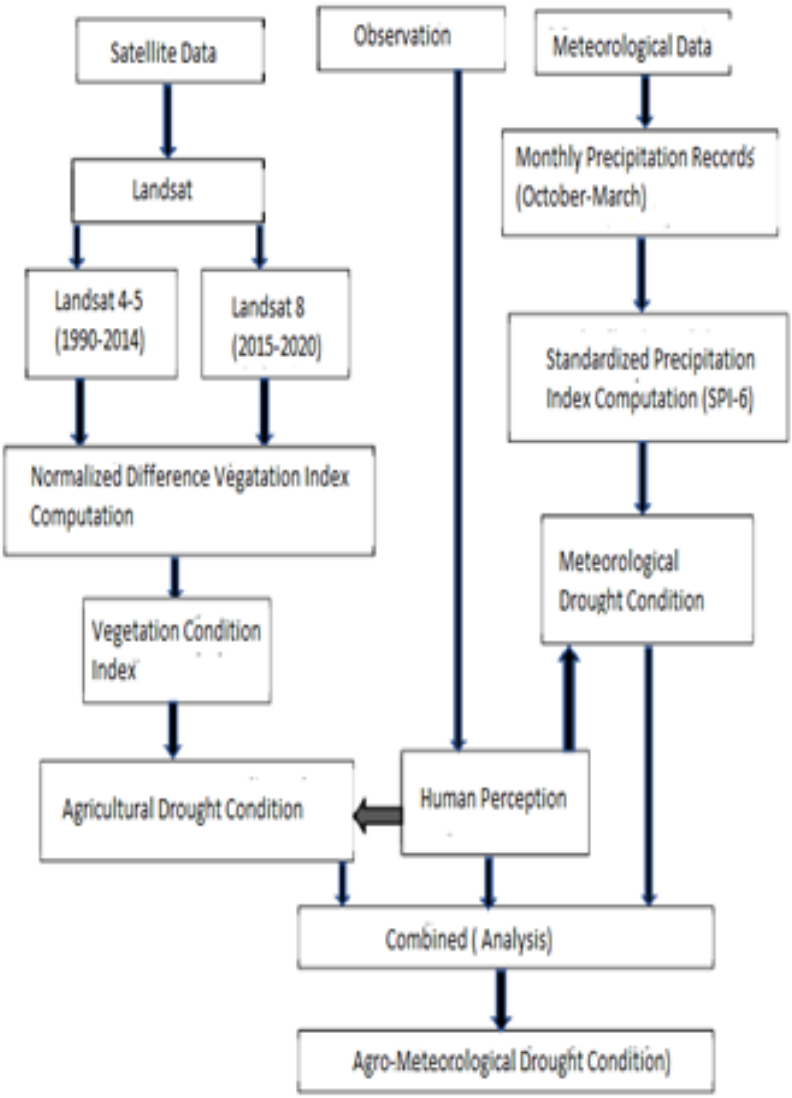


Fig 1. Agro-meteorological drought determination processes (Mupepi & Matsa, 2023).

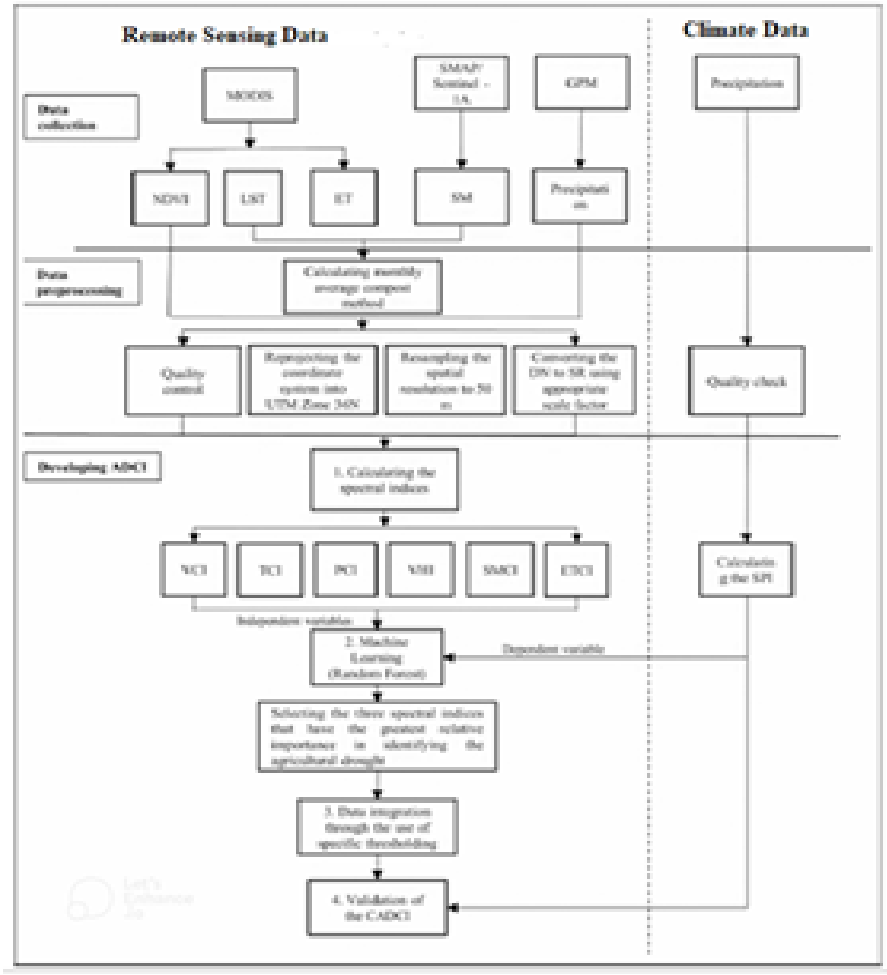


Fig 2. Comprehensive remote-sensing based agriculture drought conditions indicator (CADCI) (Alkaraki & Hazaymeh, 2023). In this charts, there are three primary parts: 1- Data collecting and their pre-processing, 2-Development of the CADCI, and 3-Validation and assessment of CADCI.

REFERENCES

Agutu, N.O., Awange, J.L., Zerihun, A., Ndehedehe, C.E., Kuhn, M., & Fukuda, Y. (2017). Assessing multi-satellite remote sensing reanalysis, and land surface models' products in characterizing agricultural drought in East Africa. Remote Sens. *Environ*. 194, 287-302. doi: 10.1016/j.rse.2017.03.041.

Ahmadi, B., & Moradkhani, K. (2019). Revisiting hydrological drought propagation and recovery considering water quantity and quality. *Hydrol. Process*, 33 (10), 1492-1505.

Alkaraki, K.F., & Hazaymeh, K. (2023). A comprehensive remote sensing-based agriculture drought condition indicator (CADCI) using machine learning. *Environmental Challenges*, 11, 100699

Bravo, R. Z. B., Cunha, A. P. M. D. A., Leiras, A., & Cyrino Oliveira, F. L. (2021). A new approach for a drought composite index. *Natural Hazards*, 108 (1), 755-773.

Clarke, B., Otto, F., Stuart-Smith, R., & Harrington, L. (2022). Extreme weather impacts of climate change: an attribution perspective. *Environmental Research*: Climate, 1 (1), 012001.

Cravens, A.E., Henderson, J., Fdiedman, J., Burkardt, N., Cooper, A.E. Haigh, T., Hayes, M., McEvoy, J., Paladino, S., Wilke, A.K., & Wilmer, H. (2021). A typology of drought decision

making: synthesizing across cases to understand drought preparedness and response actions. *Weather Climate Extremes*, 100362.

Cook, B.I, Mankin, J.S., & Anchukaitis, K.J. (2018). Climate change and drought: from past to future. *Curr. Clim. Change Rep*. 4, 164–79

Coughlan D P, van Aalst E, Choularton M, van den Hurk R, Mason B, Nissan S and Schwager H 2019 From rain to famine: assessing the utility of rainfall observations and seasonal forecasts to anticipate food insecurity in East Africa Food Secur. 11 57–68

Dai, M., Huang, S., Huang, Q., Zheng, X., Su, X., Leng, G., ... & Liu, Y. (2022). Propagation characteristics and mechanism from meteorological to agricultural drought in various seasons. *Journal of Hydrology*, 610, 127897.

Deng, H., & Chen, Y. (2017). Influences of recent climate change and human activities on water storage variations in Central Asia. *J. Hydrol*. 544, 46–57.

Dilawar, A., Chen, B., Arshad, A., Guo, L., Ehsan, M.I., Hussain, Y., Kayiranga, A., Measho, S., Zhang, H., Wang, F., & et al. (2021). Towards understanding variability in droughts in response to extreme climate conditions over the different agro-ecological zones of Pakistan. *Sustainability*, 13, 6910. https:// doi.org/10.3390/su13126910

El Mzouri, M.A., Samir, K., Chlaida, M., & El Mzouri, E. (2021). Characterization of Drought Evolution using the Standardized Precipitation Index (SPI) in Three Agro Climatic Zones of Settat Province, Morocco. *African Journal of Environment and Natural Science Research*, 4 (4), 109-122. DOI: 10.52589/AJENSR I3Y1BRCV.

Faiz, M.A., Zhang, Y., Zhang, X., Ma, N., Aryal, S. K., Ha, T.,. . . & Naz. F. (2022). A composite drought index developed for detecting large-scale drought characteristics. *Journal of Hydrology*, 605,127308. https://doi.org/10.1016/j.jhydrol.2021.127308.

Ferreira, V.G., Montecino, H.C., Ndehedehe, C.E., Heck, B., Gong, Z., de Freitas, S.R.C., & Westerhaus, M. (2018). Space-based observations of crustal deflections for drought characterization in Brazil. *Sci. Total Environ*., 644, 256–273.

Ghaffari, A. (2006). *A review of drought impacts on rainfed field crops and horticulture crops (vegetables and orchards) and of their socioeconomic consequences on the farming communities; and analysis of the policies aimed at rehabilitation of the sector*. National Consultancy under TCP/IRA/3003, FAO-IRAN Joint Project.

Guo, Y., Huang, S., Huang, Q., Leng, G., Fang, W., Wang, L., & Wang, H. (2020). Propagation thresholds of meteorological drought for triggering hydrological drought at various levels. *Sci. Total Environ*., 712, 136502.

Hua, F., Wang, W., Nakagawa, S., Liu, S., Miao, X., Yu, L., Du, Z., Abrahamczyk, S., Arias-Sosa, L.A., Buda, K., Budka, M., Carri` ere, S.M., Chandler, R.B., Chiatante, G., Chiawo, D.O., Cresswell, W., Echeverri, A., Goodale, E., Huang, G., Hulme, M.F., Hutto, R.L., Imboma, T.S., Jarrett, C., Jiang, Z., Kati, V.I., King, D.I., Kmecl, P., Li, N., L¨ ovei, G.L., Macchi, L., MacGregor-Fors, I., Martin, E.A., Mira, A., Morelli, F., Ortega-´ Alvarez, R., Quan, R.-C., Salgueiro, P.A., Santos, S.M., Shahabuddin, G., Socolar, J.B., Soh, M.C.K., Sreekar, R., Srinivasan, U., Wilcove, D.S., Yamaura, Y., Zhou, L., & Elsen, P.R. (2024). Ecological filtering shapes the impacts of agricultural deforestation on biodiversity. *Nat. Ecol. Evol*. 8, 251–266. https://doi.org/10.1038/ s41559-023-02280-w.

Ionita, M., Nagavciuc, V., Scholz, P., & Dima, M. (2022). Long-term drought intensification over Europe driven by the weakening trend of the Atlantic Meridional Overturning Circulation. *Journal of Hydrology*: Regional Studies 42, 101176. https://doi.org/10.1016/j.ejrh.2022.101176

Jiang, J., Zhou, T., Wang, H., Qian, Y., Noone, D., & Man, W. (2020). Tracking moisture sources of precipitation over central Asia: A study based on the water-source-tagging method. *Journal of Climate*, 33 (23), 10339-10355.

Kheyruri, Y., & Sharafati, A. (2022). Spatiotemporal assessment of the NASA power satellite precipitation product over different regions of Iran. *Pure Appl Geophys*, 1–13. https://doi.org/ 10.1007/S00024-022-03133-6

Lalmuanzuala, B., Sathyamoorthy, N. K., Kokilavani, S., Jagadeeswaran, R., & Kannan, B. (2022). Drought analysis in southern agroclimatic zone of Tamil Nadu using standardized precipitation index. *International Journal of Environment and Climate Change*, 12 (11), 577-585.

Li, J., Xi, M., Pan, Z., Liu, Z., He, Z., & Qin, F. (2022). Response of NDVI and SIF to meteorological drought in the Yellow River Basin from 2001 to 2020. *Water*, 14, 2978.

Ma, M., Xiong, F., Zang, H., Zhao, C., Wang, Y., & He, Y. (2025). Regional Drought Monitoring Using Satellite-Based Precipitation and Standardized Palmer Drought Index: A Case Study in Henan Province, China. *Water*, 17 (8), 1123.

Marvel, K., Cook, B.I., Bonfils, C.J., Durack, P.J., Smerdon, J.E., & Williams, A.P. (2019). Twentieth-century hydroclimate changes consistent with human influence. *Nature*, 569, 59–65.

Mishra, V., Aadhar, S., Asoka, A., Pai, S., & Kumar, R. (2016). On the frequency of the 2015 monsoon season drought in the Indo-Gangetic Plain. *Geophysical Research Letters*, 43 (23), 12-102.

Miyan, M.A. (2015). Droughts in Asian least developed countries: Vulnerability and sustainability. *Weather Clim*. Extrem. 7, 8–23.

Mupepi, O., & Matsa, M.M. (2023). A combination of vegetation condition index, standardized precipitation index and human observation in monitoring spatio-temporal dynamics of drought. A case of Zvishavane District in Zimbabwe. *Environmental Development*, 45, 100802

Novick, K.A., Ficklin, D.L., Stoy, P.C., Williams, C.A., Bohrer, G., Oishi, A.C., Papuga, S. A., Blanken, P.D., Noormets, A., & Sulman, B.N. (2016). The increasing importance of atmospheric demand for ecosystem water and carbon fluxes. *Nat. Clim. Chang*. 6 (11), 1023–1027.

Ogle, K., Barber, J.J., Barron-Gafford, G.A., Bentley, L.P., Young, J.M., Huxman, T.E., Loik, M.E., & Tissue, D.T. (2015). Quantifying ecological memory in plant and ecosystem processes. *Ecol. Lett.* 18 (3), 221–235.

Orimoloye, I. R. (2022). Agricultural drought and its potential impacts: enabling decision-support for food security in vulnerable regions. *Frontiers in Sustainable Food Systems*, 6, 838824.

Ortega-Gaucin, D., López Pérez, M., & Arreguín Cortés, F.I. (2016). Drought risk management in Mexico: pro gress and challenges. *Int J Saf Secur Eng*, 6 (2), 161–170.

Pickson, R.B., & Boateng, E. (2021). Climate change: a friend or foe to food security in Africa? *Environ. Dev. Sustain*. 24 (3), 4387–4412. https://doi.org/10.1007/s10668- 021-01621-8.

Porter, J.R., Xie, L., Challinor, A.J., Cochrane, K., Howden, S.M., Iqbal, M.M., Lobell, D.B., & Travasso, M.I. (2014). *Food security and food production systems.* In: Field CB, V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, L.L. White (Eds.). Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report

of the Intergovernmental Panel on Climate Change Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 485-533.

Sharara A, Shekede MD, Gwitira I, & et al. (2022). *Fine-scale multi temporal and spatial analysis of agricultural drought in agro ecological regions of Zimbabwe*. http://www.tandfonline.com/ action/journalInformation?show=aimsScope&journalCode= tgnh20#VsXodSCLRhE 13:1342–1365. https://doi.org/10.1080/ 19475705.2022.2072774

Shiru, S.S., Shahid, S., Dewan, A., Chung, E.S., Alias, N., Ahmed, K., & Hassan, Q.K. (2020). Projection of meteorological droughts in Nigeria during growing seasons under cli- mate change scenarios. *Sci. Rep*. 10, 10107. doi: 10.1038/s41598-020-67146-8

Sruthi, S., & Aslam, M.M. (2015). Agricultural drought analysis using the NDVI and land surface temperature data; a case study of Raichur district. Aquat. *Procedia*, 4, 1258–1264

Sun, P., Liu, R., Yao, R., Shen, H., & Bian, Y. (2023). Responses of agricultural drought to meteorological drought under different climatic zones and vegetation types. Journal of Hydrology, 619, 129305.

Van Loon, A.F. (2015). Hydrological drought explained. Wiley Interdiscip. Rev.: Water, 2 (4), 359–392.

Vicente-Serrano, S.M., Domínguez-Castro, F., Reig, F., Beguería, S., Tomás-Burguera, M., Latorre, B., ... & El Kenawy, A. (2022). A near real-time drought monitoring system for Spain using automatic weather station network. *Atmospheric Research*, 271, 106095.

Wang, T., Tu, X., Singh, V.P., Chen, X., Lin, K., Lai, R., & Zhou, Z. (2022). Socioeconomic drought analysis by standardized water supply and demand index under changing environment. *J. Clean. Prod*. 347, 131248.

Wilhite, D.A. (2016). *Drought as a natural hazard: concepts and definitions*. Droughts. Routledge, 3-18.

Xu, Y., Zhang, X., Hao, Z.C., Singh, V.P., & Hao, F.H. (2021). Characterization of propagation over china based on bivariate probabilistic quantification. *J. Hydrol.* 598, 126194.

Torabinezhad, N., Zarrin, A., & Dadashi-Roudbari, A.A. (2023). Analysis of different types of droughts and their characteristics in Iran using the standardized evapotranspiration-precipitation index (SPEI). *Journal of Water and Soil*, 37 (3), 473-486. (In Persian with English abstract). https://doi.org/10.22067/jsw.2023.81322.1257

Yiping, L., & Yaohui, L. (2017). Research progress on adaptability of meteorological drought index in China. *J. Arid. Meteorol*., 35, 709–723.

Yu, H.O., Zhang, Q., Sun, P., & Song, C.Q. (2018). Impact of droughts on winter wheat yield in different growth stages during 2001-2016 in China. *Int J Disast Risk Sc* 9, 376-391.

Zhang, Z., Xu, W., Shi, Z., & Qin, Q. (2021). Establishment of a comprehensive drought monitoring index based on multisource remote sensing data and agricultural drought monitoring. IEEE J. Sel. Top. *Appl. Earth Observ*. Remote Sens. 14, 2113–2126.

Zhang, W., Wang, Z., Lai, H., Men, R., Wang, F., Feng, K., ... & Huang, S. (2023). Dynamic characteristics of meteorological drought and its impact on vegetation in an arid and semi-arid region. *Water*, 15 (22), 3882.

ALLELOPATHY IN WEED MANAGEMENT: A BIBLIOMETRIC REVIEW

YABANCI OT YÖNETİMİNDE ALLELOPATİ: BİBLİYOMETRİK BİR İNCELEME

Dr. Ayfer GÜNEY SARITAŞ
Iğdır Üniversitesi, Ziraat Fakültesi

Dr. Öğr. Üyesi Harun ALPTEKİN
Iğdır Üniversitesi, Ziraat Fakültesi

ABSTRACT

Allelopathy is the influence of plants on the growth and development of other plants through chemical compounds (allelochemicals) that they secrete into their environment. This is an important research area for weed control, crop rotation and sustainable agricultural practices in agricultural ecosystems. Allelopathic interactions can cause various responses in plants such as germination inhibition, inhibition of root development and physiological disorders. In order to use allelopathy effectively in agricultural applications, the mechanisms of action of allelochemicals should be fully understood and appropriate application methods should be developed. Research in this field has the potential to make significant contributions to the development of sustainable agricultural systems. This study aims to analyze scientific research on allelopathy and weed management using bibliometric methods. 2484 publications obtained from the Scopus database were analyzed. Bibliometrix (R/Biblioshiny) and VOSviewer software were used to analyze the number of publications, citation analysis, author and country-based productivity, collaboration networks, and keywords. In the author productivity and H-index based analyses, pioneering researchers leading the field were identified. In the analysis, Allelopathy Journal was the journal with the highest number of publications with 236 articles, while Journal of Chemical Ecology was the journal with the highest impact value with 7172 citations. Contributions of 6,185 authors were identified in the study. This study provides a detailed analysis of the literature on the role of allelopathy in weed control and presents the current state of knowledge on the subject. In this way, researchers will be able to evaluate current developments and provide a solid basis for identifying future research topics. It also identifies current research gaps in the field of allelopathic weed control and proposes new strategies for sustainable agriculture.

Key Words: Bibliometrics, Allelopathy, Weed Management, Sustainable Agriculture.

ÖZET

Allelopati, bitkilerin çevrelerine salgıladıkları kimyasal bileşikler (allelokimyasallar) yoluyla diğer bitkilerin büyüme ve gelişimini etkilemesidir. Bu durum, tarım ekosistemlerinde yabancı ot kontrolü, ürün rotasyonu ve sürdürülebilir tarım uygulamaları açısından önemli bir araştırma alanıdır. Allelopatik etkileşimler, bitkilerde çimlenme inhibisyonu, kök gelişiminin engellenmesi ve fizyolojik bozukluklar gibi çeşitli tepkilere neden olabilmektedir. Allelopatinin tarımsal uygulamalarda etkili bir şekilde şekilde kullanılabilmesi için, allelokimyasalların etki mekanizmalarının tam olarak anlaşılması, uygun uygulama yöntemlerinin geliştirilmesi

gerekmektedir. Bu alandaki araştırmalar, sürdürülebilir tarım sistemlerinin geliştirilmesine önemli katkılar sağlayacak potansiyele sahiptir. Bu çalışma, allelopati ve yabancı ot yönetimi konusundaki bilimsel araştırmaların bibliyometrik yöntemlerle analiz etmeyi amaçlamaktadır. Scopus veri tabanından elde edilen 2484 yayın incelenmiştir. Çalışmada Bibliometrix (R/Biblioshiny) ve VOSviewer yazılımları aracılığıyla yayın sayıları, atıf analizleri, yazar ve ülke bazlı üretkenlik, işbirliği ağları, anahtar kelimeler analiz edilmiştir. Yazar üretkenliği ve H-indeksi temelli analizlerde, alana yön veren öncü araştırmacılar belirlenmiştir. *Yapılan analizlerde Allelopathy Journal,* 236 makaleyle en fazla yayın yapan dergi olurken; *Journal of Chemical Ecology,* 7172 atıfla en yüksek etki değerine sahip yayın organı olmuştur. Çalışmada 6.185 yazarın katkısı tespit edilmiştir. Anahtar kelime analizinde "allelopathy", "weed control", "weed" ve "germination" gibi terimlerin yoğunluklu olarak kullanıldığı belirlenmiştir. Bu çalışma, allelopatinin yabancı ot kontrolündeki rolünü ele alan literatürü ayrıntılı bir biçimde analiz ederek, konuyla ilgili mevcut bilgi birikimini gözler önüne sermektedir. Bu sayede araştırmacılar hem güncel gelişmeleri değerlendirebilecek hem de gelecekteki araştırma konularını belirlemede sağlam bir zemin oluşturacaktır. Ayrıca, allelopatik yabancı ot kontrolü alanındaki mevcut araştırma boşluklarını belirleyerek, sürdürülebilir tarım için yeni stratejiler önermektedir.

Anahtar Kelimeler: Bibliyometri, allelopati, yabancı ot yönetimi, sürdürülebilir tarım

GİRİŞ

Yabancı otlar, agro-ekosistemde adaptasyon sağlayarak büyüyen, kültür bitkilerine zarar veren ve yetiştirme sürecindeki tarımsal uygulamaları olumsuz etkileyen bitkilerdir (Aldrich ve Kremer, 1997; Zimdahl, 2018; Öngen, 2021). Yabancı otlar, tür, topluluk ve ekosistem düzeylerinde önemli olumsuz ekolojik etkilere sebep olabilmektedirler (Vilà ve ark., 2011). Ayrıca geniş tarım alanlarından meralara, doğal sistemlere ve rekreasyon alanlarına kadar birçok ekosistemde önemli sorunlara sebep olmaktadır (Uygur and Uygur, 2010;Güney Sarıtaş ve Gürbüz, 2024).

Tarım alanları ve tarım dışı alanlarda ürün miktarı ve kalite üzerinde önemli derecede zarara neden olan çok fazla sayıda yabancı ot bulunmaktadır (Patterson, 1985; Holm ve ark., 1991). Yabancı otlar, kültür bitkilerinin gelişimi için gerekli olan besinleri, suyu ve ışığı kısıtlayarak onlarla rekabet eder. Bu durum, yalnızca verim kaybına yol açmakla kalmayıp ürün kalitesini de bozarak ekonomik zarara sebep olur (Zimdahl, 1989).Yabancı otları kontrol altına alabilmek için herbisitler kullanılmaktadır. Herbisitler, yabancı ot kontrolünde etkili ve pratik bir yöntem olarak kabul edilse de, bazı durumlarda istenen sonuçları vermeyebilir. Çevre kirliliği, insan sağlığı riskleri ve dirençli yabancı ot popülasyonlarının artışı gibi olumsuz etkileri dikkate alınmalıdır (Zengin, 2013). Sürekli sentetik herbisit kullanımı, ekolojik dengeyi bozmakta ve herbisit direnci sorununu daha da büyütmektedir (Bhadoria, 2011). Tarım ilaçlarının yol açtığı çevre kirliliği, insan ve hayvan sağlığı üzerindeki olumsuz etkilerinden dolayı kimyasal mücadeleye alternatif oluşturabilecek çevre dostu yöntemlerin geliştirilmesi büyük önem taşımaktadır. Allelopati, son yıllarda bu amaçla üzerinde yoğunlaşılan ve araştırmalara konu olan alternatif yöntemlerden biridir (Arıkan ve Elibüyük, 2015; Özen ve ark., 2017).

Allelopati sözcüğü ilk kez Molisch isimli bir Alman araştırmacı tarafından 1937 yılında kullanılmıştır. Molisch, bu terimi Yunanca kökenli allelon (bir diğerine, karşılıklı) ve pathos (acı çekmek, zarar vermek) sözcüklerini birleştirerek oluşturmuş. Allelopati, bir bitkinin çevresinde doğal olarak gelişen diğer bitkilere zarar verici veya fayda sağlayıcı etkileri olarak kabul edilir (Weston ve Duke 2003; Macias 2003; Kocaçalışkan 2004; Willis 2007; Taraghikhah, 2024). Günümüze kadar çevresine kimyasal madde (allelokimyasal) salarak yakın veya uzak çevresindeki bitki ve hayvanları etkileyen birçok bitki belirlenmiştir. Allelokimyasal maddeler bitkilerin yaprak, çiçek, kök, meyve veya gövdelerinde bulunmaktadır. Ayrıca toprak ortamında da bulunabilmektedir. (Kocaçalışkan 2004; Willis 2007; Taraghikhah, 2024).

Bitkilerin allelokimyasallara maruz kalması çimlenme, büyüme ve gelişme süreçlerinde önemli değişikliklere yol açar. Gözlemlenen başlıca etkiler arasında çimlenmenin engellenmesi, tohumlarda renk değişimi ve şişme, kök ve gövde gelişiminin yavaşlaması, kök uçlarında deformasyon ve nekroz olması sayılabilir. Allelopatik etkilerin incelenmesinde en güvenilir yöntemlerden biri, doğal ortamda gözlemlenen bu karakteristik semptomların analizidir (Inderjit ve ark., 2008; Taraghikhah, 2024).

Bibliyometri, belirli araştırma alanlarındaki mevcut durumu değerlendirmek, bilimsel yayınları sistematik olarak analiz etmektir (Peng ve ark., 2021). R programı gibi araçlar, bibliyometrik analizlerde kullanılan (Alptekin ve ark., 2023) ve ağ verilerine dayalı görsel haritalar oluşturmaya imkan veren yazılımlardır (Guleria ve Kaur, 2021; Arruda ve ark., 2022). Bu çalışmada amaç; allelopati ile ilgili yapılmış çalışmaların bibliyometrik analizini yaparak, ilgili konuda yayın yapan ülkeler, yazarlar, vb. yaptıkları iş birliklerini ortaya koymaktır.

MATERYAL VE YÖNTEM

Araştırmada allelopatinin yabancı ot yönetimindeki rolü ile ilgili yapılan çalışmaların bibliyometrik analizini yapmak için, "Allelopati VE Yabancı ot" anahtar kelimeleri Scopus veri tabanında arama yapıldığında elde edilen 2484 yayın üzerinde VOSviewer ve R programları kullanılarak bibliyometrik analizi yapılmıştır.

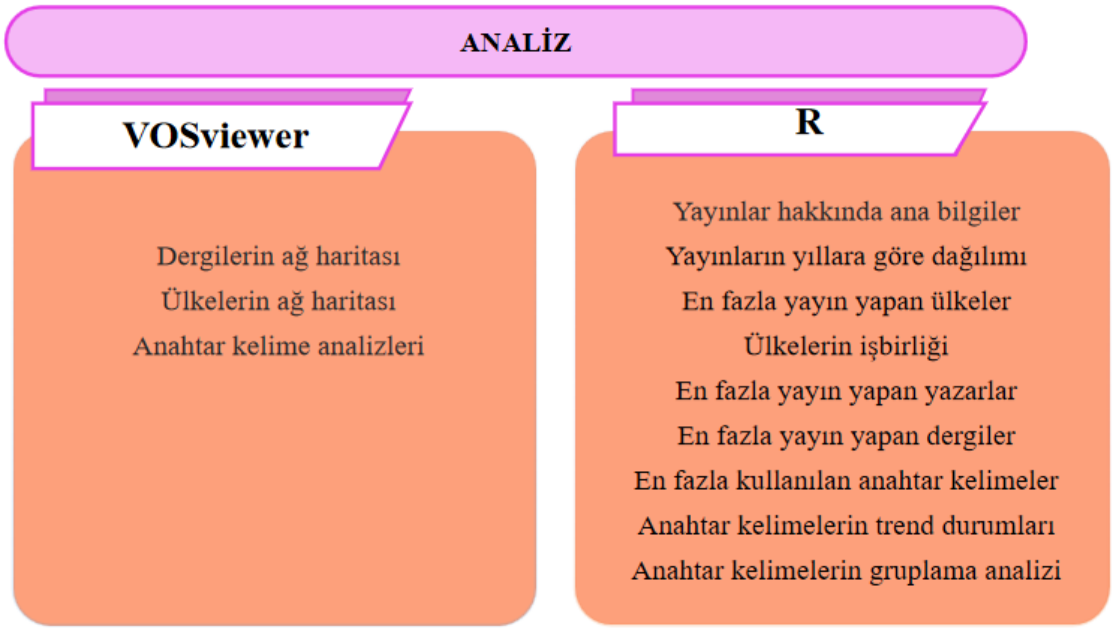
Yöntem

Bu çalışmada, allelopatinin yabancı ot yönetimindeki rolünü inceleyen 2484 bilimsel yayın Scopus veri tabanından elde edilerek bibliyometrik analiz yöntemiyle değerlendirilmiştir. Bibliyometrik analiz için kullanılan yöntem Şekil 1'de şematize edilmiştir.



Şekil 1. Bibliyometrik analizi için veri indirme ve analiz yapma şeması

Bibliometrik analizi için kullanılan R ve VOSviewer programlarında farklı analizler yapılmıştır (Şekil 2).



Şekil 2. Çalışmada kullanılan R ve Vosviewer analiz çeşitleri

Veri analizi

Ülke sıralaması, dergiler vb. ile ilgili betimsel analiz için Microsoft Excel, atıf ve anahtar kelime analizi ve görselleştirmeleri için VOSviewer ve ülkelerin işbirliği en sık kullanılan terimler, anahtar kelimelerin trend durumları ve anahtar kelimelerin gruplama analizi R programı üzerinden, bibliometrix'in web tabanlı arayüzü olan "biblioshiny" kullanılmıştır.

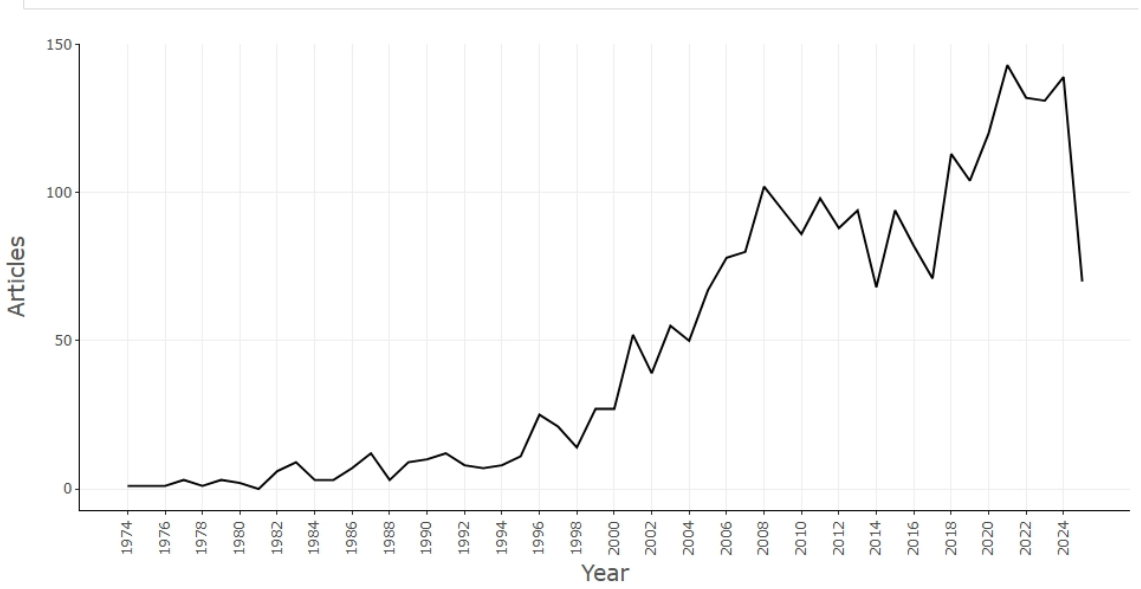
BULGULAR

Bu bibliyometrik analiz, 1974–2025 döneminde allelopatinin yabancı ot kontrolü alanında üretilen akademik yayınların temel özelliklerini ortaya koymaktadır. Toplam 2484 yayın incelenmiş olup, yıllık %8,69'luk büyüme oranıyla alana sürekli artan bir ilgi olduğu görülmektedir (Çizelge 1). Bu alandaki belgelerin ortalama yaşı 12,4 yıl olarak belirlenmiştir. Bu durum, literatürün güncel çalışmalardan oluştuğunu göstermektedir (Çizelge 1).

Çizelge 1. Allelopatinin yabancı ot kontrolüne etkisi ile ilgili yapılan yayınların ana bilgileri

Açıklama	Sonuçlar
Veri Hakkında Temel Bilgiler	
Zaman Aralığı	1974–2025
Kaynaklar (Dergiler, Kitaplar vb.)	667
Belgeler (Toplam Yayın Sayısı)	2.484
Yıllık Büyüme Oranı (%)	8,69
Ortalama Belge Yaşı	12,4 yıl
Belge Başına Ortalama Atıf Sayısı	28.72
Anahtar Kelimeleri	5.262
Yazarlar	
Toplam Yazar Sayısı	6.185
Tek Yazarlı Belgelerin Yazarı	148
Yazar İşbirliği	
Tek Yazarlı Belgeler	210
Belge Başına Ort. Ortak Yazar Sayısı	4,18
Uluslararası Ortak Yazarlık Oranı (%)	20,41
Yayın Türleri	
Makale	2.042
Kitap	7
Kitap Bölümü	115
Konferans Bildirisi	113
Editoryal	1
Not	2
Derleme	199

Yayınların ortalama 28,72 atıf alması, allelopatinin bitki ekolojisi, organik tarım ve pestisit alternatifleri gibi alanlarda sıkça referans alındığını gösterir. Özellikle allelokimyasalların tarımsal uygulamalardaki potansiyeli**,** bilimsel çalışmalara ve derleme makalelerine olan ilgiyi artırmaktadır. Çalışmada 6.185 yazarın katkısı tespit edilmiş olup belge başına ortalama 4,18 ortak yazar sayısıyla allelopatinin kimya, ekoloji, agronomi ve biyoteknoloji gibi farklı disiplinlerden araştırmacıları bir araya getirdiğine işaret etmektedir. Uluslararası ortak yazarlık oranının yüksekliği %20,41 olması, konunun küresel bir sorun olarak görüldüğünü yansıtmaktadır. Makale sayısının 2.042 olması allelopati çalışmalarının deneysel ve saha uygulamalarına (bitki ekstraktlarının herbisit etkisi) odaklandığını göstermektedir. Derlemelerin sayısının 199 olması ise literatür taramasının önemini vurgulamaktadır. Kitap bölümleri (115) ve konferans bildirileri (113) ise bilginin çeşitli platformlarda paylaşıldığını ortaya koymaktadır. (Çizelge 1). Yıllara göre yayın sayısı Şekil 3'te verilmiştir.



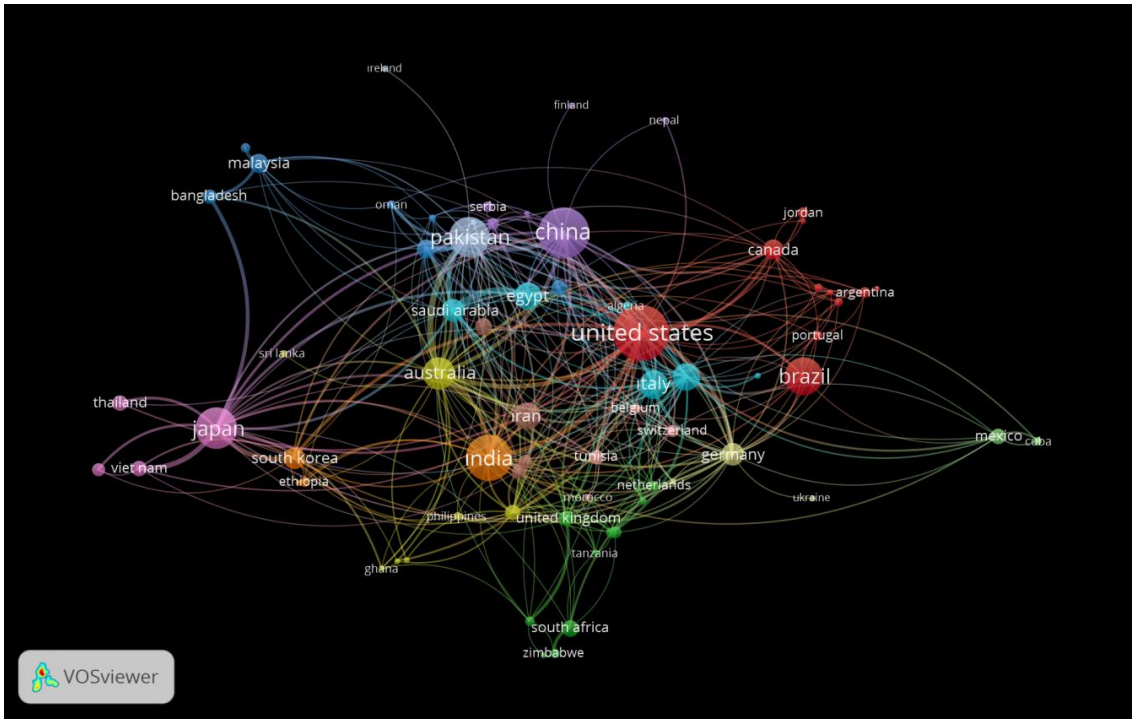
Şekil 3. Yıllara göre yayın sayısı

Yıllara göre yayın sayıları incelendiğinde, allelopatinin yabancı ot kontrolü üzerindeki etkisine ilişkin çalışmaların 1974–1990 yılları arasında yıllık makale sayısı her yıl 0-5 makale düzeyindedir. Yayın sayılarında 1995 yıllı itibariyle belirgin bir artış gözlemlenmiştir. Makale sayısı 2001 yılında 50'nin üzerine çıkmış, 2007 yılında ise 100'e yaklaşmıştır. 2010–2020 yılları arasında dalgalanmalara rağmen makale sayısı yüksek kalmıştır. Bu dönemde yıllık yayın sayısı genelde 70–120 arasında seyretmiştir. Yayın sayısında 2020–2022 yılları arasında en fazla olduğu görülmektedir. 2021 yıllında 143 yayınla en yüksek değerlere ulaşılmıştır. Genel olarak bu eğilim, konunun bilimsel gündemde giderek daha fazla yer edindiğini ortaya koymaktadır (Şekil 3). En fazla atıf alan ülkeler Çizelge 2'de sunulmuştur.

Çizelge 2. En fazla yayın yapan ülkeler

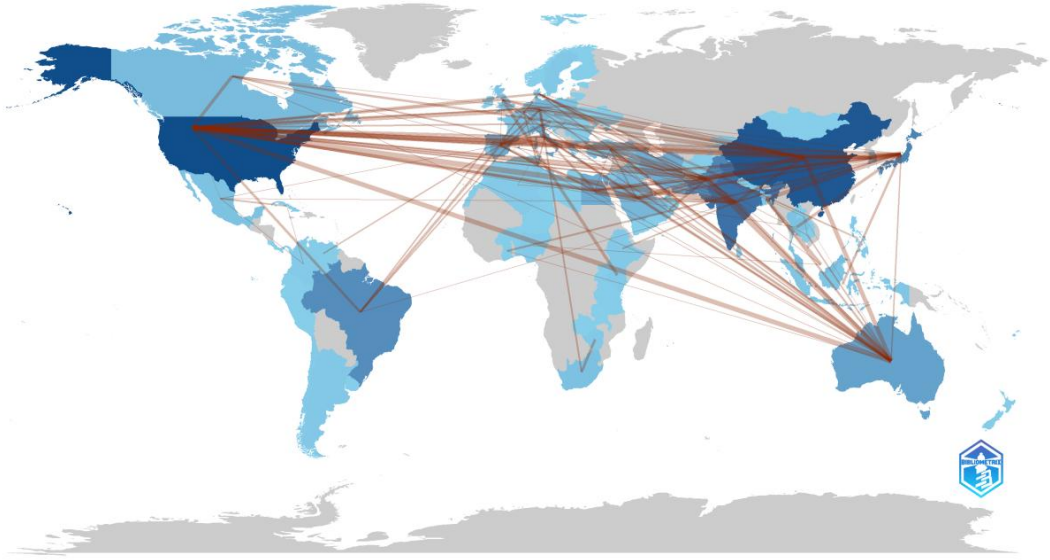
Ülke	Yayın Sayısı
Amerika Birleşik Devletleri	386
Çin	334
Hindistan	274
Japonya	214
Pakistan	205
Brezilya	181
Avustralya	127
İtalya	108
İspanya	98
Mısır	93
İran	91

Yayınların ülkelere göre dağılımı incelendiğinde, allelopatinin yabancı ot kontrolü konusundaki araştırmalarda ABD, 386 yayın ile en üretken ülke konumundadır. Çin (334 yayın) ve Hindistan (274 yayın) gibi ülkeler de bu konuda önemli katkılar sunmaktadır. Genel olarak tablo, araştırma faaliyetlerinin küresel ölçekte dağıldığını, ancak belirli ülkelerde yoğunlaştığını ortaya koymaktadır. Ülkelerin ağ haritası Şekil 4'te verilmiştir.



Şekil 4. Ülkelerin ağ haritası

Ağ analizine göre, ABD, Hindistan, Çin ve Japonya, allelopati alanındaki bilimsel üretimde öncü ülkeler olarak öne çıkmaktadır. Bu ülkeler, farklı kıtalardan birçok ülkeyle iş birliği geliştirerek disiplinin uluslararası niteliğini güçlendirmektedir. Allelopatinin yabancı ot kontrolü alanında çalışan ülkelerin işbirliği ağı kırmızı kümede, ABD, Kanada, Brezilya, Arjantin gibi Amerika kıtasındaki ülkeler hem en yüksek yayın sayısına hem de en yüksek uluslararası işbirliğine sahip ülkeleri içermektedir. Mor kümede Çin, Pakistan, Nepal dikkat çeken ülkelerdir. Bu ülkeler kendi aralarında yoğun işbirliği içindeler. Sarı kümede Almanya, Birleşik Krallık, Güney Afrika gibi Avrupa ve Afrika ülkelerinin işbirliği içerisindeki ülkeler olduğu görülmektedir (Şekil 4). Ülkelerin ortak yayın haritası Şekil 5'te gösterilmiştir.



Şekil 5. Ülkelerin ortak yayın haritası

Allelopatinin yabancı ot kontrolü alanındaki bilimsel iş birlikleri incelendiğinde, en yüksek iş birliği, Mısır ve Suudi Arabistan arasında gerçekleşmiş olup, 32 ortak yayın ile bu iki ülke güçlü bir bölgesel araştırma ortaklığı sergilemektedir. İkinci sırada yer alan İtalya ile İspanya (25

yayın) ve Pakistan ile Avusturalya (24 yayın) arasında güçlü iş birlikleri geliştirmişlerdir. ABD Avusturalya (16 yayın), Hindistan (19 yayın) ve Almanya (13 yayın) ile yoğun akademik iş birlikleri gerçekleştirmiştir. Çin'nin Avusturalya, Pakistan ve ABD (15'er yayın) ile yaptığı yüksek düzeyli iş birlikleri ise, konunun yalnızca Avrupa içinde değil, kıtalar arası düzeyde de önem taşıdığını ortaya koymaktadır. Türkiye ise 17 ülke ile 46 yayın ile iş birliği içerisinde olmuştur. En fazla Pakistan (14 yayın), Avusturalya (8 yayın) ve ABD (5 yayın) ile yapmıştır (Şekil 5). En fazla yayın yapan yazarlar Çizelge 3'te verilmiştir.

Çizelge 3. En fazla yayın yapan yazarlar

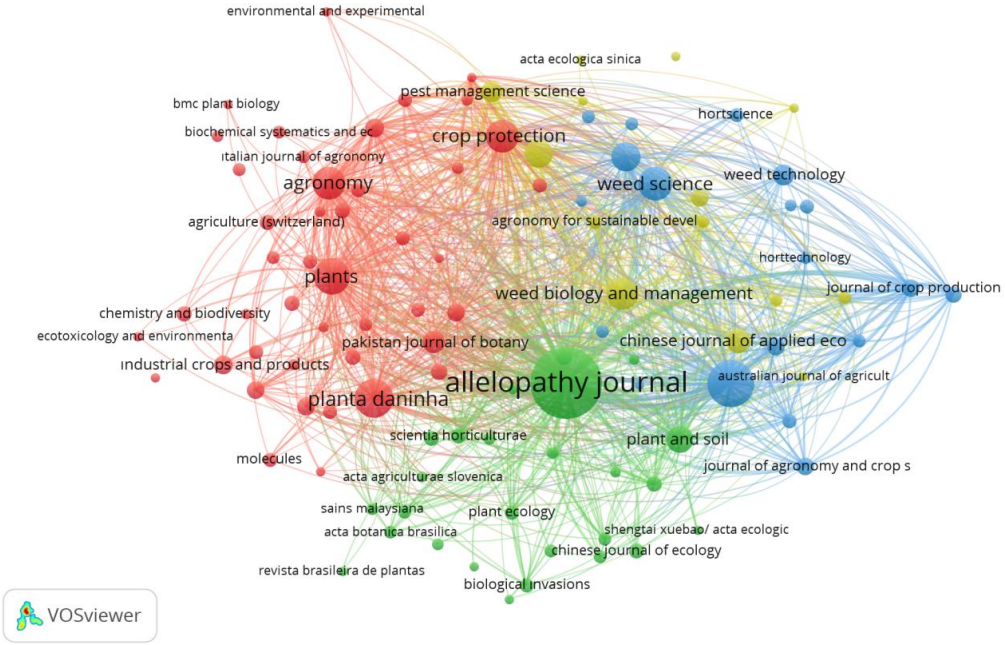
Yazarlar	Yayın sayısı (adet)	Toplam atıf	h_index	g_index	m_index	Başlama yılı
WESTON LA	34	2639	24	34	0.615	1987
XUAN TD	42	1621	21	40	0.84	2001
CHEEMA ZA	28	1520	20	28	0.769	2000
FAROOQ M	30	1585	20	30	1.053	2007
INDERJIT	27	1582	20	27	0.556	1990
KATO-NOGUCHI H	91	1207	20	29	0.769	2000
KHANH TD	29	1442	19	29	0.826	2003
CALLAWAY RM	18	4696	18	18	0.667	1999
FUJII Y	29	798	18	28	0.667	1999
CHUNG IM	20	1210	17	20	0.68	2001

Allelopatinin yabancı ot kontrolü üzerine etkisi konusunda Weston LA, 2639 atıf ve 24 h-indeksi ile alanın en etkili ismi olarak öne çıkmaktadır. Ayrıca 0.615 m-indeksi de üretkenliğini uzun süreye yaydığını göstermektedir. Elde edilen verilere göre, Kato-Noguchi H 91 yayın ile en fazla yayına sahip yazar olmuştur. Callaway RM, toplam 4696 atıf ile en fazla atıf alan yazar olarak öne çıkmaktadır. Ancak, yayın sayısının daha düşük (18) olduğu dikkate alındığında, az sayıda fakat çok etkili yayınlar yaptığı anlaşılmaktadır. Cheema ZA ve Farooq M 2000'li yıllardan itibaren üretken, yüksek atıflar (1500 üzeri) aldıkları görülmektedir (Çizelge 3). En fazla yayım yapan dergiler Çizelge 4'te sunulmuştur.

Çizelge 4. En fazla yayın yapan dergiler

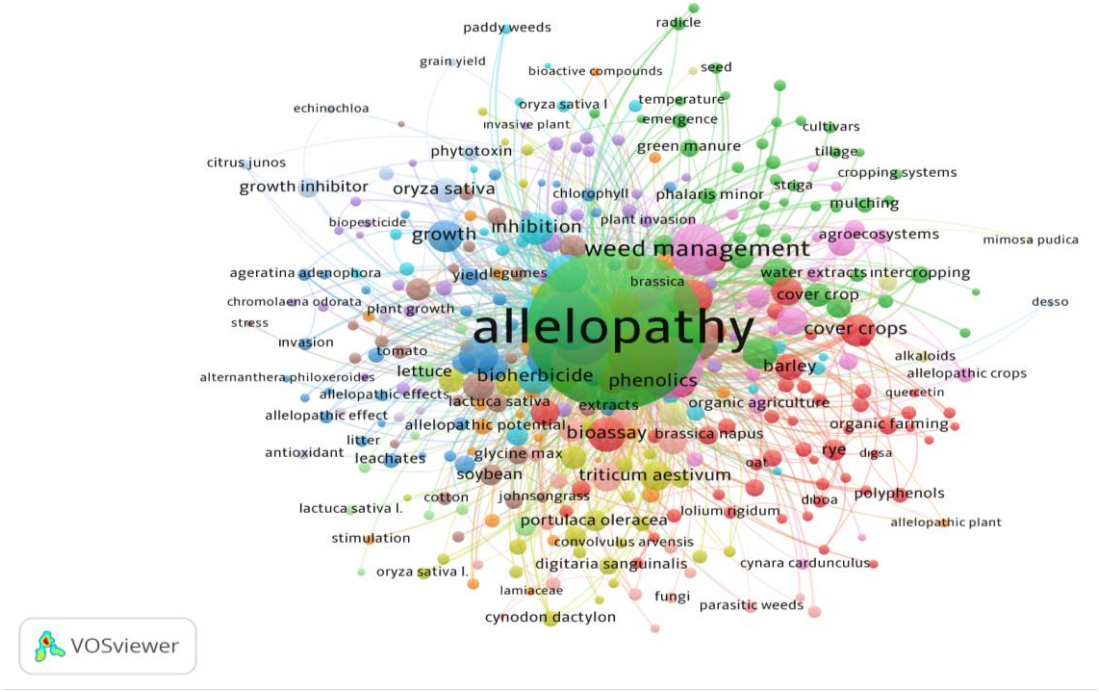
Element	h_index	g_index	m_index	Atıf	Yayın sayısı	Başlama yılı
Journal Of Chemical Ecology	52	83	1.182	7172	102	1982
Crop Protection	30	51	0.833	3576	51	1990
Weed Science	29	46	0.967	2204	54	1996
Journal Of Agricultural And Food Chemistry	28	37	0.7	2416	37	1986
Allelopathy Journal	27	36	0.9	2841	236	1996
Weed Research	26	39	0.788	2240	39	1993
Plant And Soil	22	34	0.468	1451	34	1979
Weed Biology And Management	22	36	0.88	1391	47	2001
Plants	20	30	2.5	1027	61	2018
Pest Management Science	16	22	0.696	1936	22	2003
Planta Daninha	15	21	0.75	762	69	2006
Weed Technology	14	22	0.467	797	22	1996
Agronomy	13	26	0.929	766	50	2012
Chinese Journal Of Applied Ecology	13	17	0.464	359	28	1998

Allelopathy Journal dergisi hem en fazla yayın (236) hem de atıf (2841) açısından öne çıkmaktadır. 1982 yılından beri yayımlanan Journal of Chemical Ecology dergisi 2. en fazla yayın (102 yayın), yüksek h-indeksi (52) ve g-indeksi (83**)** ile alandaki en etkili dergilerden biridir. Atıf sayısı da en yüksek (7172) olduğundan, allelopati çalışmalarının yoğun ilgi gördüğü bir dergi olduğu görülmektedir. Weed Science (54 yayın) ve Crop Protection (51 yayın) dergileri yabancı otlar ve bitki koruma konularında uzmanlaşmış olup, allelopati konusunu sıklıkla içeren makaleler yayımlamaktadır. Sonuç olarak allelopati çalışmaları**,** genellikle bitki koruma (Weed Science, Crop Protection), ekoloji (Journal of Chemical Ecology) ve doğrudan allelopati üzerine (Allelopathy Journal) odaklanan dergilerde yoğunlaşmıştır. Uzun süre yayın yapan eski dergiler daha yüksek atıf ve indeks değerlerine sahiptir. Yeni dergilerde ise m-index'in yüksek olması, kısa sürede büyük etki yaratmış olduğunu gösterir (Çizelge 4). Dergilerin ağ haritası Şekil 6'da verilmiştir.



Şekil 6. Dergilerin ağ haritası

Dergiler, atıf benzerliklerine göre farklı kümeler halinde gruplanmıştır. Yeşil kümede Allelopathy Journal, *Plant and Soil* gibi yüksek etki faktörlü dergiler yer almaktadır. Kırmızı kümede *Planta Daninha,* Plants, Agronomy gibi genel tarım ve botanik dergilerini kapsamaktadır. Mavi kümede, Weed Science ve Weed Technology gibi yabancı ot bilimi ile ilgili dergiler etrafında yoğunlaşmaktadır. Bu sonuçlar, allelopati konusunun çok disiplinli bir yapıya sahip olduğunu ve farklı bilimsel alanlarla yakın ilişki içinde geliştiğini göstermektedir (Şekil 6). Anahtar kelime analizi Şekil 7'de verilmiştir.



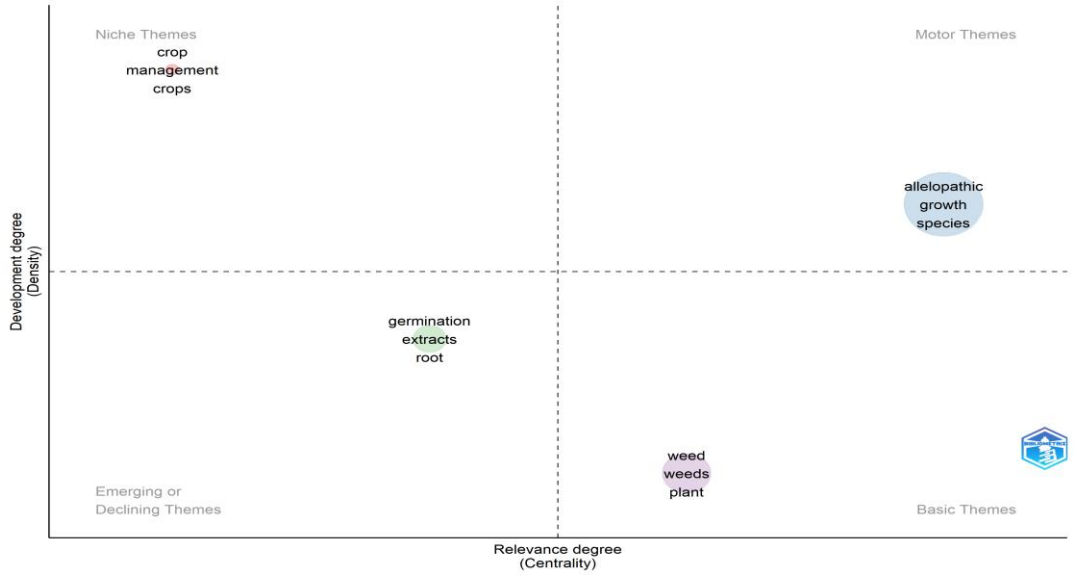
Şekil 7. Anahtar kelime analizi

Anahtar kelime analizinde, “allelopathy” terimi, hem en çok tekrarlanan hem de diğer terimlerle en fazla bağlantı kuran kelime olarak öne çıkmaktadır. Bu durum, konunun literatürde merkezi bir araştırma alanı olduğunu göstermektedir. Ayrıca “agroecosystems” gibi anahtar kelimeler, allelopatinin tarımsal üretim sistemlerinde yabancı ot yönetimi ve sürdürülebilir tarım uygulamaları bağlamında ele alındığını ortaya koymaktadır. “phenolic compounds”, “secondary metabolites”, “allelopathic crops” gibi kelimeler fenolik bileşikler ve diğer ikincil metabolitlerin allelopatik potansiyelinin değerlendirilmesine yönelik çalışmaları içermektedir. Genel olarak bu analiz, allelopatinin uygulamalı tarımsal yönetimi incelendiğini ve bu yaklaşımın kimyasal ekoloji araştırmalarıyla kesiştiğini ortaya koymaktadır (Şekil 6). En fazla kullanılan anahtar kelimeler Şekil 7’de gösterilmiştir.



Şekil 8. En fazla kullanılan anahtar kelimeler

"Allelopathy" ifadesi, 1042 kez kullanılarak çalışmanın merkezinde yer alan kavram olduğunu göstermektedir. "Weed control" (524) ve "Weed" (450) ifadeleri allelopati çalışmalarının büyük oranda yabancı otların kontrolü ile ilişkili olduğu görülmektedir."Germination" (422) ifadesi birçok çalışmanın bitki çimlenmesi üzerindeki allelopatik etkileri incelediğini göstermektedir. Buna bağlı olarak, "Article" (281), "Plant extract" (257), "Herbicide" (242), "Echinochloa" (217), "Triticum aestivum" (189) ve "Nonhuman" (191) gibi anahtar kelimeler bitkisel özütlerin kullanıldığını, kimyasal herbisitlerle karşılaştırma yapıldığını, hedef türlerin (yabancı otlar ve kültür bitkileri) belirlendiğini, deneysel uygulamaların tarım odaklı olduğunu ortaya koymaktadır (Şekil 7). Anahtar kelimelerin gruplama analizi Şekil 8'de verilmiştir.



Şekil 9. Anahtar kelimelerin gruplama analizi

Bu çalışma, bibliyometrik analiz yöntemiyle tarımsal araştırmalar alanındaki öne çıkan niş temaları ve bu temaların gelişim aşamalarını sistematik olarak incelemektedir. Motor temada "allelopathic", "growth", "species" anahtar kelimelerinin merkezi konumda olması hem alanın hemde gelişmiş konuları temsil etmektedir. Niche temada bulunan "crop", "management" ve "crops" gibi anahtar kelimeler, kendi içerisinde yüksek gelişmişlik düzeyine sahip olduğu görülmektedir. Basic temalardan "weed", "weeds ve "plant" anahtar kelimelerin düşük merkezilik ve gelişmişlik değerlerine sahiptir. Araştırma açısından halen gelişmeye açık olduğu, ama yoğunluklarının yeterince yüksek olmadığı açıkça görülmektedir. Emerging/declining temalarda "germination", "ekstracts" ve "root" gibi kavramlar gelişmekte olan yeni konuları ve bu alana olan ilginin azaldığı görülmektedir (Şekil 9).

SONUÇ

Bu çalışma, 1974–2025 yılları arasında allelopatinin yabancı ot kontrolü alanında yayımlanan 2484 akademik çalışmanın bibliyometrik analizini sunarak, alandaki gelişim dinamiklerini ve uluslararası araştırma eğilimlerini ortaya koymaktadır. Bulgular, bu alana yönelik akademik ilginin yıllar içinde %8,69 oranında artarak sürdüğünü, yüksek atıf oranları ve uluslararası iş birlikleriyle desteklenen bir araştırma alanı haline geldiğini göstermektedir. Analiz sonuçlarına göre, "allelopathy", "weed control", "germination", ve "plant extract" gibi anahtar kelimeler, literatürde en sık kullanılan ve yoğunlaşan kavramlar arasında yer almaktadır. Ayrıca, en üretken ülkeler arasında Çin, ABD, Brezilya, Pakistan, Hindistan ve Japonya öne çıkarken; bu ülkelerin yüksek yayın sayıları, araştırma altyapısı ve tarımsal üretimle ilgili politikalarıyla

paralellik göstermektedir. Yazar iş birlikleri ve ülke bazlı ortaklıklar incelendiğinde, uluslararası araştırma ağlarının özellikle Asya ve Avrupa merkezli olarak geliştiği gözlenmiştir. Dergi analizi sonuçları, bu konularda yayın yapan "Allelopathy Journal " tarım, botanik, yabancı ot yönetimi ve tarımsal uygulamalar gibi konuların öne çıktığını göstermektedir. Bu da allelopati konusunun farklı boyutlarını temsil ettiğini ortaya koymaktadır. Sonuç olarak, elde edilen veriler, allelopati ve yabancı otlar üzerine yapılan araştırmaların bilimsel olarak gelişen, çok-disiplinli ve uluslararası nitelikte olduğunu ortaya koymaktadır. Bu bibliometrik analiz, gelecekteki araştırmalarda hem öncelikli temaların hem de araştırma boşluklarının belirlenmesi açısından değerli bir yol haritası sunmaktadır.

KAYNAKLAR

Aldrich, R.J. and Kremer, R.J. (1997). Principles in Weed Management, 2nd Edition, Iowa State University, Ames/Iowa, 455p.

Alptekin, H., Gürbüz, R., & Aydın, A. (2023). Herbisitlere Dayanıklılık ile İlgili Yapılan Epigenetik Çalışmaların Bibliyometrik Analizi. Turkish Journal of Weed Science, 26(3), 211-224.

Arıkan, N. ve Elibüyük, Ġ.Ö. (2015). Yabancı otlarla mücadelede allelopatinin kullanımı. Türk Bilimsel Derlemeler Dergisi, 8(1), 46-50.

Arruda, H., Silva, E. R., Lessa, M., Proença Jr, D., & Bartholo, R. (2022). VOSviewer and bibliometrix. *Journal of the Medical Library Association*: JMLA, 110(3), 392.

Bhadoria, P. B. S. (2011). Allelopathy: A natural way towards weed management. *American Journal of Experimental Agriculture, 1*(1), 7-20.

Guleria, D., & Kaur, G. (2021). Bibliometric analysis of ecopreneurship using VOSviewer and RStudio Bibliometrix, 1989–2019. *Library Hi Tech*, 39(4), 1001-1024.

Holm, L.G., Plucknett, D.L., Pancho, J.V. and Herberger, J.P., (1991). The World's Worst Weeds: Distribution and Biology. Malabar, FL: The University Press of Hawaii. 609 p.

Inderjit, Seastedt, T. R., Callaway, R. M., Pollock, J. L., & Kaur, J. (2008). Allelopathy and plant invasions: traditional, congeneric, and bio-geographical approaches. *Biological invasions, 10*, 875-890.

Macías F.A. Galindo J.C.G. Molinillo J.M.G. and Cutler H.G. (2004). Allelopathy Chemistry and Mode of Action of Allelochemicals. CRC Press. Boca Raton London, New York Washington D.C

Macías, F. A., Galindo, J. C., & Molinillo, J. M. (Eds.). (2003). *Allelopathy: chemistry and mode of action of allelochemicals*. CRC Press.

Oyewola, D. O. & Dada, E. G. (2022). Exploring machine learning: a scientometrics approach using bibliometrix and VOSviewer. *SN Applied Sciences*, 4(5), 143.

Öngen, E. (2021). Akhardal (Sinapis alba L.) Tohumlarının Bazı Biyolojik Özelliklerinin ve Tohum Çimlenmesine Bitki Ekstraktlarının Allelopatik Etkilerinin Saptanması. Mustafa Kemal Üniversitesi. *Fen Bilimleri Enstitüsü, Yüksek Lisans Tezi*

Özen, F., Yaldız, G. ve Çamlıca M. (2017). Yabancı ot mücadelesinde bazı aromatik bitkilerinin uçucu yağlarının allelopatik etkisi. Uluslararası Tarım ve Yaban Hayatı Bilimleri Dergisi, 3(1), 40-48.

Patterson, D.T. (1985). Comparative Ecophysıology of Weeds and Crops. Weed Physiology, (Ed.: Duke, S.O.), Vol.: I, 101-129, CRC Press, Inc., Boca Raton, FL.

Paynter Q, Overton JM, Hill RL, Bellgard SE, Dawson MI. (2012). Plant traits predict the success of weed biocontrol. *J. Appl. Ecol.* 49:1140–48

Peng, G., Guan, Z., Hou, Y., Gao, J., Rao, W., Yuan, X., Guo, J., Huang, X., Zhong, Z. & Lin, J. (2021). Depicting developing trend and core knowledge of hip fracture research: a bibliometric and visualised analysis. *Journal of Orthopaedic Surgery and Research*, 16, 1-11.

Sarıtaş, A. G., & Gürbüz, R. (2024). Effects of Hot Water Obtained by Solar Energy on the Weeds Convolvulus arvensis L., Setaria viridis (L.) P. Beauv. and Amaranthus retroflexus L. *Yuzuncu Yıl University Journal of Agricultural Sciences*, *34*(2), 346-353.

Taraghikhah, M. R. (2024) İran Kaynaklı Bazı Allium Türlerinin Sekonder Metabolitleri Ve Antioksidan İle Allelopatik Potansiyellerinin Araştırılması Atatürk Üniversitesi. *Fen Bilimleri Enstitüsü, Doktora Tezi*.

Uygur, N., Uygur, S. (2010). *Yabancı otların biyolojik mücadelesi,* Türkiye Biyolojik Mücadele Dergisi, 2010, 1 (1), 79-95.

Vilà M, Espinar JL, Hejda M, Hulme PE, Jarosik V. (2011). Ecological impacts of invasive alien plants: a meta-analysis of their effects on species, communities and ecosystems. *Ecol. Lett.* 14:702–8

Weston, L. A., & Duke, S. O. (2003). Weed and crop allelopathy. *Critical reviews in plant sciences*, *22*(3-4), 367-389.

Willis, R. J. (2007). Allelopathy in the Classical World–Greece and Rome. *The History of Allelopathy*, 15-37.

Zengin, H. (2013). Yabancı Otlarla Biyolojik Mücadele Yöntemleri. *Atatürk Üniversitesi Ziraat Fakültesi Dergisi*, *28*(3).

Zimdahl, R. L. (1989). *Weeds and words. The etymology of the scientific names of weeds and crops* (pp. xix+-125).

Zimdahl, R.L. (2018). Fundamentals of Weed Science, 5 th Edition, Academic Press, 758p.

THE IMPACT OF TECHNOSTRESS ON ORGANISATIONAL FUNCTIONING

Alžbeta SIMON CSUHAJOVÁ
J. Selye University, Faculty of Economics and Informatics
https://orcid.org/0000-0001-7234-5428

ABSTRACT

According to Brod (1984) technostress is a modern disease of adaptation caused by an inability to deal with a computer technology in a healthy manner. Numerous studies have confirmed that organisations equipped with information technology are more productive than their competitors, as these tools facilitate the flow of information and increase customer satisfaction. At the same time, the rapid development of technological tools causes significant psychosocial stress in the workplace and personal lives of employees, leading to exhaustion, addiction, and a decline in quality of life. Technostress, a modern-day phenomenon resulting from the inappropriate use of technology, affects the physical and mental well-being, efficiency, work-life balance and well-being of organisations and employees. Part of our research is to identify technostressors and to understand the interrelationships. Our research examines how organisational trust affects the level of technostress within organisations. During the research, we applied the Structured Questionnaire developed by Tarafdar and colleagues in 2007, with our own modifications, and built on the research of Bencsik and Juhász (2023), who examined the relationships between technostress and organisational trust. The survey was conducted in a quantitative format, with 450 participants using an online questionnaire distributed among employees from various organisations in Slovakia and Hungary. Data were analysed using statistical methods with the help of Jasp 0.95, Jamovi and IBM SPSS Statistics 26 and IBM SPSS AMOS 26 software. The uniqueness of the research lies in the search for the relationship between organisational trust and technostress. Descriptive statistics and Structural Equation Modeling (SEM), were used to explore the relationships between the variables and to test the hypothesis. The partial results show that components of technostress such as technological overload and technological uncertainty negatively affect organisational and personal well-being, as well as interpersonal trust within the organisation. A significant relationship was found between fear of data loss and trust in management and colleagues. This paper presents partial findings from my ongoing doctoral research. The final results will be available upon completion of the dissertation process. Technostress is a measurable phenomenon that poses a serious risk to the functioning of an organisational culture. Tackling technostress requires people-centric ethical leadership, organisational trust, and digital literacy. People-centered management practices can help to keep the organisation dynamic and contribute to employee satisfaction and to successfully overcome technostress.

Keywords: Technostress, Organisational functioning, Trust, Technology overload, Work-life balance.

INTRODUCTION

The term "technostress" was first introduced by Brod (1984) and has since become an important area of research, especially in the context of digital work environments. Brod began to examine technostress as a phenomenon in the 1980s, after which Tarafdar and her colleagues conducted deeper research and expanded the concept of technostress to several components, which were

introduced into the literature as technostress creators (Tarafdar et al., 2007; Ragu-Nathan et al., 2008) Technostress has many other consequences, such as the blurring of work and private life, the deterioration of social relationships and interactions, alienation, and a constant feeling of tension. (La Torre et al., 2019). From an organisational perspective, technostress impairs motivation, increases workload, reduces commitment, and destroys organisational trust (Bencsik & Juhász, 2023). The introduction of digital technologies is inevitable, but the right organisational environment and support can reduce risk factors (Torre et al., 2020).

Digitalization is a challenge that organisations have to deal with every day in order to operate successfully. The attitude of employees, their trust or distrust in technology, is a key issue for achieving a successful transition (Bencsik et. al, 2022). Management is generally clear that new technologies lead to better decision-making and improved financial results. They understand that machine learning is essential for competitiveness; however, trust as a factor is often lacking and hinders the organisation's progress. The lack of managerial trust can be approached from three perspectives: trust in data, trust in analytical models, and trust in interpretive capabilities (Almarashdeh, 2018). According to Siau & Wang (2018), the only way to change the organisational model approach is for the management of the company to recognize the importance of trust.

Technostress and its effects on employees and organisations have received considerable attention in information systems, psychology and management research over the past two decades, with 1331 articles on the topic according to the scopus elsevier database. However, when the keywords technostress and trust are searched for together, the number of hits is only 17. From this simple search, we can see that the topic is less explored scientifically, and my research aims to fill this research gap. Empirical research directly examining the relationship between technostress and organisational trust is still lacking in the literature. This is particularly true for quantitative analyses conducted in an organisational context, which aim to explore the relationship between technostressors and trust factors.

The present study aims to fill this theoretical and methodological gap by using a structured empirical approach to investigate how technostressors influence the level of trust within an organisation. The research aims to contribute to the international and national literature on the intersection of technostress and trust, and to provide practical implications for management and Human resources (HR) practices.

CONCEPTUAL FRAMEWORK

The impact of technostress on organisational functioning

Organisational technostress occurs when new IT technologies are introduced and supporting solutions are not in place. The necessary steps should always be designed according to the organisational and security culture to which they belong. (Brod,1984; Bencsik, 2024) Two-way stress, a specific phenomenon that is caused by a phone with an internet connection for employees. A telephone for employees with a continuous Internet connection may be the cause of the phenomenon of bidirectional stress. Employees are forced to be available to their workplace and their superiors outside of their working hours, during holidays. Among other things, the fear of losing the phone, which breaks the continuous contact, causes problems. (Bencsik, 2024; Vanhala, 2019).

Nowadays, it is difficult to guarantee job stability and security and high levels of income. Continuous uncertainty contributes to a loss of trust in the workplace, which over time can even lead to a complete lack of trust in the organisation. One of the determinants of the relationship between trust and technostress is the level of trust placed in collaborative IT service providers. These collaborations are mutually beneficial. Trust acts as an intervention mechanism through which the intensity of collaboration improves the performance of the relationship. In addition,

trust plays a mediating role, while distrust has a moderating effect (Rezvani & Khosravi, 2019; Bencsik, 2024).

Organisations that prefer knowledge-based operations include Knowledge Management activities in their strategy. However, often even these organisations do not realize that knowledge assets can be accumulated in an organisation that has a trust-based organisational culture, which includes the use of technological tools. (Bencsik & Juhász, 2018; Bencsik, 2024). Trust and knowledge mobility interact trust facilitates knowledge flows, but faster and freer movement of knowledge itself increases trust. (Bencsik, 2024).

The technostress creators

Tarafdar and colleagues are key researchers in technostress research. In a 2007 study, they expanded the concept of technostress in the context of information systems. They identified five types of technostress, which they called "technostress creators":

Techno-overload: Techno-overload occurs when the use of information and communication technology (ICT) exceeds the optimal level. (Karr-Wisniewski and Lu 2010) For instance, Choi and Lim (2016) found a negative indirect relationship between techno-overload and psychological well-being, which they linked to the use of social media. They concluded that techno-overload is negatively related to employee well-being. Finally, Srivastava, Chandra, and Shirish (2015) found that technostressors, including techno-overload, are associated with manager burnout, which can be considered another negative well-being outcome.

Techno-invasion: When the boundaries between work and private life become blurred. Technology becomes so intrusive in users' lives that it adversely affects their lives. It blurs the boundaries between work and private life. Information systems enable constant and continuous communication, which means that employers can reach their employees at any time, and employees feel obliged to always be available, even on their days off. Due to the technological invasion, employees' free time is constantly decreasing, they have less quality time to spend on relaxation, and less time is left for family obligations (Bencsik & Juhász, 2023; Tarafdar et al., 2007).

Techno-complexity: The stress that comes from technological systems being too complicated and users having to constantly learn new skills. We discuss techno-complexity when users feel that understanding an information technology system requires serious effort or continuous learning. Continuous technological development is necessary to maintain the competitiveness of organisations. As a result, users' knowledge quickly becomes obsolete. Users' skills need to be continuously developed, but despite this, users often feel that they do not know the system well enough and that they need more time to be able to use information technology systems confidently (Tarafdar et al. 2007).

Techno-insecurity caused by constant technological change, which prevents users from developing a stable knowledge base. This group includes fear of losing one's job. When innovative technology is introduced, employees feel a constant concern that they will be easily replaced, that human work will be replaced by machine work and automation, organisations are constantly increasing their expectations of employees' technological skills, and if they cannot keep up with the changes, this can result in job loss (Ragu-Nathan et al., 2008; Califf et al., 2020).

Techno-uncertainty: Fear of losing their jobs due to technological changes or being replaced by someone who is more technologically skilled. This arises when they are unable to keep pace with rapid technological developments (Tarafdar et al., 2007; Ragu-Nathan et al., 2008). Users feel constant pressure to keep up with technological developments and continuously improve their skills, which requires constant effort. The constant desire to keep up can cause negative

feelings and fears in employees (Califf et al., 2020), which reduces job satisfaction and impairs overall psychological well-being. (Holmes, Bialik, & Fadel, 2019).

Organisational trust and technostress

In modern organisations, there is less chance of building personal trust, which is why impersonal trust, which means trust in the institution, its management, systems, processes, and technological readiness, is playing an increasingly important role in the life of organisations. Their research found that impersonal trust has a positive effect on organisational commitment, job satisfaction, and indirectly improves competitiveness through satisfaction and commitment. (Michalec, Hargitai, Bencsik, 2024) Table 1 presents the forms and aspects of organisational trust.

Table 1

Type of trust	Definition	Key elements	Examples
Personal organisational trust	Trust directed towards specific individuals within the organisation	Horizontal trust, vertical trust, personal interactions.	Trust in supervisors, trust in colleuges
Impersonal organisational trust	Trust in the organisation as a whole systems, processes and structures	Vision and strategy, leadership team, common goals	Trust in organisation´s decision-making process
Technology to human trust	Trust in technological systems, digital devices, and digital infrastucture	Trust in data security, reliability of sotware and hardware, acceptance of automated decision-making	Trust in company data security, keeps employees data secure

Own construction

According Saleem at al. (2021) “In organisations, the individuals interact and develop relationships that are strengthened by developing a sense of trust and reciprocity.” Trust and reciprocity in an organisation can strengthen cooperation, and trust can help to maintain or improve performance, even when technostress occurs. Increasing organisational trust can reduce the negative effects of technological stress, support employee well-being, and improve performance. According to Bencsik and Juhász 2023, the various components of technostress (e.g. technological overload, technological intrusion, complexity, uncertainty and threat) generate psychosocial pressures that can undermine trust in human relationships and human-technology relations. Trust plays an important role in organisational cultures, with high levels facilitating knowledge sharing, adaptation, and performance. A decrease in organisational trust increases competition within the organisation, and employees may worry about losing their jobs, which can cause loss of knowledge, decreased performance, or workforce turnover (Bencsik, 2023).

METHODOLOGY

Data collection, Sample Characteristics, Analysis Methods

The study includes quantitative analysis, based on numerical data and statistical analyses. Data were collected in 2024 from public and private sector employees in Slovakia and Hungary. We used an anonymous online questionnaire, which was distributed on social media, by e-mail and online. Before the main survey, test interviews were conducted to ensure the clarity of the questions. The questionnaire consisted mostly of closed questions (95%), 80% of which used a 5-point Likert scale (where respondents indicate the degree of agreement). The questionnaire was based on a questionnaire previously developed by Tarafdar et al. (2007), in which we made modifications to map our own research. Out of 5000 questionnaires sent, 450 were returned. The collected data was analysed using statistical software JASP 0.95 (IBM SPSS 28 and IBM AMOS 27), employing methods like mean, standard deviation, factor analysis, ANOVA, and Structural Equation Modeling (SEM). The research was conducted in full compliance with ethical guidelines, and the participants' data was analysed in accordance with GDPR regulations and aggregated for statistical purposes only. Sample characteristics are summarized in Tables 2.

Data were collected using a structured online questionnaire titled “The Impact of Technostress on Organisational Functioning.” The survey consisted of seven main sections: Demographic data: gender, age, education level, job position, sector, country, and the use of digital devices at work. Technostress creators: adapted from Tarafdar et al. (2007), covering five dimensions: Technological Overload (5 items) Technological Invasion (4 items) Technological Complexity (5 items) Technological Insecurity (5 items) Technological Uncertainty (4 items) Technostress inhibitors: including: Literacy Facilitation (5 items) Technical Support Provision (5 items) Involvement Facilitation (3 items) Organisational commitment: (8 items), based on the affective commitment scale. Job satisfaction: (3 items). Computer Confidence: (5 items), how confident respondents feel in the field of technological tools. Technological Stress and Trust: (6 items), developed by Bencsik and Juhász, measures trust related to artificial intelligence (AI), data security and trust in human cooperation. We used a 5-point Likert scale to measure the items (1 = Strongly disagree, 5 = Strongly agree). The questionnaires were tested on a smaller sample before being sent out, explanations were provided where necessary, and the supervisor's expert opinions were sought.

After data cleaning, we performed data analysis in the free statistical program Jasp 0.18.3, starting with descriptive statistics. This was followed by frequency analysis, which can be seen in the second table, with 236 male respondents and 214 female respondents and the age distribution of the respondents. Two age groups dominate the sample: those aged 26-35 and those aged 36-45.

The majority of respondents (62.2%) work in the private sector, 25.3% in the state and public sector, 10.3% in the non-profit sector, and the remaining part work in other areas. The distribution shows that the technostress phenomena examined are primarily characteristic of the market and public institution environments. (See Table 2)

Results

Table 2. Characteristics of respondents

Gender	Frequency	
male	236	52,44%
female	214	47,56%
Total	450	
Age	**Frequency**	**Percent**
Under 26	72	16,00%
26-35	194	43,11%
36-45	131	29,11%
46-55	40	8,89%
56-65	12	2,67%
Over 65	1	0,22%
Total	450	
Type of Workplace	**Frequency**	**Percent**
======	2	0,44%
Nonprofit s.	47	10,44%
Other s.	7	1,56%
Private Sector	280	62,22%
Public Sector	114	25,33%
Total	450	

Source: own elaboration

Table 3. Characteristics and effects of technostress (mean, standard deviation, factor w.)

Technostressor	**Item**	**mean**	**Sd szórás**	**Cronbach's α**	**Factor weights**
techno-overload	[Technology forces me to work faster.]	3.796	1.102	0.953	0.580
	[Technology forces me to do more work than I can handle.]	3.502	1.062	0.951	0.738
	[Technology forces me to work with very tight schedules.]	3.407	0.945	0.952	0.669
	[I have to change my work habits to adapt to new technologies.]	3.598	0.963	0.952	0.714
	[My workload is increased due to the complexity of technology.]	3.482	1.028	0.951	0.715
techno-invasion	[I spend less time with my family because of technology.]	3.496	1.215	0.952	0.685
	[I have to be in touch with my work even during my vacation due to technology.]	3.411	1.011	0.951	0.762
	[I sacrifice my vacation and weekends to keep up with new technologies.]	3.371	0.966	0.952	0.692
	[I feel that my personal life is invaded by technology.]	3.398	0.999	0.951	0.724
techno-complexity	[I do not know enough about technology to do my job satisfactorily.]	3.300	1.149	0.953	0.611
	[I take a long time to understand and use new technologies.]	3.233	0.979	0.952	0.663
	[I do not have enough time to upgrade my technological skills.]	3.244	0.929	0.953	0.580
	[I feel new employees know more about computer technology than I do.]	3.311	1.019	0.952	0.693
	[I often find new technologies too complex to use.]	3.293	0.989	0.952	0.651
techno-insecurity	[I feel constant threats to my job security due to new technologies.]	3.309	1.196	0.952	0.682
	[I have to constantly update my skills to avoid being replaced.]	3.302	1.035	0.951	0.759
	[I feel threatened by coworkers with newer technological skills.]	3.209	1.039	0.952	0.682
	[I do not share my knowledge with colleagues for fear of being replaced.]	3.189	1.026	0.952	0.632
	[I feel there is less knowledge sharing among coworkers due to the fear of replacement.]	3.236	1.081	0.952	0.705
techno-uncertainity	[There are always new developments in the technologies we use in our organization.]	3.604	1.239	0.951	0.735
	[There are constant changes in the computer software in our organization.]	3.420	1.018	0.951	0.769
	[There are constant changes in the computer hardware in our organization.]	3.362	1.047	0.952	0.710
	[There are frequent updates in the computer networks in our organization.]	3.444	1.067	0.951	0.722

Source: own elaboration

The conceptual model of this study was designed to investigate how various dimensions of technostress affect trust-related outcomes within the organisational context. The research integrates two theoretical frameworks: the stressor–strain–outcome (SSO) model (Koeske,

1993), which conceptualizes technostress as a source of psychological strain, and social exchange theory (SET) (Cook & Rice, 2006), which explains the relational consequences of perceived intrusion and support in the workplace.

Detailed analysis of the techno-overload component; the statements correspond to the original questionnaire developed by Tarafdar (2007) and colleagues with our modifications.

Reliability and statistical characteristics of scales

During the analysis, we examined statements related to technostress creators, and obtained mean, standard deviation, factor weight, and Cronbach's alpha values using the Jasp analytical program. Below, I summarize the most important indicators obtained during the study and their meanings.

Techno-overload: Respondents typically agree that they experience information overload, need to speed up their work pace, and constantly adapt, with averages ranging from 3.4 to 3.8. The factor weights ranged from 0.580 to 0.738, and the reliability of the scale was excellent (Cronbach's $\alpha = 0.951–0.953$).

Techno-invasion: The question is how much technology will penetrate people's private and working lives. To what extent is the balance between work and private life disrupted? The mean scores for the statements ranged from 3.37 to 3.50, with a standard deviation of 0.96–1.21. The factor weights (0.685–0.762) show that the items strongly represent the invasion, while internal consistency can again be considered high ($\alpha \approx 0.95$).

Techno-complexity: In this dimension, we examine the extent to which individuals and employees perceive the technological systems they use as complex, how confident they are in using the systems, or how uncertain they are. The averages here were also around 3.2–3.4, with factor weights typically falling between 0.69 and 0.76. The Cronbach's alpha value was 0.953, which again indicates a highly reliable scale.

Techno-uncertainty: We measure uncertainty related to technological changes and how difficult it is to keep up with technological updates. Even if you master a system, there is a chance that a new update will come out within a month, which you will have to learn again. Respondents perceived the difficulties of keeping up with constant technological updates and new systems. Factor weights are considered stable (around 0.70), and the scale reliability was $\alpha = 0.951$.

Techno-uncertainty: We examine how safe respondents feel at their workplace from a technological perspective, and how worried they are about the future, whether their job will still be needed, or how much they fear that technology or artificial intelligence will replace their role. Respondents were worried about the future, although the means were lower, the factor structure is clear, and the scale remains reliable ($\alpha = 0.952$).

Overall, we can say that we measured high factor weights and outstanding Cronbach's alpha values, which confirm the assumption that the technostress scale is psychometrically reliable and easy to interpret. The dimensions are well structured and empirically support the theoretical background.

Structural Equation Model Analysis: Technostress and Trust

In this section, we present the interpretation of the structural equation model (SEM), which maps the relationship between the dimensions of technostress and trust in the organisation. The model was developed using IBM SPSS Amos software and is based on empirical data from employee responses. The following diagram and detailed interpretation illustrate how different technostress factors affect organisational trust and interpersonal distrust.

The structural equation model (SEM) includes seven latent variables: F1- Technology overload, F2- Technology complexity, F3- Technology vulnerability, F4-Technology

uncertainty, F5 – Organisational trust, F6 – Distrust toward colleagues, F7 – Technology invasion

H	Statement	Path (Variables)	Path Coefficient (β)	*Conclusion*
H1	Techno-invasion significantly reduces organisational trust.	F7 → F5	-3.96	Supported
H2	Techno-invasion increases distrust toward colleagues.	F7 → F6	-3.55	Supported
H3	Techno- vulnerability negatively affects organisational trust.	F3 → F5	-2.83	Supported
H4	Techno-vulnerability increases distrust toward colleagues.	F3 → F6	-1.56	Supported
H5	Techno-complexity increases distrust toward colleagues.	F2 → F6	-1.45	Supported
H6	Techno-uncertainty increases distrust toward colleagues.	F4 → F6	0.38	Supported
H7	Techno-overload indirectly reduces trust through technology invasion.	F1 → F7 → F5	0.68 → –3.96	Confirmed
H8	Techno-overload indirectly increases distrust through technology invasion.	F1 → F7 → F6	0.68 → –3.55	Confirmed
H9	Complexity and uncertainty indirectly affect trust via vulnerability.	F2/F4 → F3 → F5	0.34/0.47 → –2.83	Confirmed
H10	Techno-overload increases the sense of invasion.	F1 → F7	0.68	Supported
H11	Techno-complexity increases perceived vulnerability.	F2 → F3	0.34	Supported
H12	Techno-uncertainty increases perceived vulnerability.	F4 → F3	0.47	Supported

Summary of hypotheses and main results

During the research, the hypotheses were prepared based on the structural equation model SEM created in the AMOS software. The path coefficients of the model show the statistically significant relationships that support the hypothesised relationships.

The analysis indicated that certain dimensions of technological stress have both direct and indirect effects on organisational trust and distrust towards colleagues. Technological overload (F1) strongly increases the feeling of a technological invasion, which, in turn, weakens trust and reinforces distrust within the organisation.

Technological complexity (F2) and technological uncertainty (F4) increase technological vulnerability (F3), which weakens organisational trust and causes tension among colleagues.

H1–H6: We observed direct relationships between the dimensions of technostress and trust/distrust outcomes.

H7–H9: Indirect, mediated effects through invasion and vulnerability.

H10–H12: We discovered structural relationships between the factors of technostress. Main results: The data show that technological invasion strongly undermines organisational trust (F7 → F5: β = –3.96) and increases distrust toward colleagues (F7 → F6: β = –3.55). Technological vulnerability also causes a significant decrease in trust (F3 → F5: β = –2.83) and increases interpersonal distance (F3 → F6: β = –1.56). In addition, complexity (F2 → F6: β = –1.45) and uncertainty (F4 → F6: β = 0.38) also contribute to the development of distrust towards colleagues.

Indirect relationships: Technological overload weakens trust not only directly but also through a sense of invasion (F1 → F7 → F5) and, in the same way, increases distrust (F1 → F7 → F6). Complexity and uncertainty increase vulnerability (F2 → F3: β = 0.34; F4 → F3: β = 0.47), which ultimately leads to a decrease in trust (F3 → F5). (See Figure 2.)

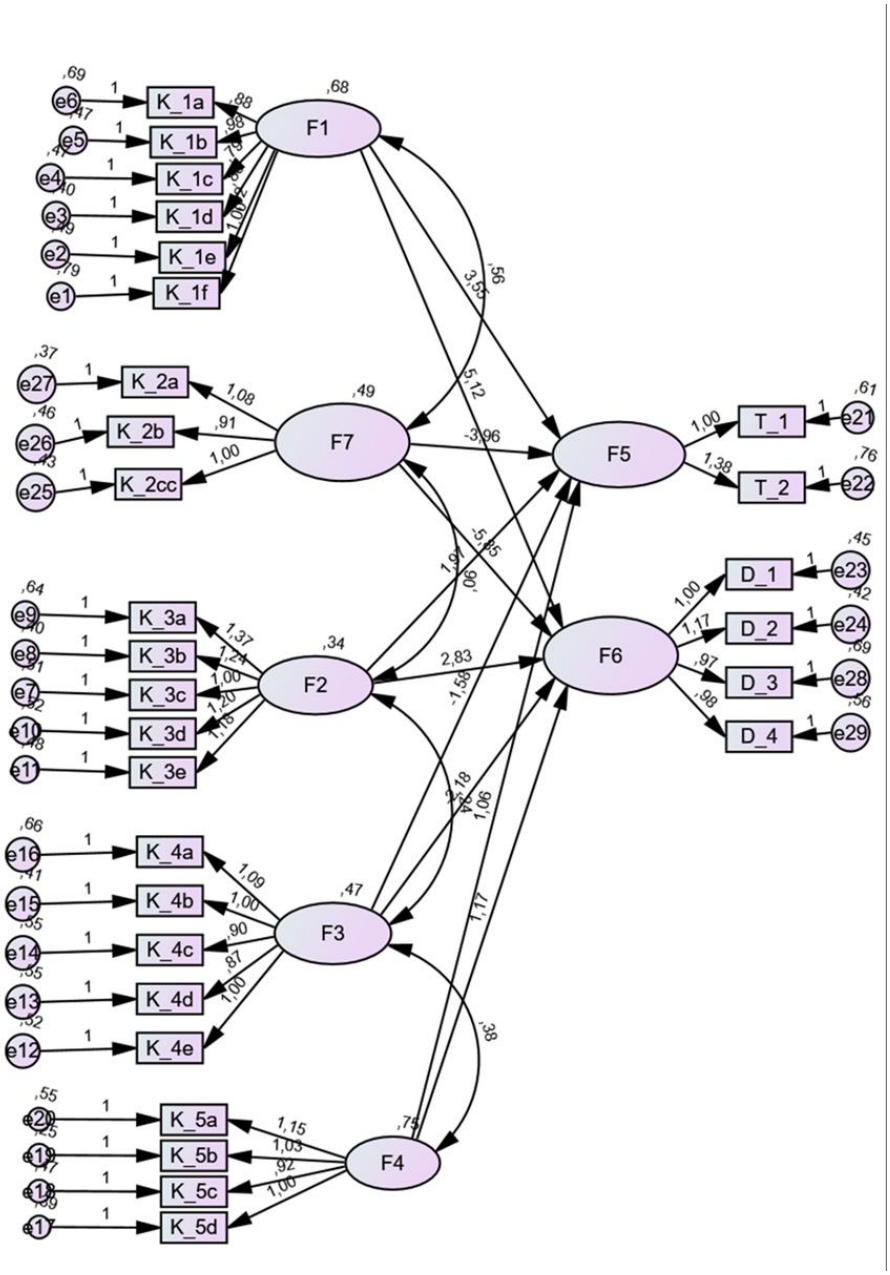


Figure 1. Structural Equation Model (SEM) of technostress and trust
Source: own elaboration, AMOS output

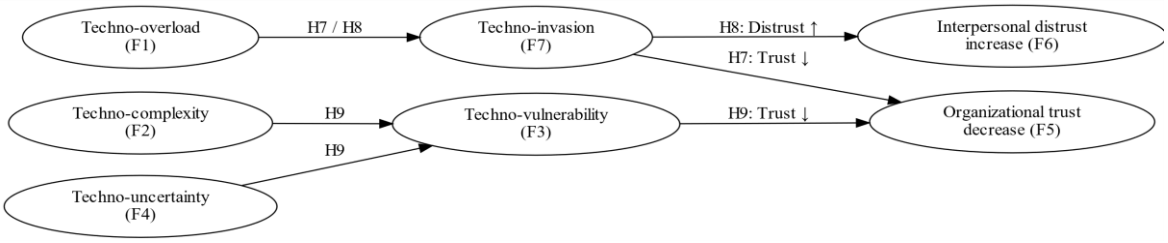


Figure 2 own resource

The results confirm the stressor–strain–outcome model (Koeske, 1993), where the dimensions of technostress appear as stressors, invasion and vulnerability act as mediators, while trust and distrust appear as outcome variables. Interpreted within the framework of social exchange theory, this shows that digital intrusion and the perception of system vulnerability undermine psychological security and weaken the quality of relationships within the organisation in the long term.

CONCLUSION AND DISCUSSION

During the research, we examined how certain dimensions of technostress affect organisational trust, human-human and human-technology trust.

According to the results of the 2024 survey, techno-invasion and techno-vulnerability lead to a decrease in organisational trust. The components of technostress reinforce each other indirectly and directly influence the organisational climate.

Our results are consistent with the research of Tarafdar et al. (2007) and Ayyagar et al. (2011), who found that the components of technostress collectively elicit negative feelings in employees and, if left untreated, lead to burnout in the long term. According to Saleem et al. (2021), techno-invasion and system vulnerability reduce psychological safety and reduce trust, which is also supported by the results of our research. In their study, Bencsik and Juhász (2023) found a close relationship between technostress and trust, examining human-technologist and human-human trust separately.

The results highlighted that technological invasion and technological vulnerability play a key role in undermining trust and that these effects are partly indirect, suggesting the complex nature of technostress. However, we found differences between certain dimensions of technostress, which warrant further investigation. The impact of technostress may vary across industries and countries, making its management a complex process. In the future, it would be worthwhile to conduct qualitative studies to gain deeper insight into the mechanisms of trust change in digital work environments.

As we move forward, technology will become more a part of our lives and work, technology can help with many tasks, there is an opportunity to automate tasks, and it can help take the burden and pressure off people. But when a technological innovation is introduced, we need to act in a way that can reduce technostress as much as possible. Technological advantages must be used in a way that does not cause damage to human relationships. If management ignores the human factor during work processes, it will have negative consequences. Trust is one of the cornerstones of organisational culture, which can ensure the right organisational atmosphere and make work processes smoother. Trust plays an important role in knowledge sharing, so that experienced colleagues dare to pass on knowledge to the younger generation. This is possible if they do not feel their position is in danger and trust the ethical behaviour of their superiors. Sources of technostress need to be proactively addressed. Workloads need to be balanced, and platform usage should be subject to rules. Out-of-office availability needs to be reduced to allow employees to properly rest after work.

The security of technological systems can be increased if employees participate in appropriate training, which helps to eliminate technological difficulties (Tarafdar, Pullins és Ragu-Nathan, 2015). It would be worth conducting training before the technological development is introduced. This way, we can avoid employees feeling exposed and uncertain about the work processes. The most important thing is that employees dare to ask for help if they do not know something, there should be a mentoring system to whom they can turn with their questions. When employees understand why things are happening, they adapt more easily to changes (Mayer, Davis, & Schoorman, 1995; Dirks & Ferrin, 2001). Organisations should strive to build and strengthen a culture of trust that reduces feelings of technological threat and uncertainty. An empathetic leadership approach and team-building training can help eliminate the difficulties caused by technostress (Bencsik and Juhász, 2023).

Acknowledgements

The author would like to express her gratitude to her supervisor, Prof. Dr. Andrea Bencsik, CSc., for her invaluable support, guidance, and expertise during the research and also grateful to the Faculty of Economics and Informatics of Selye János University for providing the institutional background and resources that made this study possible.

REFERENCES

Almarashdeh, Ibrahim. (2018). The important of service quality and the trust in technology on users perspectives to continues use of mobile services. *Journal of Theoretical and Applied Information Technology*. 96. 2954-2972.

Ayyagari, R., Grover, V., & Purvis, R. (2011). Technostress: Technological antecedents and implications. MIS Quarterly, 35(4), 831–858.

Bencsik, Andrea & Juhász, Timea. (2023). The impact of technostress on organizational functioning. *Problems and Perspectives in Management.* 21. 230-241. 10.21511/ppm.21(1).2023.20.

Bencsik, A., & Juhasz, T. (2023). Impact of technostress on work-life balance. Human Technology, 19(1), 41–61. https://doi.org/10.14254/1795-6889.2023.19-1.4

Bencsik, Andrea & Hargitai, David & Kulachinskaya, Anastasia. (2022). Trust in and Risk of Technology in Organizational Digitalization. Risks. 10. 90. 10.3390/risks10050090.

Brod, C. (1984). Technostress: The Human Cost of the Computer Revolution. Addison-Wesley.

Califf, Christopher & Sarker, Saonee & Sarker, Suprateek. (2020). The Bright and Dark Sides of Technostress: A Mixed-Methods Study Involving Healthcare IT. MIS Quarterly. 44. 809-856. 10.25300/MISQ/2020/14818.

Choi, S. B. & Lim, M. S. (2016): Effects of social and information technology overload on psychological well-being in young South Korean adults: The mediatory role of social network service addiction. *Computers in Human Behavior*, 61, 245–254.

Cook, Karen & Rice, Eric. (2006). Social Exchange Theory. 10.1007/0-387-36921-X_3.

Karr-Wisniewski, P,. & Lu, Y. (2010). When more is too much: Operationalizing technology overload and exploring its impact on knowledge worker productivity. Computers in Human Behavior, 26(5), 1061-1072. doi: http://dx.doi.org/10.1016/j.chb.2010.03.008

Koeske, G. F., & Koeske, R. D. (1993). A preliminary test of a stress-strain-outcome model for reconceptualizing the burnout phenomenon. Journal of Social Service Research, 17(3-4), 107-135.

Koeske, G. F., Kirk, S. A., & Koeske, R. D. (1993). Coping with job stress: Which strategies work best?. Journal of occupational and organizational psychology, 66(4), 319-335.

Kurt T. Dirks, Donald L. Ferrin, (2001) The Role of Trust in Organizational Settings. *Organization Science* 12(4):450-467. https://doi.org/10.1287/orsc.12.4.450.10640

La Torre, G., et al. (2019). Technostress: A Systematic Review. International Journal of Environmental Research and Public Health, 16(15), 2857.

Mayer, R. C., Davis, J. H., & Schoorman, F. D. (1995). An Integrative Model of Organizational Trust. *The Academy of Management Review*, 20(3), 709–734. https://doi.org/10.2307/258792

Michalec, Gabriella & Hargitai, David & Bencsik, Andrea. (2024). Organizational trust as a success factor. *Journal of Business Sectors.* 2. 61-67. 10.62222/XQQE2812.

Ragu-Nathan, B. S., Tarafdar, M., Ragu-Nathan, T. S., & Tu, Q. (2008). The consequences of technostress for end users in organizations: Conceptual development and empirical validation. *Information Systems Research*, 19(4), 417–433.

Rezvani, A., & Khosravi, P. (2019). Emotional intelligence: The key to mitigating stress and fostering trust among software developers working on information system projects. *International Journal of Information Management*, 48, 139–150. https://doi.org/10.1016/j.ijinfomgt.2019.02.007

Saleem, F., Malik, M. I., & Qureshi, S. S. (2021). Technostress and employee performance nexus during COVID-19: Training and creative self-efficacy as moderators. Frontiers in Psychology, 12, 595119. https://doi.org/10.3389/fpsyg.2021.595119

Siau, Keng & Wang, Weiyu. (2020). Artificial Intelligence (AI) Ethics: Ethics of AI and Ethical AI. Journal of Database Management. 31. 74-87. 10.4018/JDM.2020040105.

Srivastava, SC, Chandra, S, and Shirish, A (2015), Technostress creators and job outcomes: theorising the moderating influence of personality traits. *Info Systems J*, 25, 355–401. doi: 10.1111/isj.12067.

Tarafdar, M., Tu, Q., Ragu-Nathan, T. S., & Ragu-Nathan, B. S. (2007). The Impact of Technostress on Role Stress and Productivity. Journal of Management Information Systems, 24(1), 301–328. https://doi.org/10.2753/MIS0742-1222240109

Tarafdar M., Pullins E. B., and R.-N. T. S. (2015), Technostress: negative effect on performance and possible mitigations, Info Systems J, 25, pages 103–132. doi: 10.1111/isj.12042

Torre, T., Poggesi, S., & Blasini, F. (2020). Technostress, academic self-efficacy and resistance to innovation: An empirical study in higher education. Studies in Higher Education, 47(4), 847–861.

Vanhala, Mika. (2019). Trust as an organizational knowledge sharing enabler – validation of the impersonal trust scale. *VINE Journal of Information and Knowledge Management Systems.* 50. 349-368. 10.1108/VJIKMS-12-2018-0119.

ANALYZING ATTITUDE KINEMATICS OF SATELLITES IN SEPARATRIX MOTION USING CLASSICAL PARAMETERIZATIONS

Farid Guliyev

National Aviation Academy, System Analysis, Management and Information Processing, Baku, Azerbaijan

ORCID ID: https://orcid.org/0009-0009-6369-8833

Ismayil Ismayilov

National Aviation Academy, System Analysis, Management and Information Processing, Baku, Azerbaijan

ORCID ID: https://orcid.org/0000-0002-9013-2765

ABSTRACT

Introduction and Purpose: Attitude control is essential for satellite operations that ensures accurate orientation during communication, imaging, and scientific missions. This study examines how different attitude parameterizations, including Euler angles, Modified Rodrigues Parameters, Direction Cosine Matrices influence computational cost, numerical stability, and control accuracy. The goal is to support the selection of the most effective representation for real-time satellite applications.

Materials and Methods: This study analyzed the behavior of Euler angles, Modified Rodrigues Parameters, and Direction Cosine Matrices by integrating their differential equations using angular velocity obtained from the torque-free Euler equation of motion. All models were implemented in C with RK4 integration over 54,000 steps and converted to quaternions for consistent comparison against a reference solution. Principal angle error and computational performance were analyzed using Python for both time-domain and statistical evaluation.

Results: DCM showed the highest numerical stability with minimal principal angle error and consistent accuracy throughout the simulation, while MRP exhibited moderate error growth over time due to shadow-set switching. Euler angles produced large errors and irregular behavior caused by singularities and discontinuities. In terms of computational cost, Euler angles were fastest but least reliable, whereas DCM was most accurate but computationally heavier.

Discussion and Conclusion: This study evaluated Euler angles, MRPs, and DCMs under separatrix motion using quaternion-based integration as a reference. Among the three, DCMs demonstrated the most stable and accurate behavior throughout the simulation, even in dynamically unstable conditions. MRPs offered a good balance between efficiency and accuracy, but error drift over time due to shadow-set switching limits their use in long-term scenarios. Euler angles, though computationally efficient, suffered from severe discontinuities and singularities, making them unsuitable for reliable attitude propagation. Overall, DCM is recommended for high-precision applications, while MRPs may be a practical choice when computational resources are constrained.

Key Words: Attitude Parameterization, Euler’s equations, Attitude Determination and Control

ANGIOLYMPHOID HYPERPLASIA WITH EOSINOPHILIA PRESENTING AS AURICULAR NODULES: A RARE CASE REPORT

Uzm. Dr. Mehmet Enes GÜNER

Besni Devlet Hastanesi, Clinic of Dermatology, Adıyaman

ORCID ID: https://orcid.org/0000-0001-5424-4674

Introduction and Purpose:

Angiolymphoid hyperplasia with eosinophilia (ALHE) is an uncommon, benign vascular proliferative disorder that typically presents as erythematous or violaceous papules or nodules on the head and neck region. It may be mistaken for inflammatory, neoplastic, or infectious conditions.[1] Here, we present a case of suspected ALHE with characteristic auricular involvement, highlighting the clinical approach to this rare diagnosis.

Materials and Methods:

A 35-year-old female presented to our dermatology outpatient clinic with gradually enlarging, erythematous nodules on the left auricle over the past 3 months (Fig. 1). The lesions were asymptomatic, with no history of pain, discharge, or trauma. Physical examination revealed multiple, firm, dome-shaped nodules with a reddish hue, localized to the helix and antihelix. There was no associated lymphadenopathy. Differential diagnoses included ALHE, Kimura disease, and lobular capillary hemangioma. A punch biopsy was performed.

Results:

Histopathological examination revealed proliferation of blood vessels with prominent endothelial cells and a dense perivascular inflammatory infiltrate rich in lymphocytes and eosinophils. These findings were consistent with ALHE. The patient was offered surgical excision as definitive treatment but opted for close follow-up. No systemic involvement or peripheral eosinophilia was noted.

Discussion and Conclusion:

Although ALHE is a benign condition, its clinical resemblance to more aggressive or infectious entities may lead to diagnostic delays. Histopathological evaluation remains the gold standard for diagnosis. Awareness of its presentation, especially in sites such as the auricle, is important for timely and accurate management.



Fig.1 Nodules on left auricle

References

1. Guo, R., & Gavino, A.C. (2015). Angiolymphoid hyperplasia with eosinophilia. Archives of pathology & laboratory medicine, 139(5), 683-6.

Keywords: Angiolymphoid hyperplasia with eosinophilia; ALHE; auricle; vascular proliferation; case report

CHEMICAL PROFILE OF ROSMARINUS OFFICINALIS FROM CENTRAL ALBANIA

Blerina Xhaferaj

Departmentof of Pharmacy, Faculty of Medicine, University of Medicine, Tirana, Albania

Anila Kripa

Departmentof of Food Science and Biotechnology, Faculty of Biotechnology and Food, Agricultural University of Tirana, Albania

Aurel Nuro

Department of Chemistry, Faculty of Natural Sciences, University of Tirana, Albania

Abstract

In this study was shown data on chemical profile for *Rosmarinus officinalis* plant populations from Durres area, located in Central Albania. *Rosmarinus officinalis* is a plant of Lamiaceae family that it is grow almost in all Albania. It is widely used in Albania, since ancient times, especially in culinary, traditional medicine and as an ornamental plant. It is used fresh or dried in culinary. Although it is not used directly (as food), its taste is quite pleasant for some Albanian traditional foods. It is used to treat headaches, arthritis, rheumatism, for memory improvement, increasing of concentration, improvement on blood circulation, for hair growth/strengthening, etc.

Rosmarinus officinalis cultivated plants from Durres area (Lalzi Bay) were taken in January 2025. The air dried plant samples were cut in small pieces (1-2 cm). They were subjected of hydro-distillation for 4 hours using Clevenger type apparatus, recommended to European Pharmacopoeia, to obtain their essential oil. The chemical composition of the essential oils was analyzed by using GC/FID technique. The essential oil of each sample (10 in total) was injected in a Varian 450 GC equipped with flame ionization detector. VF-1ms capillary column (30 m x 0.33 mm x 0.25 um) were used for separation of its compounds. Main compounds found for all samples of *Rosmarinus officinalis* were: Cineol, alpha-Pinene, Camphour and Camphene. Oxygenated monoterpenes were the main group of essential oil for rosemary Profile and found levels for essential oil of *Rosmarinus officinalis* from Durres area were similar to other studies from Mediterranean and Balkan area.

Keywords: *Rosmarinus Officinalis,* Esencial oil, alpha-Pinene, Cineol, Hydro-distillation, GC/FID

Hyrje

Rosmarinus officinalis is a species of the Laminacea family. This plant, commonly known as rosemary, is is spontaneous in almost all areas of our Albania and throughout the Mediterranean region. Pervec se ajo rritet ne gjendje natyrale nga zonat bregdetare deri en zonat malore, kjo eshte nje bime qe kultivohet ne oborret e shtepive si nje bime zbukurimi dhe nje erze ne ushqime tradicionale. It can withstand drought, surviving a prolonged lack of water. The branches of

rosemary are usually straight, can reach 1.5 m. They are cover from numerous leaves which are evergreen They are 2-4 cm long and 2-5 mm wide, green above and white below, with dense and short hairs. The plants produce flowers in spring and summer, but can be in continuous bloom in warm climates. Rosemary has a tendency to bloom outside its normal flowering season; in early December, and in mid-February. Rosemary is used as an ornamental plant in gardens where it is thought to have effects and in insect control. The leaves (sometimes branches with their leaves) are used to improve the taste of various foods. They have a slightly bitter taste with a characteristic aroma that complements the aroma of cooked foods (1, 2, 3, 4). Rosemary has been known for centuries as a medicinal plant and as a spice with characteristic aroma. It is one of the oldest plants known to the human. Rosemary tea is used to improve the health of the whole body, including the health of the brain, heart and liver. Rosemary contains a large number of phytochemicals, including rosmarinic acid, camphor, caffeic acid, ursolic acid, betulinic acid, carnosic acid and carnosol. In traditional medicine, extracts and essential oil extracted from the flowers and leaves are used to treat a variety of disorders. Rosemary essential oil contains 10-20% camphor, although the chemical composition can vary greatly in different regions (3, 5, 6, 7). Also, external environmental conditions such as temperature, humidity, amount of precipitation, hours of sunshine, nature of the soil where the plant grows, etc. also have an impact on the chemical profile of the plant. This is the reason why we undertook this study to analyze the chemical constituents of cultivated plants of Rosmarinus officinalis in January 2025. Another reason is the fact that the plant is used almost all year round in a fresh or dried state, especially in food preparation. The components of essential oils are usually compounds with lower boiling points (generally from 120 to 150 Celsius degree) and most of them are very slightly soluble in water. These properties make hydro-distillation and/or steam distillation appropriate for obtain essential oils in laboratory and/or industrial scale. This is the most used method for extracting essential oils, but the polar and relatively hydrophilic compounds of the essences are not completely obtained from the plant and compounds with unstable chemical nature such as aldehydes, esters, etc. can undergo modifications under the action of temperature, water vapor and oxygen during the distillation process. The determination of the chemical structure and the percentage amounts of the components of each essence is carried out by gas chromatography and mass spectrometry analyses (4, 6,7, 8). In this study, hydro-distillation with a Clevenger apparatus was used for dried branches and leaves of rosemary samples (cultivated plants from Central Albania) followed by GC/FID determination.

Material and Methods

Materials and Reagents

High purity n-Hexane and Toluene (GC grade) were provided by Merck (Darmstadt, Germany). The mixture of n-alkanes from n-octane (C8) to eicosanes (C20) were used for the calculation of Kovats indices (KI) in GC/FID technique.

Sampling of *Rosmarinus officinalis* plants

Samples of *Rosmarinus officinalis* (branches with their leaves) were collected from cultivated populations of Lalez Bay, Durres area. Samples of rosemary were collected in January 2025. The samples were air dried in the shade to avoid losing morphological characteristics. The plant material was cut into small pieces (0.5-2 cm) before the extracting process.

Isolation of essential oils for *Rosmarinus officinalis*

The plant material of *Rosmarinus officinalis* (100 g of fresh or dry plant of Rosmarinus Officinalis) was subjected to hydro-distillation for 4 hours by using the Clevenger type apparatus (recommended by European Pharmacopeia, 2014) for the isolation of the essential oil. The essential oil was collected in 2 ml of Toluene as the extraction solvent. The extract was dehydrated by adding 1 g of anhydrous sodium sulfate. It was stored in dark vials at +4°C. The essential oil of *Rosmarinus officinalis* was subject of GC/FID analysis (8; 9).

Gas chromatographic apparatus and analysis

Gas chromatographic analysis of the essential oil of *Rosmarinus officinalis* was performed on a Varian 450 GC apparatus, equipped with a PTV injector and a flame ionization detector (FID). The injector and detector temperatures were set at 280°C and 300°C, respectively. 2 µl of essential oil (diluted in toluene) was injected in split mode (1:50). Nitrogen was used as carrier gas (1 ml/min) and make-up gas (25 ml/min). Hydrogen and air were the detector the flame gases at 30 ml/min and 300 ml/min, respectively. A VF-1ms capillary column (30 mx 0.33 mm x 0.25 um) was used to isolate the compounds in rosemary essential oil. The oven temperature was programmed as follows: from 50°C (held for 2 minutes at 50°C) to 150°C at 4°C/min, then to 280°C at 10°C/min, held at 280°C for 10 minutes. Identification of the compounds was based on the comparison of the retention times (RT) and the Kovats indices. The quantitative data of the analyzed compounds were shown in percentage: the respective peak area to the total areas of all peaks, excluding Toluene peak (6; 7; 8).

Result and Discussion

The essential oil of cultivated *Rosmarinus officinalis* plants from Durres area (Central Albania) were analyzed using the GC/FID technique. Up to 100 compounds were detected in the chromatograms for rosemary samples. The data represent only the data for the 22 main compounds that were found for all analyzed samples. The peaks with lower area than 0.05% were not considered in this study. Table 1 shows the averages, minimum, maximum and standard deviation for the percentages of compounds detected from the analysis of *Rosmarinus officinalis* essential oil samples. The total percentage of 22 main compounds was 92.5%. Peaks with area lower than 0.05% were not considered in this study. Table 1 shows the averages, minimum, maximum and standard deviation of main compounds for analyzed samples. For all samples the main compounds were alpha-Pinene, Cineole, Camphor, alpha-Terpineol, Verbenone, Camphene and Linalool (Figure 1). This is a similar profile reported for rosemary plants in other studies from Albania and Mediterranean countries (7-11).

Figure 2 shown profile for the terpene classes in rosemary samples. Their profile was: oxygenated monoterpenes > bicyclic monoterpenes > monocyclic monoterpenes > aromatic monoterpenes > aromatic monoterpenes > sesquiterpenes. Again, this is a terpene profile reported in other studies from Albania and/or Mediterranean countries (7-11). High levels of oxygenated compounds are characteristic for the chemical profiling of rosemary plants regardless of whether they are fresh or dried, or at different times of the year.

Figure 3 shown the percentages of the main groups of compounds found at rosemary samples from Central Albania. Total of oxygenated monoterpenes was 59.3%. Cineol (19.8%) and after that Camphor (12.3%), Borneol (8.6%) and Verbenone (8.1%) were found in higher percentage. Other oxygenated terpenes (Linaleol, Bornyl Acetate, alpha-Terpineol, Terpilen-4-ol and Terpinyl Acetate) were found in lower percentage (from 0.6 to 4.1%).

Figure 4 shown the individual percentages for bicyclic monoterpenes which was the second contributor group in rosemary samples. Alpha-Pinene was found higher with 18.3%. It was the

second compound after the Cineol. Camphene and beta-Pinene were found respectively with 5.5% and 1.6%. Also, the profile of bicyclic monoterpenes was similar to previous reports on this plant (7-11).

Figure 5 shown percentages of monocyclic monoterpenes in rosemary samples from Durres area. Phellandrene, alpha-Terpinene, gamma-Terpinene, Limonene and Terpinolene were found with a total of 3.6%. Limonene was the main compound of this group at about 2.5%. The other compounds were less than 0.5%. In general, their levels were lower than in previous reports (7-11).

Figure 6 shown levels of aliphatic monoterpenes (Myrcene) and aromatic monoterpenes (p-Cymene and Estragol). Myrcene was about 1.6% while the total aromatic terpenes were about 3%. Their presence is similar to previous reports of this class (7-11).

Figure 7 shown the percentages for sesquiterpenes in rosemary samples. Total of alpha-Humulene and beta-Caryophyllene were with 0.8%. This should be related not only to the chemical profile of the plant but also to the processes of terpene metabolism which depend on external atmospheric conditions (air temperature, humidity, amount of precipitation, hours of sunshine, etc.). Myrcene was about 1.6% while the total aromatic terpenes were about 3%. Their presence is similar to previous reports of this class (7-11).

Figure 7 shown the percentages for sesquiterpenes in rosemary samples. Total of alpha-Humulene and beta-Caryophyllene were with 0.8%. This should be related not only to the chemical profile of the plant but also to the processes of terpene metabolism which depend on external atmospheric conditions (air temperature, humidity, amount of precipitation, hours of sunshine, etc.).

Table 1. Percentages of the main compounds for the essential oil of *Rosmarinus officinalis* from Central Albania

	Mean	Min	Max	STDEV
alfa-Pinene	18.670	16.620	20.730	1.701
Camphene	4.952	3.220	6.210	1.277
beta-Pinene	1.980	1.080	3.280	1.187
Myrcene	1.554	1.210	2.160	0.365
alfa-Felandrene	0.460	0.200	1.250	0.443
alfa-Terpinene	0.302	0.200	0.480	0.105
para-Cimene	1.664	1.550	1.770	0.091
Limonene	2.488	1.480	3.400	0.786
Cineol	19.790	18.650	22.830	1.724
gamma-Terpinene	0.372	0.330	0.400	0.027
Terpinolen	0.630	0.490	0.690	0.080
Linalool	4.070	2.680	4.860	1.060
Camphour	12.254	11.360	14.840	1.472
Borneol	8.692	6.730	9.730	1.154
alfa-Terpineol	0.642	0.120	1.160	0.472
Terpinen-4-ol	1.140	0.160	2.130	0.727
Estragol	1.358	0.410	2.300	0.752
Verbenon	8.124	5.580	11.280	2.508
Bornyl acetat	1.348	0.840	2.180	0.510
Terpinil acetat	1.202	0.470	1.570	0.456
beta-Cariophyllene	0.452	0.240	0.810	0.261
alfa-Humulene	0.354	0.240	0.540	0.113
Total	**92.498**	**90.210**	**95.090**	**1.853**
Bicyclic monoterpene	25.60	20.92	30.22	4.17
Monocyclic monoterpene	3.62	2.21	5.53	1.36
Alifatic monoterpene	1.55	1.21	2.16	0.37
Aromatic monoterpene	3.02	1.96	4.07	0.84
Oxygenated monoterpene	59.25	47.49	73.57	10.91
Sesquiterpene	0.81	0.48	1.35	0.37

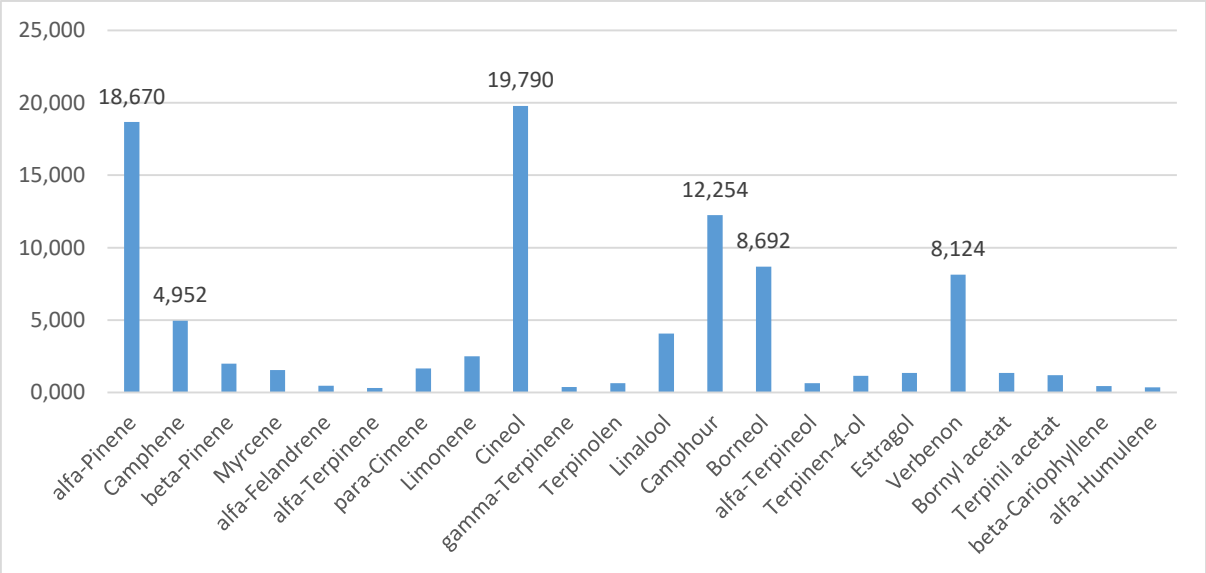


Figure 1. Percentages of main compounds in the essential oil of Rosmarinus officinalis

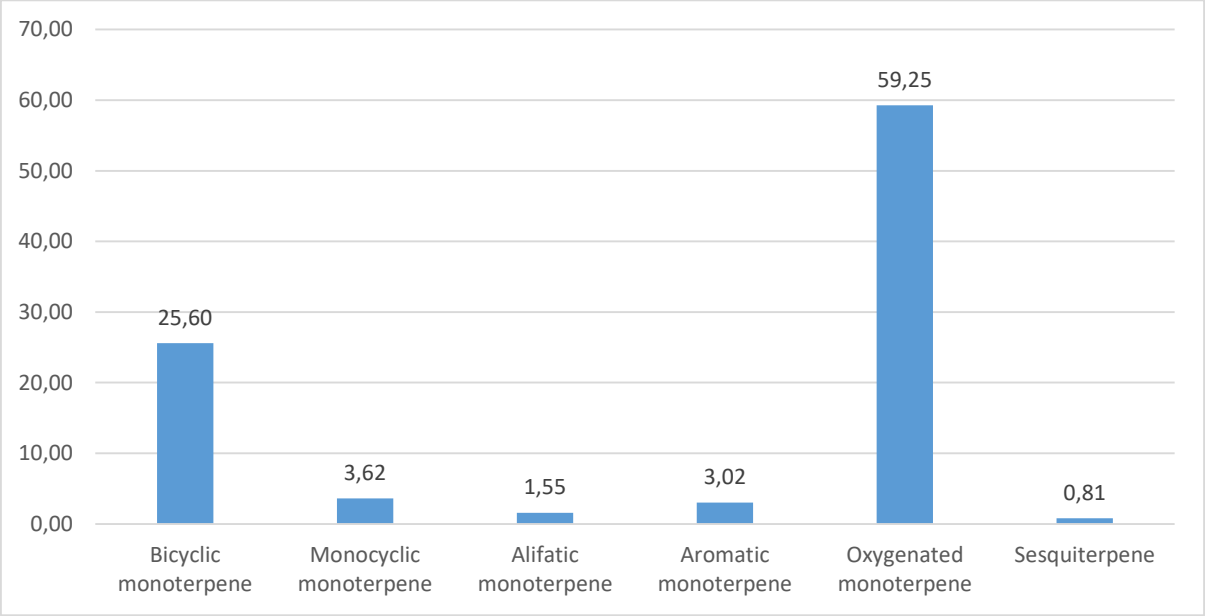


Figure 2. Distribution of terpene classes in the essential oil of rosemary

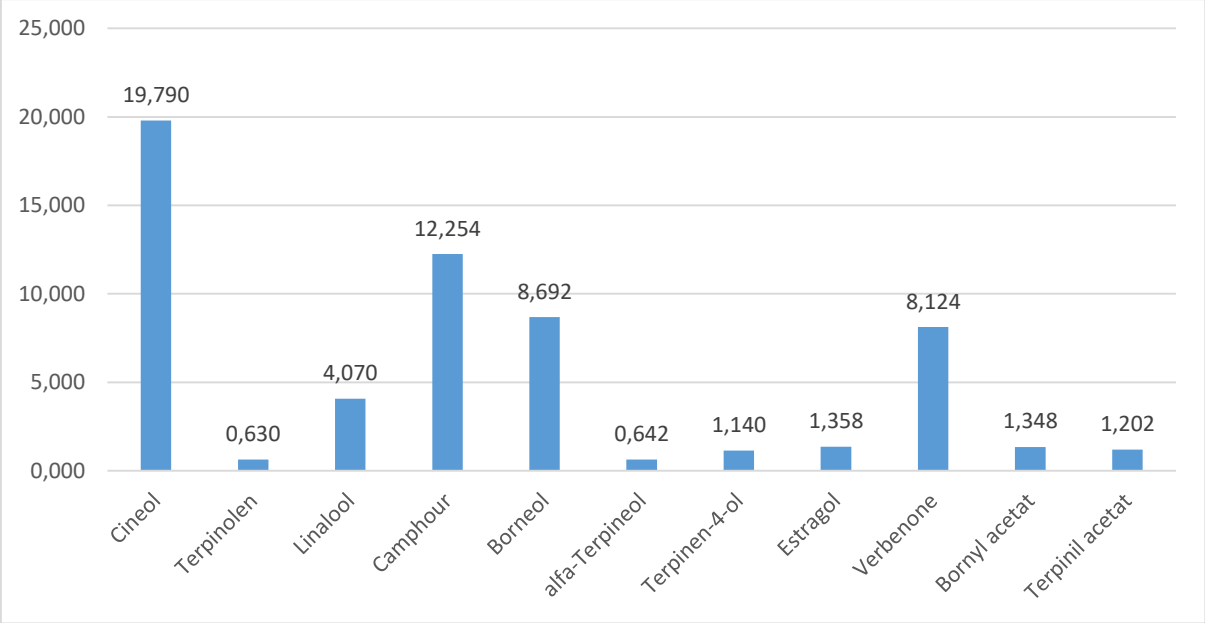


Figure 3. Oxygenated monoterpenes in the essential oil of rosemary samples

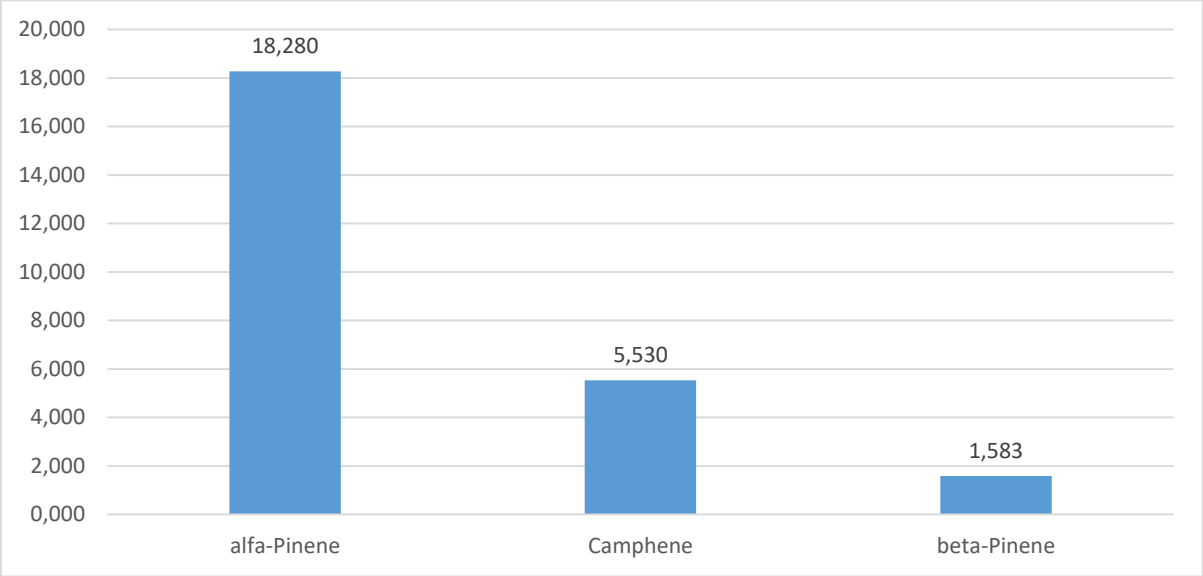


Figure 4. Bicyclic monoterpenes in the essential oil of rosemary samples

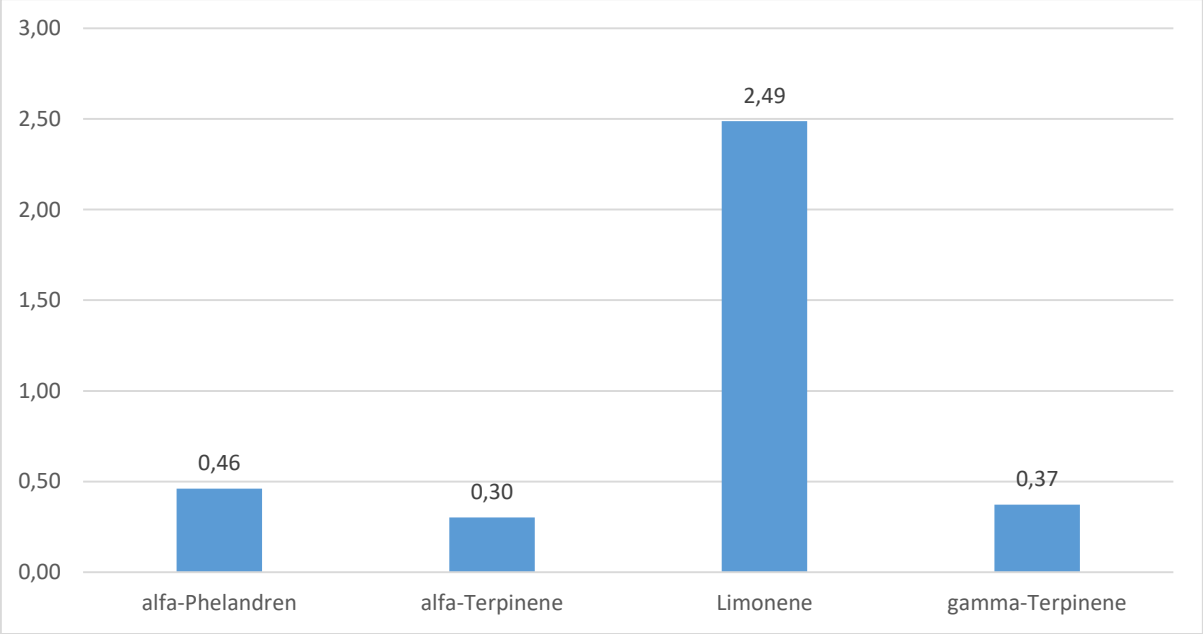


Figure 5. Monocyclic monoterpenes in the essential oil of rosemary samples

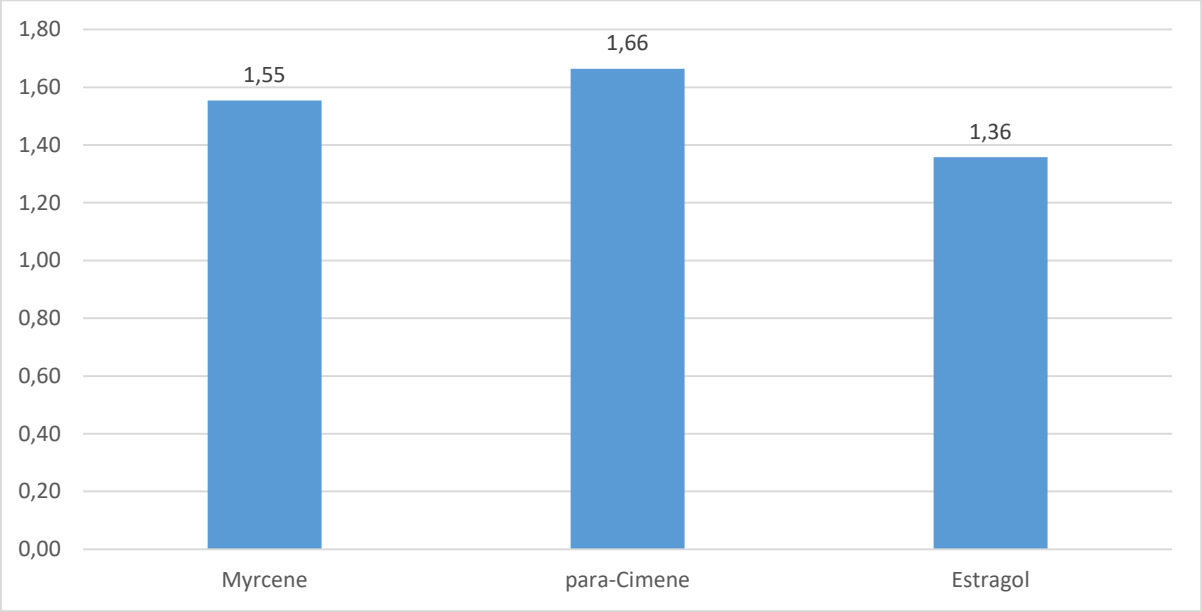


Figure 6. Aliphatic and aromatic monoterpenes in the essential oil of rosemary samples

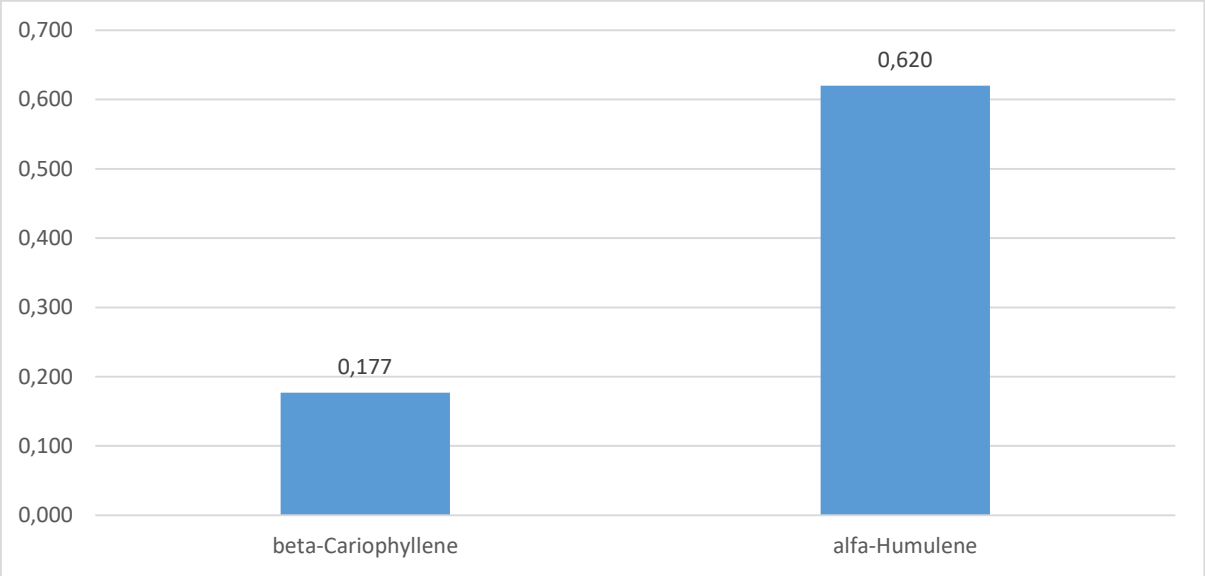


Figure 7. Sesquiterpenes in the essential oil of rosemary samples

Conclusions

This study shown chemical composition of the essential oil of *Rosmarinus officinalis* samples from Central Albania (Durres area). The samples were analyzed by using hydro-distillation technique followed by GC/FID technique. The data presents 22 main compounds that were found for the essential oils *Rosmarinus officinalis* cultivated plants in January 2025. The main compounds that were found in most abundance in analyzed plants were: alpha-Pinene, Cineol, Camphor, alpha-Terpineol and Verbenone. The profile and levels of compounds for rosemary samples from the Central Albania were similar to other studies reported from the Mediterranean and Balkan Peninsula areas (7-11). The main contribution to the essential oil of rosemary is for oxygenated monoterpenoids where the main levels belong to Cineole, Camphor and Borneol. After that were bicyclic monoterpenes. Alfa-Pinene was the second contributor after the Cineole. Aromatic monoterpenes was the third class and after that monocyclic monoterpenes.

Sesquiterpenes have the smallest contribution to rosemary essences. The chemical profile of rosemary plants from Central Albania was similar to other reports from Albania regardless of the study area or the time of their harvest. The influence of external factors such as temperature, humidity, hours of sunshine, soil quality, etc. have an impact on the levels of chemical individuals that the plant has. This is the reason why there are also differences in previous reports for this plant.

References

1. Uran Asllani "Esencat e bimëve aromatike shqiptare", (2004). Tiranë

2. Wolfgang Kathe, Susanne Honnef & Andreas Heym. "Medicinal and Aromatic Plants in Albania, Bosnia-Herzegovina, Bulgaria, Croatia and Romania". A study of the collection of and trade in medicinal and aromatic plants (MAPs), relevant legislation and the potential of MAP use for financing nature conservation and protected areas" WWF Deutschland / TRAFFIC Europe-Germany (2003).

3. Bozin B., Mimica-Dukic N., Simin N., Anac-kov G., "Characterization of the volatile composition of essential oils of some Lamiaceae spices and the antimicrobial and antioxidant activities of the entire oils", J. Agric. Food Chem.,54, (2006) 1822-1828.

4. Bibi, S. , Shazia, I. , & Zahoor, A. B. (2016). Chemical composition of REO (Rosmarinus officinalis L.) leaves under salt stress. Pure and Applied Biology, 2, 355–360.

5. Borges, R. S. , Ortiz, B. L. S. , Pereira, A. C. M. , Keita, H. , & Carvalho, J. C. T. (2019). Rosmarinus officinalis essential oil: A review of its phytochemistry, anti-inflammatory activity, and mechanisms of action involved. Journal of Ethnopharmacology, 229, 29–45. 10.1016/j.jep.2018.09.038

6. Moore, J. , Yousef, M. , & Tsiani, E. (2016). Anticancer effects of REO (Rosmarinus officinalis L.) extract and REO extract polyphenols. Nutrients, 8(11), 731. 10.3390/nu8110731

7. *Inatani R., Nakatani N., Fuwa H. Antioxidative effect of the constituents of REO (Rosmarinus officinalis L.) and their derivatives. Agric. Biol. Chem. 1983;47:521–528. doi: 10.1271/bbb1961.47.521*

8. Adams RP., "Identification of essential oil components by gas chromatography/mass spectroscopy", Allured Publishing Cor-poration, (1995) Carol Stream: Illinois, USA.

9. Daferera D.J., Ziogas B.N., Polissiou M.G., "GC–MS analysis of essential oils from some Greek aromatic plants and their fungitoxicity on Penicillium digitatum", Journal of Agricultural Food Chemistry, 48, (2000) 2576–2581.

10. David F., Scanlan F., Sandra P., Szelewski M., "Analysis of essential oil compounds using retention time locked methods and retention time databases, Application, Agilent Technologies", (2010), 5988-6530EN.

11. Akhbari, M. , Masoum, S. , Aghababaei, F. , & Hamedi, S. (2018). Optimization of microwave assisted extraction of essential oils from Iranian Rosmarinus officinalis L. using RSM. Journal of Food Science and Technology, 55(6), 2197–2207. 10.1007/s13197-018-3137-7

ERGONOMIC ADVANCES IN URBAN FOLDING BIKES: A CASE STUDY OF THE BROMPTON T LINE 4-SPEED AND TERN VERGE X11

Dr. Nguyen Thi Bich Van

Faculty of Interior Architecture, University of Architecture Hochiminh City, Vietnam

Tong Hoang Bao Giang

Institute of International Education, University of Architecture Hochiminh City, Vietnam

Abstract

Urban folding bicycles have increasingly garnered attention as compact, efficient, and adaptable solutions to meet the evolving demands of contemporary urban commuting. Within this framework, ergonomic considerations have emerged as a critical component of product innovation, reflecting a growing alignment with user-centered design and modern consumer expectations. This study examines the ergonomic advancements embodied in two prominent models: The Brompton T Line 4-speed and the Tern Verge X11 by evaluating aspects such as rider comfort, folding and unfolding efficiency, and overall maneuverability. Through a comparative analysis, the research emphasizes the rising prioritization of human-centered design principles in the development of urban mobility technologies. The findings reveal a heightened focus on human factors in the design of folding bicycles, offering valuable insights for future ergonomic enhancements in this domain.

Keywords: urban folding bicycle, ergonomic design, human factors, sustainable mobility,

commuter comfort, ergonomic advances in urban folding bikes

Introduction

Urban environments are facing increasing challenges related to traffic congestion, air pollution, and limited transport capacity. In response, urban policy in many cities is gravitating towards the promotion of non-motorised modes of transport, particularly walking and cycling, as a means to improve public health, reduce environmental burdens, and support broader societal goals (Reduce & Transit, n.d.). This growing focus is reflected not only in policy changes but also in efforts to reorganize infrastructure to better support these modes. Governments are also shifting away from car-centric urban development (Peñalosa, 2004) and showing growing interest in creating walkable, bike-friendly environments, while also paying more attention to developing multimodal transport systems that combine active travel with public transport. In this context, bicycles have gained renewed interest as a practical and sustainable alternative for urban commuting, not only for short-distance travel but also as a key component in connecting with larger public transportation systems (Geurs et al., 2016). Folding bicycles, in particular, are receiving increased attention for their ability to meet the specific demands of dense urban environments. Their compact form and ease of transport make them well-suited for integration with public transit systems, allowing users to transition smoothly between cycling and other modes of travel (Vervisch et al., 2018). They also offer practical advantages in dense urban environments, as they are easier to store in limited or restricted spaces, such as offices, apartments, or other indoor areas (Roh et al., 2018).

Despite their benefits, folding bikes continue to face several ergonomic challenges. Limited adjustability can result in poor posture and increased risk of injury, especially when the design does not accommodate a range of body sizes or cycling styles. Improper fit has been linked to discomfort, repetitive musculoskeletal issues, and reduced performance (Dias Scoz et al., 2025; Streisfeld et al., 2017). Many models are also reported to have excess weight and bulk, making them harder to carry when folded. (Vervisch, Christiaens, & Detand, 2018). In addition, folding mechanisms are often complex or unintuitive, slowing down transitions and requiring precise handling, which may not align with the fast pace of daily commuting. Other design limitations, such as small wheel sizes and mid-frame joints, tend to reduce riding comfort and stability compared to standard bicycles (Maleque et al., 2012).

However, recent developments in material use, frame design, and folding systems have resulted in noticeable improvements in the performance and user experience of folding bicycles in daily urban contexts. This study aims to investigate the role of ergonomics in the evolution of folding bike design, with a particular focus on recent models and their implications for urban mobility. This study addresses the following questions:

- How have ergonomic innovations been incorporated into recent folding bike models, and how do these improvements address common ergonomic challenges associated with folding bicycles?
- What does an ergonomic focus in folding bike design reveal about the role of human factors in shaping urban mobility products?
- To what extent do ergonomic advancements enhance the practicality and effectiveness of folding bikes for urban mobility, and how might these improvements influence the adoption of cycling for urban commuting?
- What implications do human-centered design features in folding bikes hold for future innovations in folding bike design, as well as bicycle and product design more broadly?

To answer these questions, a case study of two high-performance models, the Brompton T Line 4-speed and the Tern Verge X11 was conducted, both bikes were designed for urban commuting, with differing folding mechanisms but sharing comparable qualities in weight, size, and functional features.

Methodology

This study adopts a multi-method approach to investigate the ergonomic advancements of the Brompton T Line 4-speed and the Tern Verge X11 folding bikes.



Figure 1: *Brompton T Line – 4-speed folding bicycle (Photo from Brompton Bicycle)*



Figure 2: *Tern Verge X11 folding bicycle (Photo from Tern Bicycle)*

Observation from Online Sources

This study focused on young commuters aged 25 to 45, identified as the demographic with the highest market potential (Vervisch et al., 2018). A total of 20 videos were selected from platforms such as YouTube and manufacturers' websites. Ths selection was based on their relevance to urban commuting, clear demonstration of key actions (e.g., folding, unfolding, riding, and carrying), and credibility of the uploader (e.g., professional reviewers or experienced cyclists). The observations focused on rider posture, bike handling, folding procedures, and overall user interaction. Key features were coded under common ergonomic themes such as comfort, usability, and physical effort.

Secondary Data Collection

Technical specifications and product information were gathered from the official Brompton and Tern websites, along with third-party review platforms and cycling publications. These sources provided detailed data on weight, frame geometry, folded dimensions, construction materials, locking mechanisms, and innovative traits specific to each model. In addition, the study examined peer-reviewed literature related to bicycle ergonomics and folding bike usability to support the evaluation framework. Relevant research on ergonomic qualities were reviewed to identify which design aspects or modifications are most beneficial to the models' usability, particularly in terms of comfort, folding efficiency, and ease of handling. These findings helped inform the selection of comparison criteria and provided theoretical support for interpreting the observed innovations in both models.

Comparative Analysis

Both models were compared across four ergonomic categories, selected based on recurring themes in the reviewed literature and observed user needs in urban commuting:

- User Fit and Adjustment: Assessed through factors such as rider-bike fit, adjustable components, and customization options that influence posture, comfort, and adaptability to different body types.
- Folding and Unfolding Efficiency: Evaluated by analyzing the number of steps required, folding time, locking complexity, and intuitiveness of the mechanism.
- Handling and Portability: Considered in terms of weight distribution, folded size, and the overall ease of transporting the bike
- Riding Performance: Assessed based on frame compliance and stability during different riding conditions, reflecting how design and material choices affect control and ride quality.

Findings from all three methods were cross-referenced to identify consistent ergonomic patterns and innovations. This triangulated approach aimed to reduce bias and provide a reliable overview of how each model addresses ergonomic concerns in the context of urban commuting.

Results and Discussion

The results of this section, presented through a comparison of the two folding bike models, illustrate the different approaches to addressing ergonomic challenges and how these design changes influence the overall user experience. The findings also reflect the growing attention given to ergonomics in contemporary folding bike design.

Ergonomic Customization and User Fit

One key issue in folding bike design is the limited scope for customization, which can hinder proper bike fitting and reduce overall user comfort. This concern has been acknowledged in bicycle retail and design literature, where the demand for personalized products has driven manufacturers to explore modularization and flexible design strategies (Jafari et al., 2015; Yazdanparast et al., 2010; Brun et al., 2009; Randall et al., 1998).

Both the T Line 4-Speed and the Verge X11 demonstrate parallel innovation in modular design, enabling personalized ergonomic fit through component interchangeability. In both models, riders can upgrade or replace key contact-point components such as saddles, pedals, grips, and even handlebars from stock or aftermarket lines (e.g., Ergon grips and saddles on the Verge, and Brompton-compatible saddles, grips, pedals). This modularization allows for fine-tuning of comfort and fit, tailored to individual anatomy or riding style preferences. While both models support modular customization, they differ in how ergonomic adjustability is integrated into their core design.

The Brompton T Line 4-Speed incorporates several design considerations that address bike fitting. Although the handlebar height is fixed within each model, users can choose between distinct handlebar types: flat, mid, or high rise, each designed to suit different ergonomic preferences. It also includes a height-adjustable seat post that accommodates a wide range of body proportions and riding postures (its carbon seat post comes in both standard (535 mm) and extended (595 mm) lengths, accommodating a wide range of rider inseam proportions). In addition, the Pentaclip saddle clamp allows precise fore-aft and tilt adjustment and provides approximately 20 mm of height variation depending on orientation. These design options together allow riders to tailor saddle position, handlebar reach, and overall fit without compromising the compact folding architecture.

The Verge X11 emphasizes bike adjustability to support a broad range of riding styles and user proportions. Its adjustable Syntace VRO stem allows users to position the handlebar either further forward for a more aggressive sport oriented posture or higher for increased upright comfort. Similar to the Brompton model, the bike's seat post can easily be adjusted to accommodate varying torso lengths, enabling a more personalized ergonomic setup.

Weight and Folded Dimensions

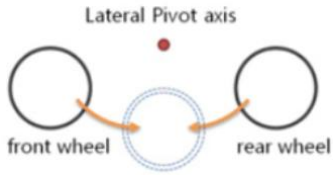
Material innovation is a key advancement in the development of modern folding bicycles, addressing earlier limitations related to weight and portability. Traditionally, folding bikes were constructed from heavier materials such as steel or aluminum alloys, which increased overall weight and made them less convenient to carry or transport when folded.

The Brompton T Line 4-Speed uses a full titanium Grade-9 frame complemented lightweight components, including a carbon crankset, seat post, fork, and handlebar, achieving a base weight of approximately 7.95 kg for the 4-speed version. The bike folds down to just 64.0 × 58.0 × 27.0 cm, making it one of the most compact folding bicycles available.

The Tern Verge X11 features a hydro-formed 7005-aluminum alloy frame with smooth TIG welding, offering a strong yet lightweight build at 10.2 kg. Weight reduction is further supported by carbon components, such as the SRAM Force 1 crankset. Its folded dimensions measure approximately 80.0 × 74.0 × 38.0 cm, which is noticeably larger than the T Line. While being bulkier, the Verge X11 still provides a reasonably compact package for urban commuting and storing.

Folding Mechanisms and Portability

Another notable challenge for folding bicycle users is the complexity and physical demands of the folding process. Ease of folding is closely linked to the type of folding mechanism, which is determined by the number and orientation of pivot axes (Hyeong et al., 2016). This is particularly important for commuters who combine cycling with other forms of public transportation, as they must be able to fold and unfold their bicycles repeatedly. To address this, designers have explored more effective pivot orientations and simplified locking mechanisms, resulting in more intuitive and quick folding systems.



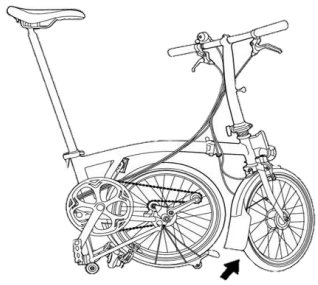
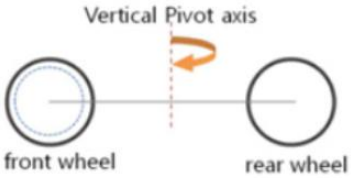


Figure 3: *Lateral Fold (Top illustration from Hyeong et al., 2016. Bottom illustration from Brompton Bicycle)*



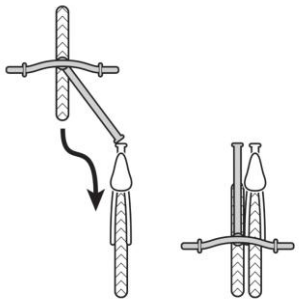


Figure 4: *Vertical Fold (Top illustration from Hyeong et al., 2016. Bottom illustration from Tern Bicycle)*

The Brompton T Line 4 Speed utilizes a multi stage lateral folding system (Fig. 3). The folding sequence includes swinging the rear wheel, unlocking the main frame hinge to bring the front wheel alongside the rear, lowering the seat post to lock the folded parts in place, and finally folding down the handlebar post, resulting in a compact, self-standing, and portable package. Additionally, small transport wheels integrated into the rear frame enable the folded bike to be rolled like a suitcase by holding the saddle. The bike also features intuitive clamp style hinges and tactile locking actions, creating a seamless and user friendly folding/unfolding experience.

In comparison, the Tern Verge X11 employs a vertical fold or half fold mechanism (Fig. 4), with a pivot axis perpendicular to the ground that allows the wheels to fold side by side. Folding continues by lowering the seat post and folding down the handlebar post. Its OCL frame joint provides secure locking with limited mechanical complexity, enabling users to fold the bike in approximately 10 seconds. When folded, the bike can stand on its own, and can be transported in various ways, such as being rolled like a suitcase on its own wheels, carried on the shoulder, or placed in a dedicated carry bag.

Riding Performance

Folding bicycles are often perceived as lacking the performance capabilities of non-folding bikes. To reduce folded dimensions, the structural geometry of a conventional bicycle must be modified and integrated with hinge assemblies. In the case of the Brompton T Line 4-speed and the Tern Verge X11, both models feature a monotube frame design instead of the traditional diamond one, which improves folding efficiency but may reduce structural strength and load-bearing capacity. Additionally, folding bikes frequently utilize smaller wheel diameters, which can compromise frame compliance and increase exposure to cycling-induced vibrations and impact forces. These factors contribute to greater fatigue stress on the rider, especially during longer commutes or when traveling over uneven surfaces (Shah et al., 2020).

One structural innovation addressing the related concerns is the use of oval rather than circular tubing in key frame sections. In conventional diamond-frame bicycles, round tubing is commonly used for the triangulated geometry's ability to distribute loads evenly, ensuring structural stability. In contrast, monotube folding bike frames concentrate most of the structural stress along a single main tube. Finite element analysis shows that von Mises stress distribution

often reveals critical areas at the tube joint located beneath the rider's position, where vertical loads are highest. To address this, some designs employ ovalised tubing, which increases vertical stiffness, improves the safety factor, and provides greater resistance to deformation compared to circular tubing (Cahyono et al., 2017).

Beyond frame geometry, innovations in material selection and component design have also contributed to improved riding performance. The Brompton T Line uses titanium for its frame, a material recognized for its high stiffness-to-weight ratio and moderate compliance, which contributes to effective vibration damping and reduced rider fatigue stress (Shah et al., 2020). Despite its significantly smaller wheel size (349 mm vs. 622 mm on standard urban bicycles), the Brompton's frame design and clamp-style lateral hinge system offer stable handling and structural integrity, reducing flex and minimizing physical strain during riding. As for the Tern Verge X1, the bike employs a hydro-formed aluminum frame, which exhibits lower compliance than titanium but offers cost advantages. To compensate for this, the model is equipped with larger 451 mm wheels (which are closer in scale to standard 700C wheels) enhancing ride quality by mitigating surface impact and cycling stress. Furthermore, Verge X11's proprietary hinge system reinforces the typically weaker joints and folding points, resulting in improved stability and structural performance. This is achieved by increasing hinge height and moving the pivoting surfaces outward to enhance torsional rigidity, integrating four igus bearings between stainless steel and aluminum components for smooth, low-friction motion, and employing an interlocking joint that eliminates lateral flex. Additionally, the AutoLock mechanism adds a secondary locking layer for enhanced safety.

Discussion

Both models incorporate a variety of customization opportunities and optimize their folding mechanisms with simplified pivot axes and minimal safety locks for faster, more intuitive operation. The models also employ lightweight, high-strength materials and incorporate hinge and lock-point designs that reinforce weaker joints and folding points, helping to mitigate the structural limitations that come with achieving a compact size. Lastly, when it comes to portability, the Brompton model uses small transport wheels for rolling when folded, while the Tern one offers multiple carrying options, including compatibility with the brand's transport bags.

This highlights that human factors are now central in shaping urban mobility products, as revealed by the recent ergonomic focus in folding bike design. Manufacturers are now looking at the broader picture of the overall user experience, considering every point of human interaction. This means designing folding bikes that not only function as compact and practical alternatives to conventional bicycles, but also offer comfort, easy operation, safety, and strong riding performance. Such priorities demonstrate that human factors directly influence the final design solution, determining how effectively a product meets the practical demands and quality-of-use expectations of urban commuters.

Additionally, by addressing users' concerns through ergonomic advancements, folding bike design can encourage greater adoption for urban commuting. In "Analysis of "Element" Folding Bike Purchase Decision with Motivation as an Intervening Variable", Pribadi and Chan (2023) report that comfort, ease of folding, and portability are major factors influencing purchasing decisions. These align closely with the ergonomic attributes of the compared models, suggesting that such design improvements can significantly enhance user satisfaction and, in turn, promote wider adoption of folding bikes for daily commuting. Similarly, in "Not all prospective bicyclists are created equal: The role of attitudes, socio-demographics, and the built environment in bicycle commuting", Heinen, Maat, and van Wee (2011) identify several barriers for potential cyclists: lack of secure storage at workplaces, fear of theft or vandalism, difficulties taking a bike on public transit, and challenges in carrying heavy loads. The ergonomic features outlined in the previous section, such as compact folding dimensions,

reduced weight, and ease of carrying directly respond to these issues. For example, a smaller folded size and lighter frame make it easier to bring the bike indoors, solving storage and theft concerns, while portability improvements address the difficulties of taking it on transit or moving it when not riding. These connections show how targeted ergonomic design can remove practical obstacles and encourage hesitant riders to commute by bike.

Finally, these findings suggest that future innovations in folding bike and product design can incorporate ergonomic enhancements through varied strategies aligned with brand-specific objectives. Designers should also address the entire chain of user interactions to ensure that all stages are seamlessly integrated, as a cohesive user experience cannot be achieved through isolated improvements in any single aspect.

Conclusion

The study highlights the growing integration of ergonomic advancements in contemporary folding bike design, reflecting an increasing prioritization of user experience. Through the comparative analysis, it was shown that ergonomic challenges can be addressed and design enhancements implemented in multiple ways, while maintaining alignment with brand-specific objectives, target user groups, and varied riding contexts (e.g., sport, urban commuting, or mixed terrain). These advancements not only improve operational efficiency but also have the potential to encourage wider adoption of folding bikes in urban environments, thereby contributing to sustainable mobility and environmental benefits.

The findings of this research contribute to the body of knowledge on the relationship between ergonomics and product design, offering practical insights for designers, manufacturers, and policymakers. Furthermore, the study serves as a guideline for future developments in folding bike design and product design more broadly by emphasizing the integration of human factors and user experience considerations into the design process.

It is important to note that this study focuses on design analysis and user interaction with existing models, without incorporating quantitative performance testing or user surveys. Future research should consider empirical evaluations to validate design effectiveness and strengthen the evidence base for ergonomic innovations in urban mobility products.

References

1. Arunachalam, M., & Rajesh, R. (2014). A typical approach in conceptual and embodiment design of foldable bicycle. *International Journal of Computer Applications*, *87*(19).
2. Brompton Bicycle. (n.d.). *T Line (4-speed) urban folding bike*. Retrieved August 10, 2025, from Brompton website: https://www.brompton.com/p/830/t-line-urban-23
3. Brun, A., & Zorzini, M. (2009). Evaluation of product customization strategies through modularization and postponement. International Journal of Production Economics, 120(1), 205-220.
4. Bridger, R. (2008). Introduction to ergonomics. Crc Press.
5. Reduce, G. H. G., & Transit, B. R. Promotion of non-motorised transport.
6. Cahyono, S. I., Anwar, M., Diharjo, K., Triyono, T., Hapid, A., & Kaleg, S. (2017, January). Finite element analysis of electric bicycle frame geometries. In *AIP Conference Proceedings* (Vol. 1788, No. 1, p. 030084). AIP Publishing LLC.
7. Dias Scoz, R., Rui de Oliveira, P., Chamorro Pelegrina, C., Hespanhol, L., Augusto Melo-Silva, C., Filipe Teixeira de Júdice, A., ... & Ferreira Amorim, C. (2025). Effectiveness of a 3D bikefitting method in riding pain, fatigue, and comfort: a randomized controlled clinical trial. *Sports Biomechanics*, *24*(3), 624-637.

8. DINSDALE, N., & DINSDALE, N. (2014). MODERN-DAY BIKEFITTING CAN OFFER PROACTIVE THERAPISTS NEW OPPORTUNITIES. *SportEX Dynamics*, (39).

9. Emerson, N. J., & Hall, W. (2021). Design for ergonomics in the bicycle industry: an engineering design concept. *International Journal of Product Development*, *25*(1), 1-10.

10. Geurs, K. T., La Paix, L., & Van Weperen, S. (2016). A multi-modal network approach to model public transport accessibility impacts of bicycle-train integration policies. *European transport research review*, *8*(4), 25.

11. Habib, K. N., Mann, J., Mahmoud, M., & Weiss, A. (2014). Synopsis of bicycle demand in the City of Toronto: Investigating the effects of perception, consciousness and comfortability on the purpose of biking and bike ownership. *Transportation research part A: policy and practice*, *70*, 67-80.

12. Hyeong, J., Roh, J., & Kim, S. (2016). Optimization of pivot obliquity for a foldable bicycle. *International Journal of Precision Engineering and Manufacturing*, *17*(7), 931-936.

13. Jafari, H., Nyberg, A., Osnes, T. L., & Schmitz, A. (2015). Customization in bicycle retailing. *Journal of Retailing and Consumer Services*, *23*, 77-90.

14. Macdermid, P. W., Miller, M. C., Macdermid, F. M., & Fink, P. W. (2015). Tyre volume and pressure effects on impact attenuation during mountain bike riding. *Shock and Vibration*, *2015*(1), 191075.

15. Maleque, M. A., Hossain, M. S., & Dyuti, S. (2011). Material properties and design aspects of folding bicycle frame. *Advanced materials research*, *264*, 777-782.

16. Martens, K. (2004). The bicycle as a feedering mode: experiences from three European countries. *Transportation Research Part D: Transport and Environment*, *9*(4), 281-294.

17. Penalosa, E. (2004) Socially and environmentally sustainable transport. Presentation

18. Randall, T., Ulrich, K., & Reibstein, D. (1998). Brand equity and vertical product line extent. *Marketing science*, *17*(4), 356-379.

19. Priego Quesada, J. I., Pérez-Soriano, P., Lucas-Cuevas, A. G., Salvador Palmer, R., & Cibrián Ortiz de Anda, R. M. (2017). Effect of bike-fit in the perception of comfort, fatigue and pain. *Journal of sports sciences*, *35*(14), 1459-1465.

20. Pribadi, I., & Chan, S. (2023). Analysis of "Element" Folding Bike Purchase Decision with Motivation as Intervening Variable. *European Journal of Business and Management Research*, *8*(2), 96-102.

21. Piatkowski, D. P., & Marshall, W. E. (2015). Not all prospective bicyclists are created equal: The role of attitudes, socio-demographics, and the built environment in bicycle commuting. *Travel behaviour and society*, *2*(3), 166-173.

22. Roh, J., Hyeong, J., & Kim, S. (2018). Influence of folding mechanism of bicycles on their usability. *Applied ergonomics*, *69*, 58-65.

23. Rajak, D. K., Pagar, D. D., Menezes, P. L., & Linul, E. (2019). Fiber-reinforced polymer composites: Manufacturing, properties, and applications. *Polymers*, *11*(10), 1667.

24. Shah, J., Shah, S., Mehta, G., Gandhi, J., & Gor, M. (2020). Vertical stiffness of bicycle frame and its influence on rider comfort. *SN Applied Sciences*, *2*(10), 1629.

25. Streisfeld, G. M., Bartoszek, C., Creran, E., Inge, B., McShane, M. D., & Johnston, T. (2017). Relationship between body positioning, muscle activity, and spinal kinematics in cyclists with and without low back pain: A systematic review. *Sports health*, *9*(1), 75-79.

26. Servaas, M. (2000). The significance of non-motorised transport for developing countries: strategies for policy development

27. Sagot, J. C., Gouin, V., & Gomes, S. (2003). Ergonomics in product design: safety factor. *Safety science*, *41*(2-3), 137-154.

28. Tern Bicycles. (n.d.). *N-Fold Technology: The faster fold*. Retrieved August 10, 2025, from https://www.ternbicycles.com/en/tech/471/n-fold-technology

29. Vervisch, T., Christiaens, Y., & Detand, J. (2018). The design of a composite folding bike to improve the user experience of commuters. In *MATEC Web of Conferences* (Vol. 167, p. 01001). EDP Sciences.

30. Yazdanparast, A., Manuj, I., & Swartz, S. M. (2010). Co-creating logistics value: a service-dominant logic perspective. *The International Journal of Logistics Management*, *21*(3), 375-403.

CORROSION INHIBITION BY A IMIDAZOLIDINE DERIVATIVE (IMD_8) FOR CARBON STEEL IN MOLAR HYDROCHLORIC ACID: EXPERIMENTAL, QUANTUM COMPUTATIONAL, AND MOLECULAR DYNAMICS STUDIES

A.Bazit
Laboratory of Advanced Materials and Process Engineering, Faculty of Sciences, Ibn Tofail University, P.O. Box. 133, 14000 Kenitra, Morocco.

L. Adlani
Laboratory of Advanced Materials and Process Engineering, Faculty of Sciences, Ibn Tofail University, P.O. Box. 133, 14000 Kenitra, Morocco.

W. Guerrab
Laboratory of Medicinal Chemistry, Drug Sciences Research Center, Faculty of Medicine and Pharmacy, Mohammed V University in Rabat, Rabat, Morocco

D. Karra
Laboratory of Advanced Materials and Process Engineering, Faculty of Sciences, Ibn Tofail University, P.O. Box. 133, 14000 Kenitra, Morocco.

D. Benmessaoud left
Laboratory of Interface Materials and Environment, Faculty of Sciences Ain Chock, Hassan II University, B.P. 5366 Maârif, Casablanca, Morocco.

M. Zertoubi
Laboratory of Interface Materials and Environment, Faculty of Sciences Ain Chock, Hassan II University, B.P. 5366 Maârif, Casablanca, Morocco.

Y. Ramli
Laboratory of Medicinal Chemistry, Drug Sciences Research Center, Faculty of Medicine and Pharmacy, Mohammed V University in Rabat, Rabat, Morocco

H. Zarrok
Laboratory of Advanced Materials and Process Engineering, Faculty of Sciences, Ibn Tofail University, P.O. Box. 133, 14000 Kenitra, Morocco.

A. Zarrouk
Laboratory of Materials, Nanotechnology and Environment, Faculty of Sciences, Mohammed V University in Rabat, P.O. Box. 1014, Rabat, Morocco

M. El Hezzat
Laboratory of Advanced Materials and Process Engineering, Faculty of Sciences, Ibn Tofail University, P.O. Box. 133, 14000 Kenitra, Morocco.

Abstract

The present research is focused on conducting a newly synthesized imidazolidine derivative, (IMD_8) , as a corrosion inhibitor for carbon steel (CS) in molar hydrochloric acid (1M HCl) solution. Chemical and electrochemical techniques, namely Potentiodynamic polarization (PDP) and electrochemical impedance spectroscopy (EIS) were used to evaluate the effectiveness of the IMD_8 molecule, along with quantum chemical methods. The organic

compound was found to be a good anti-corrosion compound with a maximum inhibition efficiency (IE%) of 98% at 10^{-3} M. Consistent with the PDP results, the inhibitor IMD_8 acts as a mixed type inhibitor. The adsorption of IMD_8 on CS surface appears to follow the Langmuir model. Scanning electron microscopy (SEM) and UV-visible revealed the formation of a barrier film limiting the accessibility of corrosive ions to the CS surface. Theoretical studies were performed to support the results from experimental techniques (PDP and EIS). In addition, theoretical studies were conducted using density functional theory (DFT) and molecular dynamics simulation (MDS) to study the most reactive locations of the IMD_8 molecule and its adsorption process.

Key words: imidazolidine derivative; carbon steel; PDP/EIS; SEM/UV-visible; DFT/MDS.

DEVELOPMENT OF DOUBLE CROSS-LINKED ELASTOMERIC EXTERIOR COATINGS WITH BENZOPHENONE DERIVATIVES AND CALCIUM CARBOXYLATE IONS

BENZOFENON TÜREVLERİ VE KALSİYUM KARBOKSİLAT İYONLARI İLE ÇİFT ÇAPRAZ BAĞLANMIŞ ELASTOMERİK DIŞ CEPHE KAPLAMALARININ GELİŞTİRİLMESİ

Sinem BOYRAZ

Arge Uzmanı Marshall Boya ve Vernik San. A.Ş., Kocaeli / Türkiye

ORCID ID: https://orcid.org/0009-0008-0219-9486

Ahmet Can ÜNAL

Arge Müdürü Marshall Boya ve Vernik San. A.Ş., Kocaeli / Türkiye

ORCID ID: https://orcid.org/0000-0002-5443-8776

ABSTRACT

In this study, an innovative formulation has been developed to provide both high elasticity and superior mechanical strength in exterior paints. The photo-crosslinking mechanism of benzophenone derivatives under UV light has been combined with the ionic bridging effect of calcium carboxylate ions and applied in a binder matrix with a low glass transition temperature (Tg). Thanks to this dual cross-linking strategy, the paint film has been optimised not only for high UV resistance but also for structural flexibility and impact resistance.

The developed formulations were evaluated with variations in binder content ranging from 30% to 42% and PVC values ranging from 34% to 40%. Calcite and talc minerals of different sizes and morphologies were used as fillers. Within the scope of performance tests, the product's water transmission rate was measured at ≤ 0.1 kg/(m²·h^0.5), meeting the targeted success criterion. Additionally, the crack bridging property was classified as A4 class (>1250 µm) according to the EN 1062-7 standard, demonstrating superior performance in terms of film elasticity and resistance to surface tension. These indicators reveal that the formulation provides both waterproofing and effective protection against elastic surface tension.

The results obtained demonstrate that the dual-mechanism cross-linking provides an effective solution for exterior coatings and offers crack control beyond traditional systems. This developed system fills an important gap in the innovative product segment by offering long-term durability and user satisfaction in exterior applications.

Keywords: Benzophenone derivatives, calcium carboxylate, dual cross-linking, elastomeric exterior wall paint, crack bridging

ÖZET

Bu çalışmada, dış cephe boyalarında hem yüksek elastikiyet hem de üstün mekanik dayanımın aynı anda sağlanmasına yönelik yenilikçi bir formülasyon geliştirilmiştir. Benzofenon türevlerinin UV ışını altında gerçekleştirdiği foto-çapraz bağlanma mekanizması, kalsiyum karboksilat iyonlarının iyonik köprüleme etkisiyle birleştirilmiş ve düşük camsı geçiş sıcaklığına (Tg) sahip bir bağlayıcı matriks içinde uygulanmıştır. Bu çift mekanizmalı çapraz

bağlanma stratejisi sayesinde, boya filmi yalnızca yüksek UV dayanımı değil, aynı zamanda yapısal esneklik ve darbe direnci bakımından da optimize edilmiştir.

Geliştirilen formülasyonlar, %30–42 bağlayıcı oranı ve %34–40 PVC değer aralıklarında varyasyonlar ile değerlendirilmiştir. Dolgu olarak farklı boyut ve morfolojilerde kalsit ve talk mineralleri kullanılmıştır. Performans testleri kapsamında, ürünün su aktarım hızı ≤ 0,1 kg/(m²·h^0.5) değerinde ölçülerek hedeflenen başarı kriteri karşılanmıştır. Ayrıca çatlak köprüleme özelliği EN 1062-7 standardına göre A4 sınıfında (>1250 µm) konumlanarak, film elastikiyeti ve yüzey gerilimlerine karşı direnç bakımından üst düzey performans sergilemiştir. Bu göstergeler, formülasyonun hem su geçirimsizliği hem de elastik yüzey gerilimlerine karşı etkin koruma sağladığını ortaya koymaktadır.

Elde edilen sonuçlar, çift mekanizmalı çapraz bağlanmanın dış cephe kaplamalarında etkin bir çözüm sunduğunu ve geleneksel sistemlerin ötesinde çatlak kontrolü sağladığını göstermektedir. Geliştirilen bu sistem, dış cephe uygulamalarında uzun vadeli dayanıklılık ve kullanıcı memnuniyeti sunarak yenilikçi ürün segmentinde önemli bir boşluğu doldurmaktadır.

Anahtar Kelimeler: Benzofenon türevleri, kalsiyum karboksilat, çift çapraz bağlanma, elastomerik dış cephe boyası, çatlak köprüleme

RESEARCH ON THE ESTABLISHMENT OF AN EFFECTIVE OCCUPATIONAL ACCIDENT REPORTING SYSTEM

ETKİLİ BİR İŞ KAZASI BİLDİRİM SİSTEMİNİN OLUŞTURULMASINA YÖNELİK ARAŞTIRMA

Ahmet Aykut AKTAŞ

Yıldız Teknik Üniversitesi, İnşaat Fakültesi İnşaat Mühendisliği Bölümü, Hidrolik ABD, Davutpaşa, İSTANBUL

0009-0005-2536-5991

Ahmad Abu Arra

Yıldız Teknik Üniversitesi, İnşaat Fakültesi İnşaat Mühendisliği Bölümü, Hidrolik ABD, Davutpaşa, İSTANBUL

0000-0001-8679-175

Doç. Dr. Eyüp ŞİŞMAN

Yıldız Teknik Üniversitesi, İnşaat Fakültesi İnşaat Mühendisliği Bölümü, Hidrolik ABD, Hidrolik laboratuvarı 1.kat no:18 Davutpaşa, İSTANBUL

0000-0003-3996-9967

ABSTRACT

In this study, research was conducted based on the opinions of occupational safety experts, technical personnel, and labor inspectors working in the sector to ensure a more effective reporting of occupational accidents. Experts in the field know that certain shortcomings occur in the preparation of accident notification forms following occupational accidents. The most prominent issue in this process is the lack of detailed information recorded regarding how the accident occurred. The primary objective of the study is to establish a more effective occupational accident reporting system that can be utilized for compiling occupational accident statistics, enhancing the reporting processes, and most importantly, preventing the recurrence of such accidents. Within the scope of the research, current occupational accident reporting procedures were analyzed, and deficiencies and areas needing improvement were identified. Moreover, experts' evaluations were obtained regarding the content, preparation process, and standardization of occupational accident notification forms. According to the findings of the study, experts emphasized that the lack of detailed explanations about the incident's occurrence, the need for simplification of existing forms, the requirement for root cause analysis to be mandatory, and the necessity of sector-specific detailing are significant areas that require improvement. Additionally, it was suggested that individuals responsible for reporting should receive specialized training and AI-supported modules should be employed in the reporting process. 94.3% of experts emphasized the need to simplify accident reporting forms, 88.6% highlighted that data should be transparent and openly accessible, 77.1% stated that it is important for reporting forms to be prepared by professionals, and 80% emphasized that the section explaining how the incident occurred should be detailed according to sectoral characteristics and types of accidents. Additionally, 94.3% of experts stated that root cause analysis should be conducted in occupational accident reporting forms to enable a clearer

understanding of the incident. In comparison, 74.3% indicated that conducting such analysis could contribute to the development of policies aimed at accident prevention. Creating an accident reporting form that addresses these identified shortcomings and enhances the effectiveness of current processes—along with providing professional support in the preparation of such forms—will contribute to achieving consistency and transparency in occupational health and safety practices.

Keywords: Occupational accidents, occupational health and safety, occupational accident reporting system, occupational accident notification forms, AI-assisted monitoring; Open data and transparency.

ÖZET

Bu çalışmada iş kazası bildirimlerinin sağlıklı şekilde yapılabilmesi, eksiklerin tespiti ve atılabilecek adımların belirlenebilmesi için, sektörde çalışan iş güvenliği uzmanları, teknik personel ve iş müfettişlerinin görüşlerine dayalı bir araştırma yürütülmüştür. Yaşanan iş kazalarından sonra bildirim formlarının düzenlenmesi hususunda birtakım aksaklıkların yaşandığı konu üzerinde çalışan uzmanlar tarafından da bilinmektedir. Kaza bildirim formlarının düzenlenmesi sürecinde yaşanan aksaklıklardan en önemlisi, kazanın oluş şekline ilişkin ayrıntılı bilgilerin kayıt altına alınmamasıdır. Çalışmanın amacı iş kazası istatistiklerinin doğru şekilde derlenebilmesi, bildirim süreçlerinin sağlıklı yapılabilmesi ve en önemlisi yaşanan iş kazalarının tekrarlanmaması, için faydalanılacak kapsamlı bir kayıt sistemi oluşturulması olup, etkili iş kazası bildirim sistemi geliştirilmesine yönelik potansiyel iyileştirme alanları belirlenerek, stratejik öneriler ortaya konulmuştur. Araştırma kapsamında ilk olarak mevcut iş kazası bildirim süreçleri analiz edilmiş, bu sürecin eksik yönleri ve geliştirilmesi gereken alanlar belirlenmiştir. Sonrasında iş kazası bildirim formlarının içeriği, düzenlenme süreci ve standardizasyonuna dair uzman görüşlerine başvurularak, hazırlanan sorular üzerinden değerlendirmeleri alınmıştır. Araştırma sonuçlarına göre; özellikle olayın oluş şeklinin açıklanmasında net ifadeler kullanılmaması sebebiyle kaza bildirim formlarından olayın doğru şekilde anlaşılamadığı, mevcut bildirim formlarının daha yalın ve herkes tarafından anlaşılabilir olması, kök neden analizinin zorunlu hale getirilmesi ve sektörlere göre detaylandırılması gerektiği uzmanlarca vurgulanmıştır. Bunların yanı sıra bildirimi yapacak kişilerin özel eğitim almasının gerektiği belirtilmiş ve yapay zekâ destekli modüllerin geliştirilmesi ve kullanılması önerilmiştir. Uzmanların % 94,3'ü bildirim formlarının sadeleştirilmesi gerektiğini, % 88,6'sı verilerin şeffaf ve açık erişimli olması gerektiğini, % 77,1'i bildirim formların uzman kişilerce düzenlenmesinin önemli olduğunu, % 80'inin olayın oluş şeklinin açıklandığı kısmın sektörel özelliklere ve kaza tiplerine göre detaylandırılması gerektiğini vurgulamışlardır. Bunun yanı sıra uzmanların % 94,3'ü iş kazası bildirim formlarında olayın oluş şeklinin daha net anlaşılabilmesi için kök neden analizinin yapılması gerektiğini, % 74,3'ü ise kök neden analizi yapılması ile kazaların önlenmesine yönelik politika geliştirme süreçlerine katkı sağlanabileceğini belirtmiştir. Bahse konu aksaklıkların göz önünde bulundurulduğu, mevcut süreçlerin etkinliğini artırmaya yönelik bir kaza bildirim formu oluşturulması ve formların düzenlenmesinde profesyonel destek sağlanması, iş sağlığı ve güvenliği uygulamalarında tutarlılık ve şeffaflık sağlamaya katkıda bulunacaktır.

Anahtar Kelimeler: İş kazaları, İş sağlığı ve güvenliği, İş kazası bildirim sistemi, İş kazası bildirim formları, Yapay zekâ destekli izleme, Açık veri ve şeffaflık

COMPARISON OF USA (OSHA) AND TÜRKİYE (SGK) IN WORK ACCIDENT REPORTING PROCESSES

İŞ KAZASI BİLDİRİM SÜREÇLERİNDE ABD (OSHA) VE TÜRKİYE (SGK) KARŞILAŞTIRILMASI

Ahmet Aykut AKTAŞ

Yıldız Teknik Üniversitesi, İnşaat Fakültesi İnşaat Mühendisliği Bölümü, Hidrolik ABD, Davutpaşa, İSTANBUL

0009-0005-2536-5991

Ahmad Abu Arra

Yıldız Teknik Üniversitesi, İnşaat Fakültesi İnşaat Mühendisliği Bölümü, Hidrolik ABD, Davutpaşa, İSTANBUL

0000-0001-8679-175

Doç. Dr. Eyüp ŞİŞMAN

Yıldız Teknik Üniversitesi, İnşaat Fakültesi İnşaat Mühendisliği Bölümü, Hidrolik ABD, Hidrolik laboratuvarı 1.kat no:18 Davutpaşa, İSTANBUL

0000-0003-3996-9967

ABSTRACT

Occupational health and safety has become an increasingly important concept worldwide, including in Turkey. However, the legislation, standards, practices, and safety measures related to this field vary significantly depending on the level of development of each country. Industrialization has brought with it a growing labor force, which in turn has resulted in heavy working conditions and unsafe workplace environments. Consequently, government intervention in working life has become essential to protect employees' health and safety. The supervision of working life and conditions by governments also differs according to each country's administrative structure and level of development. Within their respective legal frameworks, states have developed various practices and inspection systems, which encompass the monitoring, auditing, and recording of occupational health and safety practices as integral components.

This study specifically examines the differences in legislation and administrative practices between the United States and Turkey regarding the "reporting processes of occupational accidents." In this context, the legal frameworks in both countries were reviewed, and the purposes and justifications for recording accidents were analyzed. The study further compares the differing definitions of "occupational accident" in the two legal systems and investigates how these definitions influence the reporting processes of events classified as occupational accidents. Moreover, the content of accident notification forms used in both countries was examined to assess whether these forms effectively support the compilation and interpretation of accident statistics in alignment with their intended purpose.

Additionally, the study explores the procedures for preparing accident notification forms in compliance with legislation, as well as the relevant enforcement mechanisms in both countries.

The findings reveal that while the United States and Turkey share similarities in legislation and general practices, notable differences exist in the bureaucratic aspects and operational procedures of the reporting process. The research highlights that OSHA (Occupational Safety and Health Administration) in the United States adopts a more transparent policy regarding data sharing, whereas in Turkey, significant portions of such data remain undisclosed due to legal constraints. The objectives of record-keeping also differ: OSHA's primary purpose is to prevent potential future accidents through collaboration with key stakeholders (workers, employers, and government), whereas in Turkey, the process is largely aimed at facilitating post-accident procedures managed by the Social Security Institution (SGK).

Differences in the legal definitions of occupational accidents between the two countries are also reflected in the design and content of their reporting forms. Furthermore, the study observes that, unlike Turkey, the United States provides training and consultancy services to ensure the accurate preparation of accident notification forms, illustrating a critical divergence in practical implementation. Another significant distinction is the legal recognition of employee participation in the accident reporting process in the United States, granting every worker the right to report workplace accidents, a right that is absent from Turkish legislation.

Keywords: Occupational accidents, Accident reporting process, OSHA, SGK, Turkey, United States

ÖZET

Dünyada ve Türkiye'de iş sağlığı ve güvenliği gittikçe önem kazanan bir kavram olması yanında, mevzuatlar, uygulamaları, standartlar ve konuya ilişkin alınması gerekli güvenlik önlemleri ülkelerin gelişmişlik düzeyine göre değişkenlik göstermektedir. Sanayileşme ile artan işgücü ağır çalışma ve güvenliksiz işyeri koşullarını da beraberinde getirmiştir. Bunun sonucunda çalışanların sağlık ve güvenliklerini korumak adına devletlerin çalışma hayatına müdahalesi zorunlu bir hal almıştır. Çalışma hayatının ve çalışma şartlarının devletler tarafından denetlenmesi her ülkenin idari yapısına ve gelişmişlik düzeyine göre değişkenlik göstermektedir. Her devlet kendi mevzuatı kapsamında bir takım uygulamalar ve denetim sistemleri geliştirmiştir. İş sağlığı ve güvenliği uygulamalarının izlenmesi, denetlenmesi ve kayıt altına alınması da bu sistemlerin içerisinde yer alan alt başlıklardır.

Bu çalışmada, yukarıda bahsedilen başlıklardan "iş kazalarının bildirim süreçleriyle" ilgili Amerika Birleşik Devletleri ve Türkiye arasındaki mevzuat ve işleyiş farklılıkları araştırılıp değerlendirilecektir. Bu kapsamda öncelikle ABD ve Türkiye'de uygulanan mevzuat araştırılmış, kazaların kayıt altına alınmasındaki amaç ve gerekçeler irdelenmiştir. Bunun yanı sıra iki ülkenin "iş kazası tanımı" irdelenerek, farklılıkları ortaya konulmuş, iş kazası olarak tanımlanan olayların bildirim süreçlerindeki farklılıkları araştırılmıştır. Çalışma kapsamında iki ülke için kaza bildirim formları da incelenerek, iş kazası istatistiklerinin amacına uygun bir şekilde derlenmesi ve yorumlanması noktasında, kaza bildirim formlarının içeriği sorgulanmıştır. Ek olarak kaza bildirim formlarının mevzuata uygun düzenlenmesi konusunda iki ülkenin uygulamaları ve kaza bildirim süreçleri ve ilgili yaptırımlar da araştırılmıştır. Sonuç olarak, iki ülke arasında mevzuat ve uygulama açısından benzerlikler bulunmakla birlikte kaza bildirim süreçlerindeki bürokratik işlemler ve uygulamalar noktasında birtakım farklılıkların bulunduğu tespit edilmiştir. Yapılan araştırma sonucunda ABD'de verilerin paylaşılması konusunda OSHA'nın daha açık bir politika izlediği, Türkiye'de ise bir takım yasal kısıtlardan dolayı verilerin önemli bir kısmının paylaşılamadığı anlaşılmaktadır. Verilerin kayıt altına alınmasında iki ülkenin amacında da belirgin farklar olduğu tespit edilmiştir. OSHA'nın kayıt tutmaktaki öncelikli amacı gelecekte yaşanma ihtimali olan kazaları önlemek ve bu hususun paydaşlarla (işçi, işveren, devlet) birlikte hareket ederek yapılmasıdır. Türkiye'de ise durum kaza sonrası SGK tarafından yürütülecek işlemlerin belirlenmesidir. Amerika ve Türkiye mevzuatları incelendiğinde kaza tanımları açısından da farklılıklar bulunmakta olup, bu durum

kaza bildirim formlarının içeriğine de yansımıştır. Ayrıca Amerika'da kaza bildirim formlarının doğru şekilde düzenlenebilmesi için eğitim ve danışmanlık hizmetlerinin sunulduğu görülmekte olup bu durum iki ülke arasındaki önemli bir uygulama farklılığını gösterir. Yine ABD'de kaza bildirim sürecinde çalışanların katılımı da yasal bir hak olarak tanımlanmış olup, her çalışanın işyerinde yaşanan iş kazasını bildirme hakkı bulunmaktadır. Türkiye'de ise çalışanlar açısından mevzuatta böyle bir uygulama bulunmamaktadır.

Anahtar Kelimeler: İş kazaları, İş kazası bildirim süreci, OSHA, SGK, Türkiye, ABD

THE EFFECT OF RAISING PROCESS ON HANDFEEL PROPERTIES OF BLANKETS

Gamze D. TETIK

Uşak University, Faculty of Engineering and Natural Sciences, Department of Nanotechnology Engineering, Uşak, Türkiye

ORCID ID: https://orcid.org/0000-0002-5968-7244

Gizem CELEP

Uşak University, Faculty of Health Sciences, Department of Occupational Health and Safety, Uşak, Türkiye

ORCID ID: https://orcid.org/0000-0001-9618-6708

Fulya YILMAZ

Uşak University, Graduate Education Institute, Department of Textile Engineering, Uşak, Türkiye

ORCID ID: https://orcid.org/0000-0003-1242-0515

ABSTRACT

The handfeel properties of textile fabrics are crucial for making accurate determinations and selecting the right fabric softness for the application area. Handfeel properties are prominent in many fabric types, such as clothing, bedding, upholstery, blankets. There are both subjective and objective methods for measuring handfeel. The TSA analyzer is a user-friendly device that performs this measurement objectively. The aim of this study is to reveal the effect of the raising process on the handfeel properties of blankets. In this study, two types of woven blankets made up of recycled polyester, polyacrylonitrile, cotton, and viscose fibers were investigated in terms of handfeel properties objectively. Beforehand, structural characteristics of blankets such as basis weight, thickness, yarn density, and yarn count were determined. Afterwards, softness, roughness, and stiffness properties of both raised and unraised four blankets were measured by TSA analyzer. The effect of raising on handfeel properties of recycled blankets were revealed in this study. According to the results of the TSA analyzer, the raised blankets were softer and smoother than the unraised blankets regardless of the fabric structural parameters. Raising mechanical treatment is essentially the process of fluffing the fabric by raising fibers from the blanket's surface, giving it a nappy appearance. The nappy surface structure makes raised blankets softer, more voluminous, and fluffy. Furthermore, flexibility which can be related to stiffness, was found to be higher in unraised blankets.

Keywords: Blanket; Handfeel; Raising; Recycling; Tactile.

INTRODUCTION

The 80% of the blanket production is met by Uşak which is considered as the blanket capital of Türkiye. Blankets have common use not only in daily life but also essential top needed items

which are used in natural disasters by various organizations such as Red Crescent, United Nations (UN), and the Red Cross. According to the report of Uşak Chamber of Commerce and Industry (UCCI) (2018) which is based on the data from the second quarter of 2017, blankets have been imported by 205 countries and in total it is not less than $100.000 in the last five years. Based on the world export rate data in 2016, Türkiye was ranked as 4th country after China, India, and Germany. Market share of imported blanket types (Figure 1) are blankets produced from synthetic yarns, cotton yarns, various types of woolen yarns, other types of blankets and electrical blankets respectively (UCCI, 2018).

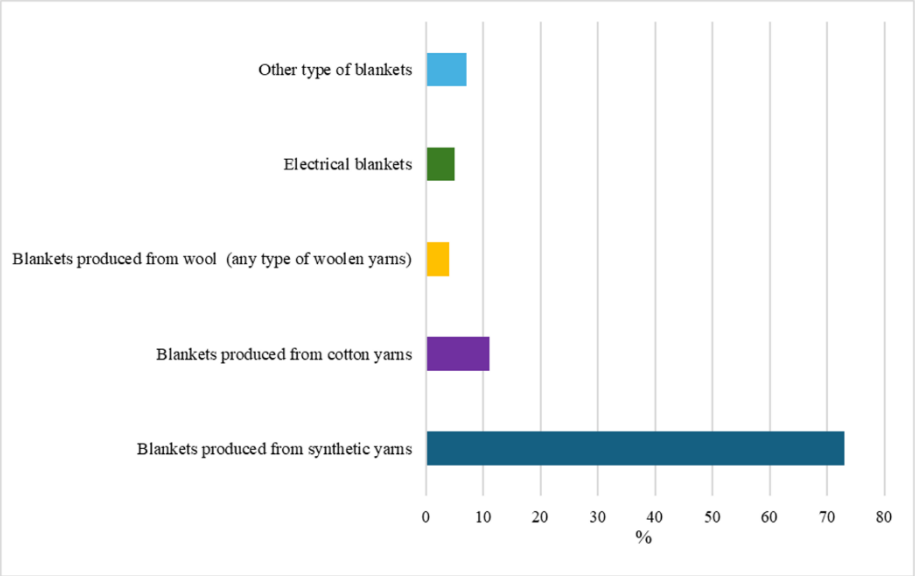


Figure 1. Market Share of Imported Blanket Types (Reproduced from UCCI, 2018)

Blankets are produced by weaving and knitting methods. The production steps of blankets consider yarn production, knitting or weaving processes, intermediate quality control, raising, brushing, shearing, stitching and edge finishing, quality control, and labeling -packaging (Acar and Bahadır Ünal, 2024). The primary yarn types used in blanket production are wool, cotton, acrylic, and polyester. As wool yarn types, lamb, camel, cashmere, and angora wools are used (UCCI, 2018). Wool fiber is utilized in winter blankets, providing warmth. However, it is weighty. Cotton blankets keep the body less warm than wool blankets. Acrylic blankets are lighter than cotton and wool blankets. They also keep the body warm. The application and individual preferences influence the selection of fibers for blankets (Kadolph, 2013). Warp and weft threads in blanket production have different counts and characteristics. Generally, warp threads are open-end yarns, while weft threads are strayhgarn wool yarns. Raising is the process of bringing fibers within the yarn structure through the blanket surface. This feature is given by the raising machine depending on the desired fluffing effect. Through this process, blankets generally extend by approx. 2–3% lengthwise and shrink by approx. 22–25% widthwise. This process gives some features like increased volume, softer handling, thermal comfort and desired appearance. It also leads to a decrease about 1.15% - 13.1% in fabric basis weight. Weight loss also during brushing and shearing processes can range from 2.4% to 7.3% (Yılmaz, 2007).

Raising is an important process to give blankets the desired look, handfeel, and thermal characteristics. By this process, the fluff layer is formed, and the aesthetic look is given by special extra processing such as laying down, raising up and cutting naps from the surface. Due to the voluminous structure of the blankets, the air is trapped between the gaps, so thermal insulation is enhanced (Açıkgöz, 1996).

Beyond improving the physical properties of blankets depending on user preferences, the environmental impact of textile production processes is also a crucial issue that should be emphasized. The recycling of textiles provides multidimensional contributions in areas such as

the conservation of natural resources, energy saving, and waste reduction. Hence, it is an important issue in terms of sustainability. Waste is generated in many stages of textile production, such as yarn production and fabric production. The reuse of waste and its return to the textile industry offers significant economic and environmental advantages. Recycling waste reduces the need for raw materials, lowers production costs, and minimizes the negative impact of waste on the environment. Recycling possibilities encompass not only the mechanical breakdown of textiles but also chemical processing and the utilization of recycled textiles to generate new fibers. During the mechanical opening of the fibers, damage given to the fibers and shortening of the fiber lengths are unavoidable. For this reason, recycled fibers are widely used in the production of nonwoven surfaces and open end rotor yarn production (Schwippl, 2020). Recycled fibers are also commonly used in the blanket industry. Utilizing regenerated yarns in products like blankets and piques, it is possible to transform waste into high-value products (Zafer Development Agency, 2019) like upcycling.

Studies on blankets in the literature are limited, and existing research has focused on properties such as air permeability, thermal resistance, tactile characteristics, weight loss, and color change in repeated washings (Celep et al., 2023; Değirmenci and Topalbekiroğlu, 2022; Lan et al., 2021). Among these properties, tactile comfort has received particular attention in recent studies due to its significance in user experience. Studies have examined the tactile comfort of blankets made from virgin fibers, focusing on their texture and sensory characteristics. Similarly, research has also been conducted on blankets made from recycled fibers, evaluating how regeneration processes affect their tactile performance. Niwa et al. (1999) used a connecting method to obtain values from mechanical parameters to subjective evaluation method. Their method depends on the assumption that there was similarity between suiting and blanket in terms of good tactile feeling. They compared acrylic, alpaca, cashmere, wool, and cotton in different structures such as woven, mayer, new mayer, and tufted. They used the equations obtained from the evaluation of hand values (HV) and total hand value (THV). Niwa et al. (2001) developed mathematical equations for blankets to determine handle properties which depended on compression, surface properties, thickness, weight, and thermal parameters. The handfeel properties were subjected to experts' subjective evaluation. Shanmugam et al. (2021) studied cotton blended woolen blankets to improve the handfeel and appearance characteristics of blankets. They concluded that woolen blankets have higher thickness and elongation. Thermal resistance tended to decrease with the cotton ratio increase in blankets. On the other hand, they also evaluated the smoothness of the blankets according to the Thurston pair comparison method, as they concluded; the smoothness of the blankets increased with the cotton intent in the blanket. Kumpikaite et al. (2022) compared various patterned woven blankets from wool and regenerated wool yarns. They used mainly two groups of woolen blankets; one was 100% woolen yarns while the other one was produced from regenerated woolen weft yarns and woolen warp yarns. They made a statistical comparison of these two main groups in terms of the shrinkage and air permeability. As a result, they stated that the shrinkage in the directions of both weft and warp sides depended on the float length regardless of raw material type. The air permeability results of the blankets differed due to their intersection number and also the float length, and regenerated woolen blankets had higher air permeability. But the weave type statistically didn't affect the air permeability parameter of the woolen blankets. Tayyar et al. (2025) investigated regenerated woven blankets in different ratios of acrylic, cotton and polyester yarns for weft and warp yarns in three weft density. They produced blankets in plain and twill configuration. They tested air permeability, tensile strength, elongation and bending rigidity of raised and unraised blankets to compare the effect of raising. According to the results they stated that recycled fibers were identified as a viable option in blanket production, provided that they met the required quality standards, and were also considered favorable due to their environmental and economic impacts.

Apart from other studies in literature, the originality of our study depends on the objective evaluation of handfeel properties of recycled blankets considering raising process.

MATERIALS AND METHODS

Two blankets in raised and unraised forms were evaluated in this study (Figure 2). The first and second blankets are single layer and double layer woven fabric, respectively. The warp yarns are 42 Tex recycled polyester (rPES) for both blankets. The weft yarns are 241 Tex, and 510 Tex recycled Co/ PAN/ viscose blend for the first and second blankets, respectively. The yarn densities are the same and 13 ends/cm - 12 picks/cm for two blankets. Thickness values are 0.78 mm and 1.31 mm. Since the first blanket is single layer, its basis weight is lower. The basis weights of raised blankets are 339 g/m^2 and 568 g/m^2 for the 1st and 2nd one, respectively. Basis weight values are higher in unraised blankets (360 g/m^2 and 668 g/m^2 for the 1st and 2nd blanket, respectively) (Table 1). This is due to the breakage of fibers as they are pulled by raising wires from both ends during the raising process (Yılmaz Akyürek, 2016).

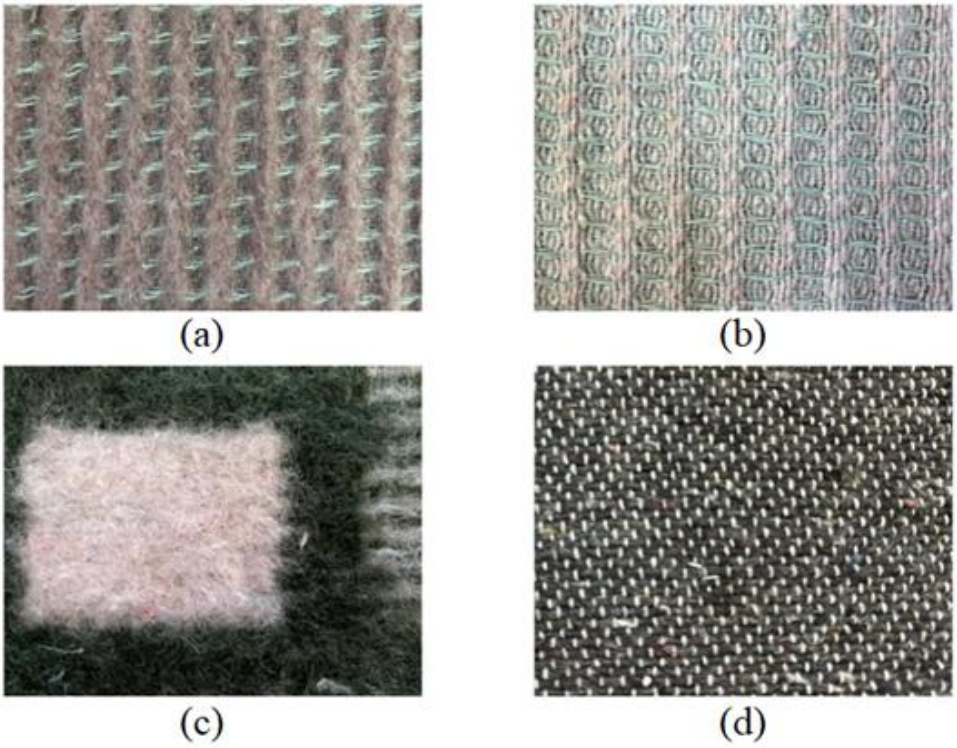


Figure 2. Photos of blanket 1 (a, b) and blanket 2 (c, d) (left: raised, right: unraised)

Table 1. Properties of blankets

Property \ Blanket Type	1	2
Warp yarn count and type	42 Tex rPES	
Weft yarn count and type	241 Tex recycled Co, PAN, viscose blend	510 Tex recycled Co, PAN, viscose blend
Woven fabric type	Single layer	Double layer
Warp and weft density	12 picks/cm, 13 ends/cm	
Basis weight g/m^2 (unraised)	360 ± 5	668 ± 7
Basis weight g/m^2 (raised)	339 ± 5	568 ± 7

TSA-Softness Analyzer (Emtec Electronic GmbH, Germany) is a device that objectively measures the handfeel properties of nonwovens and textile surfaces. The TSA device measures handfeel characteristics such as softness, roughness, and stiffness. Measurements are performed in two stages on the device. In the first stage, referred to as sound analysis, softness and roughness values are measured, while in the second stage, stiffness values are obtained by deformation measurement. When the measurement begins, the measuring head, consisting of rotor and paddles, descends toward the fixed fabric surface. The rotor rotates and a load of 100 mN is applied. Under this load, the rotation of the paddles causes two different vibrations: the vibration of the sample and the vibration of the paddles. The sample vibration value provides information about roughness (TS750 peak), while the vibration of the paddles provides information about softness (TS7 peak). The TS750 peak is usually around 200-1200 Hz, and a high value indicates that the surface is rougher. The TS7 peak is usually around 7000 Hz, and a high TS7 peak indicates that the sample is harder (Emtec Electronic Technical Leaflet, 2025).

RESULTS AND DISCUSSIONS

TSA Analyzer results of blankets are classified as roughness, smoothness, and stiffness values. The TS750 peaks of blankets which indicate roughness of fabrics are given in Figure 3. For both blankets, unraised forms have rougher structure than raised forms. This is because the main effect of raising process that makes the fabric more voluminous and fluffier. Blanket 1 is rougher than blanket 2 before and after the raising process.

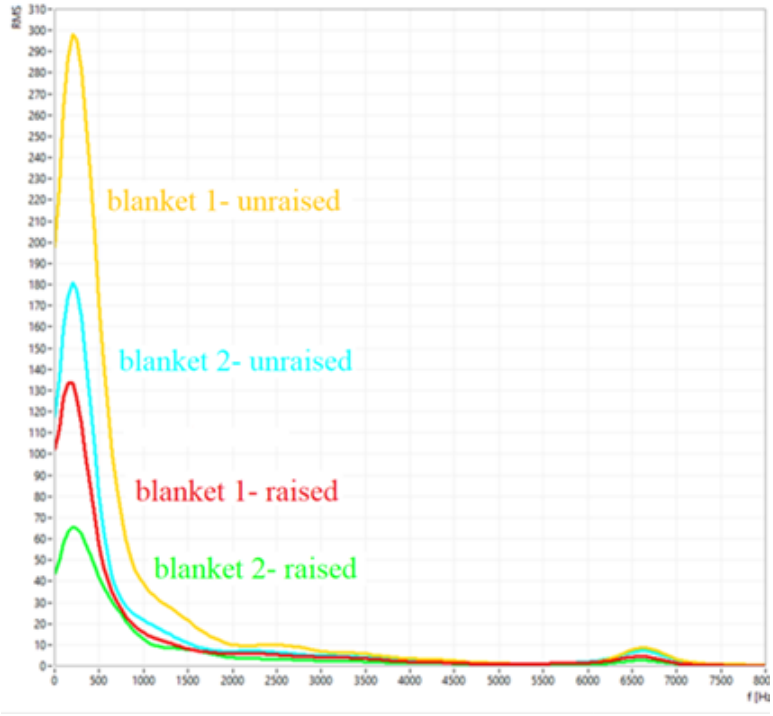


Figure 3. TS750 peaks of blankets

When the TS7 values, which represent the softness parameter, are compared, blanket 1 is found to have a higher value than blanket 2 (Figure 4). This indicates that blanket 2 is softer, as lower TS7 values correspond to increased softness. When we examine the effect of the raising process on the softness properties of the blankets, we observe that the raised blankets exhibit higher softness in both samples. This result suggests that the raising process improves surface properties, resulting in a softer feel.

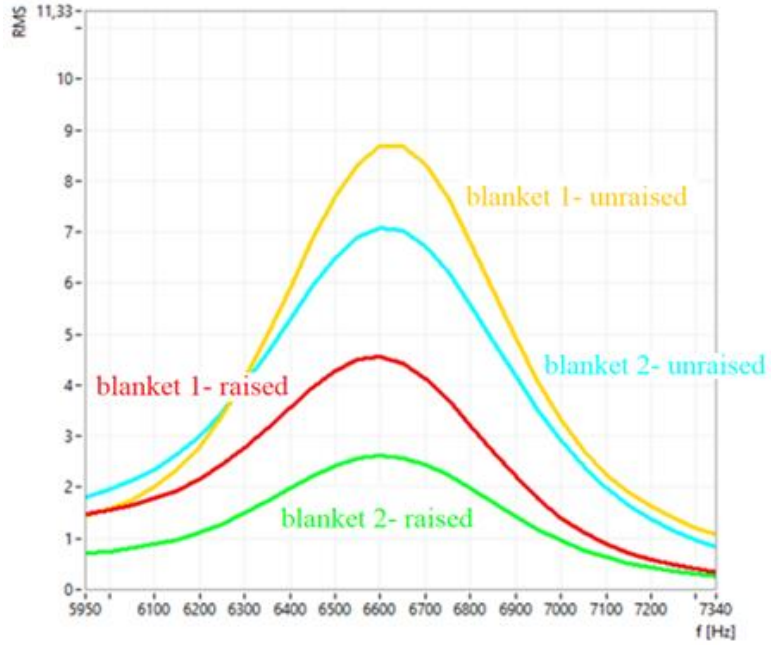


Figure 4. TS7 peaks of blankets

Blanket 1 and 2 exhibit different stiffness values. Unraised blanket 1 has a stiffness value of 2.23 mm/N and raised blanket 1 has a stiffness value of 3.12 mm/N. Unraised blanket 2 has a stiffness value of 1.38 mm/N and raised blanket 2 has a stiffness value of 3.91 mm/N. The higher the stiffness value the more flexible the fabric. Raised forms of the blankets are more flexible than the unraised forms. The single layer blanket is stiffer than the double layer blanket. When the recovery (%) values of blankets are considered, it can be concluded that raised blankets which are the softer and flexible ones have higher recovery values. Single layer blanket has a higher recovery (%) value than double layer blanket in both forms.

CONCLUSION

Raising is a mechanical finishing process which makes fabrics more voluminous and fluffier. The wires wrapped on the drum raise the fibers on the surface of the fabric and give a nappy appearance. Blankets are the fabrics which are commonly presented to customers after a raising finish process. This process leads fabrics to be softer. Enhancing these properties engender an improvement in the thermal comfort properties of blankets which are the main features for blankets.

In customer preferences handfeel properties of fabrics play crucial roles. Softness, roughness, and stiffness constitute the handle properties. Evaluation of these properties can be performed in subjective and objective manners. Objective evaluation is performed in this study. The mentioned properties of blankets are measured by TSA analyzer. There are two blankets chosen for the evaluation. One of the blankets is a single layer woven blanket and the other one is a double layer woven blanket. Both blankets are obtained in raised and unraised forms. Handfeel properties of the blankets measured by TSA analyzer exhibit that raised blankets have softer and smoother structure for both blankets. The results of the study demonstrated that the stiffness and flexibility characteristics of the blankets are influenced by the raising process. Both blanket samples become more flexible after the raising process.

ACKNOWLEDGEMENT

We thank Emtec Electronic GmbH (Germany) for lending us the EMTEC TSA analyzer.

REFERENCES

Acar, E. & Bahadır, Ünal, Z. (2024). *Research on Sleep Support Textile Products*. Iksad Publishing House.

Açıkgöz, A. (1996). Battaniye Üretiminde Şardonlamanın Etkileri. MSc Thesis, Afyon Kocatepe University, Natural and Applied Sciences Graduate Institute.

Celep, G., Tetik, G. D., & Yilmaz, F. (2023). Seeking Alternative Textile Resources from the Perspective of Recycled Blankets. *TexMat Research Journal*, *1*(1), 18-26.

Değirmenci, Z. & Toplabekiroğlu, M. (2022). The effect of softener on the performance and thermal comfort properties of warp knitted acrylic blankets, *El-Cezerî Journal of Science and Engineering (ECJSE)*, 9(2), 542-553. Doi: 10.31202/ecjse.974718.

Emtec Technical Leaflet, 2025, https://www.emtec-electronic.de/images/stories/infomaterial/20_TSA2/01_Tissue/01_Leaflet/emtec_TSA2_tissue_leaflet_EN.pdf (Date accessed: 04.08.2025)

Kadolph, S. J. (2013). *Textiles: Pearson new international edition*. Pearson Education Limited.

Kumpikaitė, E., Laureckienė, G., Milašienė, D. & Petraitienė, S. (2022). Investigation of the Shrinkage and Air Permeability of Woolen Blankets and Blankets Made with Regenerated Wool. *Materials*, *15*(10), 3596.

Lan, X. Wang, Y., Peng, J., Si, Y., Ren, J., Ding, B. & Li, B. (2021). Designing Heat Transfer Pathways for Advanced Thermoregulatory Textiles, *Materials Today Physics*, 17, 100342, doi: 10.1016/j.mtphys.2021.100342.

Niwa, M., Inoue, M., & Kawabata, S. (1999). The Objective Evaluation of Blanket Hand and Durability: A Preliminary Investigation. *International Journal of Clothing Science and Technology*, *11*(2/3), 90-108.

Niwa, M., Inoue, M., & Kawabata, S. (2001). Objective Evaluation of the Handle of Blankets. *Textile Research Journal*, *71*(8), 701-710.

Schwippl, H. (2020). The Increasing Importance of Recycling in the Staple-Fiber Spinning Process. Rieter Machine Works Ltd: Winterthur, Switzerland.

Shanmugam, N., Shakyawar, D. B., Kumar, A., Kadam, V., & Jose, S. (2021). Development of Wool-Cotton Blended Blanket and Assessment of Its Quality. *Indian Journal of Small Ruminants*, *27*(2), 264-270.

Tayyar, A. E., Macit, H., Şevkan Macit, A. & Alan, G. (2025). Evaluation of Mechanical Properties of Woven Blankets with Recycled Yarns. *Pamukkale University Journal of Engineering Sciences*, *31*(3), 484-490.

Uşak Chamber of Commerce and Industry (UCCI). (2018). Blankets and Travel Blankets, Product Group Target Market Analysis and Foreign Trade Report. https://usaktso.org/images/haber/thumbs/Bilgi_Bankasi/Sektor_Rapor/Battaniye_Raporu.pdf

Yılmaz, S. (2007). The Situation of Blanket Industry in Turkiye and Blanket Production Metods. *Journal of Science and Technology of Dumlupınar University*, (014), 113-118.

Yılmaz Akyürek, B. (2016). Experimental Determination of the Effect of Napping on Mechanical Properties of Bi-Elastic Woven Fabrics, *Tekstil ve Mühendis*, 23(101), 1-11.

Zafer Development Agency. (2019). Uşak Province Textile Recycling Sector Report.

ASSESSMENT OF RADIOLOGICAL HEALTH RISKS CAUSED BY INTERNAL EXPOSURE TO WORKERS IN BENTONITE QUARRIES

BENTONİT OCAKLARINDA ÇALIŞAN İŞÇİLERİN MARUZ KALDIKLARI İÇ IŞINLAMADAN KAYNAKLANAN RADYOLOJİK SAĞLIK RİSKLERİNİN DEĞERLENDİRİLMESİ

Dr. Öğr. Üyesi Onur METİN

Kastamonu Üniversitesi, Taşköprü Meslek Yüksekokulu

Prof. Dr. Şeref TURHAN

Kastamonu Üniversitesi, Fen Fakültesi

ABSTRACT

Industrial minerals, which have an important place in our daily lives, are non-renewable resources with unique chemical composition and physical properties that occur naturally under varying conditions in different geological environments. Minerals provide a very important resource for the construction, chemical, agricultural, and manufacturing industries worldwide. Bentonites, which are composed of montmorillonite, one of the smectite groups of clay minerals, have unique physical and chemical properties such as high cation sorption, cation exchange capacity, and large surface area. Bentonites can be used in a wide range of areas such as drilling muds, pet litters, waterproofing and sealing applications, animal feed additives, oil and grease absorbents, agricultural carriers, filtration, purification, decolorizing agents, asphalt emulsions, catalysts and additives in the ceramic, cement and concrete industry, etc. Like other industrial minerals, bentonites also contain terrestrial radionuclides such as uranium (^{238}U), thorium (^{232}Th) and radioactive potassium (^{40}K) at varying levels depending on the geochemical structure of the region where they are found. Quarry workers may be exposed to ionizing radiation emitted from these radionuclides in two ways: internal and external irradiation. Internal irradiation generally occurs due to ionizing radiation emitted from these natural radionuclides taken into the body as a result of accidental ingestion of bentonite particles and inhalation of bentonite dust. In this study, radiological risks originating from internal irradiation to which quarry workers are exposed were assessed by estimating annual effective radiation doses accompanying inhalation and ingestion and corresponding cancer risks based on the activity contents of ^{238}U, ^{232}Th, and ^{40}K measured in bentonite samples collected from bentonite mines in Türkiye. The average total annual effective radiation dose value was found to be 24.2 μSv/y, and the average total cancer risk corresponding to this dose was found to be 9.7×10^{-5}. The radiological risk assessment results showed that the internal irradiation of the adult workers in bentonite quarries, although significantly smaller than the total radiation dose (296 μSv/y) and cancer risk (1.2×10^{-3}) they receive as a result of inhalation and ingestion of natural radionuclides in the food they consume, is not negligible.

Keywords: Bentonite, Uranium, Thorium, Natural radioactivity, Annual effective dose, Cancer risk

ÖZET

Günlük hayatımızda önemli bir yer tutan endüstriyel mineraller, farklı jeolojik ortamlarda değişen koşullar altında doğal olarak oluşan, kendine özgü kimyasal bileşime ve fiziksel

özelliklere sahip yenilenemeyen kaynaklardır. Mineraller, dünya çapında inşaat, kimya, tarım ve üretim endüstrileri için çok önemli bir kaynak sağlar. Kil minerallerinin smektit gruplarından biri olan montmorillonitten oluşan bentonitler, yüksek katyon soğurması, katyon değişim kapasitesi ve geniş yüzey alanı gibi benzersiz fiziksel ve kimyasal özelliklere sahiptir. Bentonitler, sondaj çamurları, evcil hayvan kumları, su yalıtımı ve sızdırmazlık uygulamaları, hayvan yemi katkı maddeleri, yağ ve gres emiciler, tarımsal taşıyıcılar, filtrasyon, arıtma, renk giderici maddeler, asfalt emülsiyonları, katalizörler ve seramik, çimento ve beton endüstrisinde katkı maddeleri vb. gibi çok geniş bir alanda kullanılabilmektedir. Diğer endüstriyel mineraller gibi bentonitler de bulundukları bölgenin jeokimyasal yapısına bağlı olarak değişen seviyede uranyum (^{238}U), toryum (^{232}Th) ve radyoaktif potasyum (^{40}K) gibi karasal radyonüklitler içerir. Ocak çalışanları, bu radyonüklitlerden yayılan iyonlaştırıcı radyasyonlara iç ve dış ışınlama olmak üzere iki şekilde maruz kalabilir. İç ışınlama, genelde bentonit parçacıklarının kazara yutulması ve bentonit tozlarının solunması sonucu vücuda alınan bu doğal radyonüklitlerden yayılan iyonlaştırıcı radyasyonlar nedeniyle oluşur. Bu çalışmada, Türkiye'deki bentonit ocaklarından toplanan bentonit örneklerinde ölçülen ^{238}U, ^{232}Th ve ^{40}K'ın aktivite içerikleri esas alınarak ocak işçilerinin maruz kaldığı iç ışınlamadan kaynaklanan radyolojik riskler, soluma ve sindirmeye eşlik eden yıllık etkin radyasyon dozları ve bunlara karşılık gelen kanser riskleri hesaplanarak değerlendirildi. Ortalama toplam yıllık etkin radyasyon doz değeri 24,2 μSv ve bu doza karşılı gelen ortalama toplam kanser riski $9{,}7 \times 10^{-5}$ olarak bulundu. Radyolojik risk değerlendirme sonucu, ocak işçilerinin bentonit ocaklarında kaldıkları iç ışınlama, tükettikleri gıdalardaki doğal radyonüklitlerin solunması ve sindirilmesi sonucunda aldıkları toplam radyasyon dozundan (296 μSv/y) ve kanser riskinden ($1{,}2 \times 10^{-3}$)'den önemli ölçüde küçük de olsa ihmal edilmeyecek olduğunu gösterdi.

Anahtar kelimeler: Bentonit, Uranyum, Toryum, Doğal radyoaktivite, Yıllık etkin doz, Kanser riski

INTRODUCTION

Bentonite is a soft, porous, and easily shaped, absorbent material rich in aluminum, sodium, and potassium (Kurnaz et al. 2022). Bentonites possess unique physical and chemical properties, including high cation sorption, cation exchange capacity, and large surface area. Bentonites generally come in two main varieties: calcium (or non-swelling) bentonite, the most common, and sodium bentonite (or swelling bentonite), the more industrially important (Kurnaz et al. 2022). Bentonites have a wide range of applications, including drilling muds, pet litters, waterproofing and sealing applications, animal feed additives, oil and grease absorbents, agricultural carriers, filtration, purification, decolorization agents, asphalt emulsions, catalysts, and additives in the ceramic, cement, and concrete industries, among others (Kurnaz et al. 2022). Türkiye was the fourth largest producer of bentonite after China, the United States, and India, with 1.5 million tonnes as of 2019 (Kurnaz et al. 2022). Regardless of formation or origin, bentonites are composed of montmorillonite, one of the smectite group of clay minerals (Kurnaz et al. 2022).

Like other industrial minerals, bentonite contains terrestrial radionuclides such as radium (^{226}Ra), thorium (^{232}Th), and radioactive potassium (^{40}K) in varying activity concentrations depending on the geochemical makeup of the region in which it is found (UNSCEAR 2000). Ionizing radiation (alpha–, beta–, and gamma– rays) emitted from these radionuclides can lead to human radiological exposure in two ways: external and internal. External exposure occurs when all or part of the body is exposed to gamma rays emitted from radionuclides. Internal exposure results from ionizing radiation emitted from radionuclides taken into the body through ingestion, inhalation, dermal absorption, and wound contamination. When industrial minerals contain high levels of radioactivity, radiological hazards are generally associated with mine workers, but specific exposures and associated hazards may also involve those handling the end

products from which these minerals are used. Ingestion doses result primarily from the radionuclides found in food and drinking water. The total annual effective dose from inhalation and ingestion of terrestrial radionuclides is 310 μSv, of which 170 μSv is from ^{40}K and 140 μSv is from the long-lived radionuclides in the uranium-radium (^{238}U-^{226}Ra) and ^{232}Th decay chains (UNSCEAR 2000). Assessment of radiological risks arising from natural and artificial radioactivity is very important for human and environmental health and requires continuous measurement, monitoring, and evaluation of environmental radioactivity.

This study is the first to assess the radiological health risk resulting from internal irradiation (or exposure) caused by inhalation of bentonite dust and/or accidental ingestion of bentonite particles by workers working in commercial bentonite quarries located in different provinces in Türkiye. For the radiological evaluation, the annual effective doses due to the inhalation and ingestion of radionuclides in bentonite and the corresponding lifetime cancer risks were estimated.

MATERIAL AND METHODS

Sample collection, preparation, and measurement

In this study, a total of 90 bentonite samples were collected from 21 bentonite quarries (BQs) located in Ankara, Çankırı, Çorum, Edirne, Konya, Ordu, Trabzon, and Tokat provinces of Türkiye (Fig. 1) (Kurnaz et al. 2022). The collection and preparation of bentonite samples collected from these quarries and the measurement procedure of ^{226}Ra, ^{232}Th, and ^{40}K using a gamma-ray spectrometry with high-purity germanium (HPGe) detector were given in the study done by Kurnaz et al. (2022). In this study, radiological health risk evaluation was performed for the bentonite quarry workers by taking the activity concentration of ^{226}Ra, ^{232}Th, and ^{40}K measured by Kurnaz et al. (2022).

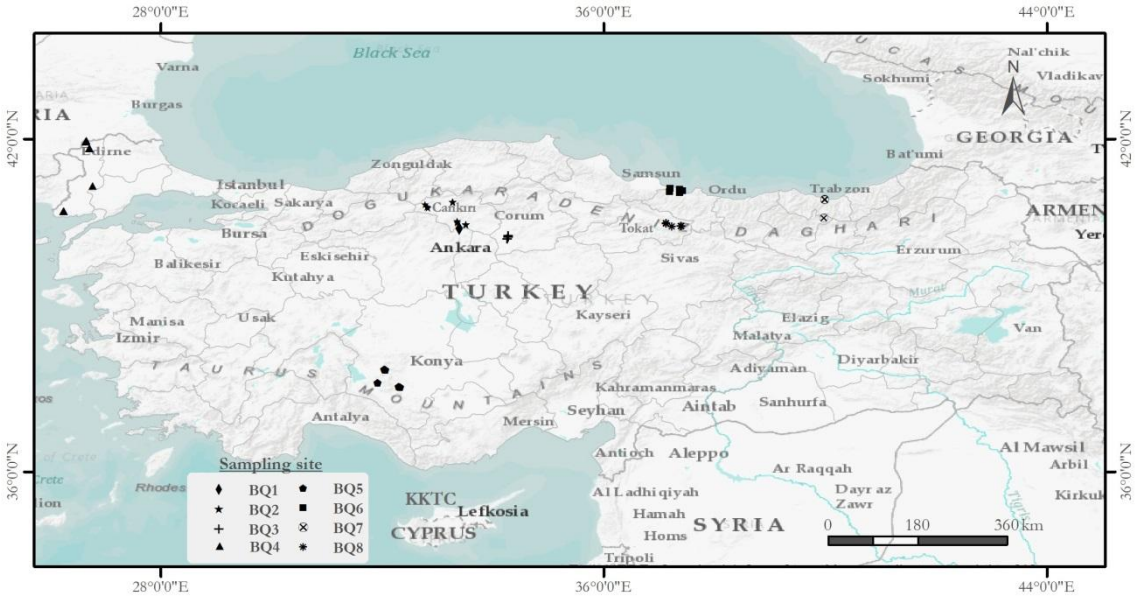


Fig. 1. Locations of bentonite quarries (Kurnaz et al. 2022)

Radiological risk assessment

Radiological health risks caused by the ionizing radiation emitted from the terrestrial radionuclides in the bentonite samples were assessed for adult workers, taking into account internal exposure. Internal exposures occur in the intake of the terrestrial radionuclides in the bentonite samples by inhalation and ingestion (UNSCEAR 2000). The annual effective dose due to the inhalation was estimated as follows (UNSCEAR, 2008):

$$AED_{Inh} = (A_{Ra} \times DCFINH_{Ra} + A_{Th} \times DCFINH_{Th} + A_K \times DCFINH_K) \times V \times C \times T \quad (1)$$

where AED_{Inh} is the annual effective dose due to the inhalation (μSv/y); A_{Ra}, A_{Th} and A_K is the activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in bentonite samples; $DCFINH_{Ra}$, $DCFINH_{Th}$ and $DCFINH_K$ is the effective dose coefficient for adult workers due to the inhalation and taken as 1.6, 42 and 0.003 μSv/Bq for ^{226}Ra, ^{232}Th and ^{40}K, respectively (ICRP 119 2012); V is breath frequency (20 m^3/d), and C is the average muscovite dust concentration (50 μg/m^3) (UNSCEAR 2000) and T is the exposure time (20 y × 365 d/y).

The annual effective dose due to the ingestion was estimated as follows (UNSCEAR 2008):

$$AED_{Ing} = (A_{Ra} \times DCFING_{Ra} + A_{Th} \times DCFING_{Th} + A_K \times DCFING_K) \times AI \quad (2)$$

where AED_{Ing} is the annual effective dose due to the ingestion (μSv/y); A_{Ra}, $A_{Th,}$ and A_K are the activity concentration of ^{226}Ra, ^{232}Th, and ^{40}K in bentonite samples; $DCFING_{Ra}$, $DCFING_{Th,}$ and $DCFING_K$ are the effective dose coefficient for adult workers due to the ingestion and taken as 0.044, 0.23, and 0.0062 μSv/Bq for ^{226}Ra, ^{232}Th, and ^{40}K, respectively (ICRP 119 2012) and AI is an annual intake of muscovite particle (100 mg/d ×105 d/y). Hence, the total annual effective dose (AED_{Total}) is calculated as follows:

$$AED_{Total} = AED_{Inh} + AED_{Ing} \quad (3)$$

The total excess lifetime cancer risks $ELCR_{Total}$ due to inhalation and ingestion were estimated as follows (ICRP 60, 1990):

$$ELCR_{Total} = AED_{Total} \times \cdot LT \cdot R_F \quad (4)$$

where AED_{Total} is the total annual effective dose given in Eq. (3); LT is the average lifetime (70 y), and R_F is the cancer risk factor of 0.057/Sv (ICRP 60, 1990).

RESULTS AND DISCUSSION

Some descriptive statistical information related to the radiological parameters of internal exposure estimated for adult workers working in all the bentonite quarries. The radiological parameter values calculated for workers working in quarries located in Ankara, Çankırı, Çorum, and Edirne are given in Table 2. The radiological parameter values calculated for workers working in quarries located in Konya, Ordu, Trabzon, and Tokat are given in Table 3. It can be seen from Table 1 that the values of the AED_{Inh} varied from 6.13 to 53.94 μSv/y with an average of 23.97 μSv/y, which is higher than the world average annual effective dose of 5.8 μSv from inhalation of ^{238}U and ^{232}Th series radionuclides in air (UNSCEAR 2008). The values of the AED_{ing} varied from 0.09 to 0.45 μSv/y with an average of 0.23 μSv/y, which is significantly lower than the world average annual effective dose of 290 μSv from the ingestion of primordial radionuclides (UNSCEAR 2008). The values of AED_{Total} varied from 6.23 to 54.38 μSv/y with an average of 24.20 μSv/y, which is approximately 12 times lower than the world total average annual effective dose of 296 μSv from internal exposure due to the primordial radionuclides. From Tables 2 and 3, the highest value of AED_{Total} was found for the bentonite quarry located in Edirne.

Table 1. Some descriptive statistical information on radiological parameters

	Radiological parameters			
	AED_{Inh} (μSv/y)	AED_{Ing} (μSv/y)	AED_{Total} (μSv/y)	$ELCR_{Total}$
Mean	23.97	0.23	24.20	9.65×10^{-5}
Standard error	1.21	0.01	1.22	4.86×10^{-6}
Median	21.34	0.23	21.58	8.61×10^{-5}
Standard deviation	11.47	0.09	11.56	4.61×10^{-5}
Sample variance	131.60	0.01	133.72	2.13×10^{-9}
Kurtosis	-0.88	-1.17	-0.88	-8.81×10^{-1}
Skewness	0.50	0.27	0.50	5.01×10^{-1}
Range	47.81	0.35	48.16	1.92×10^{-4}
Min	6.13	0.09	6.23	2.48×10^{-5}
Max	53.94	0.45	54.38	2.17×10^{-4}

The values of the $ELCR_{Total}$ varied from 2.5×10^{-5} to 2.2×10^{-4} with an average of 9.7×10^{-5}. The $ELCR_{Total}$ is lower than the world average value of 1.2×10^{-3}.

CONCLUSIONS

This study evaluated for the first time the radiological health risk of workers in commercial bentonite quarries in Türkiye due to exposure to bentonite or particles. The results revealed that the radiation dose to which the workers were exposed was low. However, it is recommended that workers take radiation protective measures to minimize radiation exposure.

Table 2. Radiological parameters for workers in Ankara, Çankırı, Çorum, and Edirne

Quarry code	Location	Radiological parameters			
		AED_{Inh} (□Sv/y□	AED_{Ing} (□Sv/y)	AED_{Total} (□Sv/y)	$ELCR_{Total}$
BQ1-1	Ankara	18.69	0.18	18.87	7.5E-05
BQ1-2		13.72	0.12	13.85	5.5E-05
BQ1-3		10.39	0.12	10.52	4.2E-05
BQ1-4		25.42	0.23	25.65	1.0E-04
BQ1-5		20.17	0.19	20.37	8.1E-05
BQ1-6		13.28	0.13	13.41	5.3E-05
BQ1-7		13.91	0.13	14.04	5.6E-05
BQ1-8		16.00	0.15	16.15	6.4E-05
BQ2-1	Çankırı	15.02	0.15	15.17	6.1E-05
BQ2-2		13.52	0.15	13.67	5.5E-05
BQ2-3		12.44	0.12	12.56	5.0E-05
BQ2-4		11.01	0.13	11.14	4.4E-05
BQ2-5		12.58	0.13	12.72	5.1E-05
BQ2-6		12.81	0.16	12.97	5.2E-05
BQ2-7		19.39	0.19	19.59	7.8E-05
BQ2-8		16.08	0.15	16.23	6.5E-05
BQ2-9		15.96	0.19	16.14	6.4E-05
BQ2-10		12.11	0.12	12.23	4.9E-05
BQ2-11		11.56	0.12	11.68	4.7E-05
BQ2-12		11.96	0.13	12.09	4.8E-05
BQ2-13		12.84	0.13	12.97	5.2E-05
BQ2-14		10.63	0.11	10.73	4.3E-05
BQ2-15		11.19	0.11	11.30	4.5E-05
BQ2-16		12.83	0.13	12.97	5.2E-05
BQ2-17		17.41	0.18	17.59	7.0E-05

BQ2-18		15.38	0.16	15.54	6.2E-05
BQ2-19		17.98	0.18	18.17	7.2E-05
BQ3-1		13.39	0.13	13.52	5.4E-05
BQ3-2		15.14	0.15	15.28	6.1E-05
BQ3-3		11.96	0.12	12.07	4.8E-05
BQ3-4		11.63	0.12	11.75	4.7E-05
BQ3-5	Çorum	11.71	0.13	11.84	4.7E-05
BQ3-6		12.69	0.13	12.82	5.1E-05
BQ3-7		12.33	0.14	12.47	5.0E-05
BQ3-8		12.50	0.14	12.64	5.0E-05
BQ3-9		10.62	0.13	10.75	4.3E-05
BQ4-1	Edirne	29.13	0.29	29.42	1.2E-04
BQ4-2		34.12	0.33	34.44	1.4E-04
BQ4-3		31.73	0.31	32.04	1.3E-04
BQ4-4		30.28	0.31	30.58	1.2E-04
BQ4-5		30.87	0.30	31.17	1.2E-04
BQ4-6		30.37	0.29	30.66	1.2E-04
BQ4-7		13.82	0.14	13.97	5.6E-05
BQ4-8		15.18	0.16	15.34	6.1E-05
BQ4-9		22.38	0.23	22.61	9.0E-05
BQ4-10		16.72	0.19	16.91	6.7E-05
BQ4-11		42.26	0.37	42.63	1.7E-04
BQ4-12		36.93	0.33	37.26	1.5E-04
BQ4-13		53.94	0.45	54.38	2.2E-04
BQ4-14		48.50	0.42	48.92	2.0E-04

Table 3. Radiological parameters for workers in Konya, Ordu, Trabzon, and Tokat

Quarry code	Location	Radiological parameters			
		AED_{Inh} (□Sv/y□	AED_{Ing} (□Sv/y)	AED_{Total} (□Sv/y)	$ELCR_{Total}$
BQ5-1	Konya	22.52	0.22	22.74	9.1E-05
BQ5-2		11.58	0.11	11.69	4.7E-05
BQ5-3		12.95	0.15	13.09	5.2E-05
BQ5-4		20.31	0.24	20.55	8.2E-05
BQ5-5		17.77	0.25	18.02	7.2E-05
BQ5-6		23.88	0.29	24.16	9.6E-05
BQ6-1	Ordu	36.87	0.31	37.18	1.5E-04
BQ6-2		40.70	0.34	41.04	1.6E-04
BQ6-3		33.39	0.28	33.68	1.3E-04
BQ6-4		33.04	0.33	33.37	1.3E-04
BQ6-5		36.12	0.34	36.46	1.5E-04
BQ6-6		38.13	0.36	38.49	1.5E-04
BQ6-7		47.87	0.45	48.32	1.9E-04
BQ6-8		37.99	0.32	38.30	1.5E-04
BQ6-9		38.07	0.33	38.39	1.5E-04
BQ6-10		42.93	0.38	43.31	1.7E-04
BQ6-11		39.37	0.34	39.70	1.6E-04
BQ6-12		41.23	0.35	41.58	1.7E-04
BQ6-13		30.64	0.27	30.91	1.2E-04
BQ6-14		40.24	0.34	40.58	1.6E-04
BQ6-15		36.60	0.31	36.91	1.5E-04

BQ6-16		42.02	0.36	42.38	1.7E-04
BQ6-17		39.88	0.35	40.24	1.6E-04
BQ6-18		35.77	0.34	36.11	1.4E-04
BQ6-19		35.92	0.31	36.22	1.4E-04
BQ6-20		35.43	0.30	35.73	1.4E-04
BQ7-1	Trabzon	30.69	0.27	30.96	1.2E-04
BQ7-2		19.56	0.20	19.76	7.9E-05
BQ7-3		6.13	0.09	6.23	2.5E-05
BQ8-1	Tokat	28.75	0.31	29.06	1.2E-04
BQ8-2		12.92	0.14	13.06	5.2E-05
BQ8-3		27.64	0.31	27.95	1.1E-04
BQ8-4		28.01	0.32	28.33	1.1E-04
BQ8-5		25.64	0.26	25.90	1.0E-04
BQ8-6		24.65	0.27	24.92	9.9E-05
BQ8-7		27.80	0.28	28.08	1.1E-04
BQ8-8		26.96	0.28	27.24	1.1E-04
BQ8-9		30.51	0.31	30.83	1.2E-04
BQ8-10		27.19	0.28	27.47	1.1E-04
BQ8-11		26.75	0.28	27.03	1.1E-04

REFERENCES

ICRP 119 (2012). Compendium of dose coefficients based on ICRP Publication 60. Ottawa.

ICRP 60 (1990). Recommendations of the International Commission on Radiological Protection, vol. 212, No.1-3, publication 60.

Kurnaz A, Turhan Ş, Metin O, Altıkulaç A, Duran C. (2022). Evaluation of terrestrial radionuclide levels and concomitant radiological risks of bentonites used in many industries. International Journal of Environmental Health Research, 33(12), 1706–1715.

UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation). (2000). Sources and effects of ionizing radiation. United Nations Publication, New York, USA, 2000.

UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation). (2008). Sources and effects of ionizing radiation. United Nations Publication, New York, USA, 2010.

ASSESSMENT OF RADIOLOGICAL HEALTH RISKS ARISING FROM INTERNAL EXPOSURE TO WHICH AGRICULTURAL WORKERS AROUND A COAL-FIRED THERMAL POWER PLANT MAY BE EXPOSED

KÖMÜR YAKITLI TERMİK SANTRALİN ETRAFINDAKİ TARIM ÇALIŞANLARININ MARUZ KALABİLECEĞİ İÇ IŞINLAMADAN KAYNAKLANAN RADYOLOJİK SAĞLIK RİSKİNİN DEĞERLENDİRİLMESİ

Prof. Dr. Şeref TURHAN

Kastamonu Üniversitesi, Fen Fakültesi

Dr. Öğr. Üyesi Onur METİN

Kastamonu Üniversitesi, Taşköprü Meslek Yüksekokulu

ABSTRACT

Coal contributes significantly to electricity production and accounts for more than one-third of the world's total production. Lignite coal is a significant domestic energy source in Türkiye. The combustion of coal in electricity production produces a huge amount of bottom ash and fly ash as waste. A significant portion of the carbonaceous material in coal undergoes oxidation during the combustion process, causing natural radionuclides to concentrate in the resulting waste ash. It is concerning that the combustion of coal tends to increase the concentrations of naturally occurring radionuclides such as uranium (^{238}U), thorium (^{232}Th), and potassium (^{40}K). Inhalation and ingestion of wind-blown dust rich in ash particles are potential routes of exposure to radionuclides. Depending on the performance of the stack emission control system, significant amounts of ash may be emitted into the atmosphere and deposited on agricultural lands surrounding the plant due to the significant amount of waste generated. Therefore, this study aims to provide a comprehensive assessment of the radiological risks to agricultural workers working in a coal-fired power plant and its surrounding soil areas. For this purpose, the total annual effective radiation dose (AED) and the corresponding cancer risk (CR) were estimated based on the elemental concentrations of uranium, thorium and potassium analyzed in the surface soil collected from the vicinity of a coal-fired thermal power plant located in Kangal district of Sivas province, Türkiye, to assess the radiological health risks to which workers may be exposed via inhalation and ingestion. The average AED value was found as 4.7 μSv/y, and the corresponding total CR value was 1.95×10^{-5}. The radiological assessment revealed that adult agricultural workers were exposed to an additional dose well below the AED value of 296 μSv/y due to internal exposures from natural radioactivity (excluding radon).

Keywords: Thermal power plant, Soil, Natural radioactivity, Radiological health risk

ÖZET

Kömür, elektrik üretimine önemli ölçüde katkıda bulunur ve dünyanın toplam üretiminin üçte birinden fazlasını oluşturur. Linyit kömürü, Türkiye'de önemli ve önemli bir yerli enerji kaynağıdır. Elektrik üretiminde kömürün yanması sonucunda atık olarak devasa miktarda taban külü ve uçucu kül ortaya çıkar. Kömürdeki karbonlu malzemenin önemli bir kısmı yanma işlemi sırasında oksidasyona uğrayarak doğal radyonüklitlerin ortaya çıkan atık küllerde

yoğunlaşmasına neden olur. Kömürün yanmasının doğal olarak oluşan uranyum (^{238}U), toryum (^{232}Th) ve potasyum (^{40}K) gibi radyonüklitlerin konsantrasyonlarını artırma eğiliminde olması endişe vericidir. Kül parçacıkları bakımından zengin rüzgârla savrulan tozun solunması ve yutulması, radyonüklitlere veya maruz kalmanın potansiyel yollarıdır. Baca emisyon kontrol sisteminin performansına bağlı olarak, oluşan önemli miktarda atık nedeniyle atmosfere önemli miktarlarda kül yayılabilir ve tesisin çevresindeki tarımsal alanlarda birikebilir. Bu nedenle, bu çalışma, bir kömür yakıtlı termik santral ve çevresindeki toprak alanlarında çalışan tarım işçilerin maruz kalabileceği radyolojik risklerin kapsamlı bir değerlendirmesini sunmayı amaçlamaktadır. Bu amaç için Türkiye'nin Sivas ilinin Kangal ilçesinde yer alan kömür yakıtlı termik santral etrafından toplanan yüzey toprağında analiz edilen uranyum, toryum ve potasyumun elementel konsantrasyonları esas alınarak işçilerin solunum ve sindirim yolu ile maruz kalabileceği radyolojik sağlık risklerini değerlendirmek için toplam yıllık etkin radyasyon dozu (TYERD) ve bunlara karşılık gelen kanser riski (CR) hesaplandı. Ortalama TYERD değeri 4,7 μSv/y ve buna karşılık gelen toplam CR değer ise $1{,}9 \times 10^{-5}$ olarak bulundu. Radyolojik değerlendirme, yetişkin tarım işçilerinin, doğal radyoaktiviteden kaynaklanan iç maruziyetlerden (radon hariç) dolayı aldığı TYERD değeri olan 296 μSv/y'ın çok altında bir ek doza maruz kaldığını ortaya koymuştur.

Anahtar kelimeler: Termik santral, Toprak, Doğal radyoaktivite, Radyolojik sağlık riski

INTRODUCTION

Social, industrial, and technological advances that raise humanity's living standards are rapidly increasing the need for energy, making it indispensable. All developed and developing countries are striving to meet their energy demands primarily by using their own, highly secure resources. In this context, coal's abundance and easy and safe transportation make it crucial for global energy security. The use of coal in global electricity production has consistently surpassed other primary sources, and nearly half of the world's total electricity is generated by coal-fired thermal power plants (Turhan and Jamasali, 2024). Coal-fired thermal power plants are a significant component of Türkiye's electrical energy production. Türkiye's installed electricity capacity currently reaches 116.5 gigawatts (GW), one-fifth of which comes from a total of 69 coal-fired thermal power plants (MERN 2025). Türkiye's total coal reserves are approximately 22 billion tons, of which 20.5 billion tons consist of lignite and asphaltite (MERN 2025). Lignite coal has a calorific value ranging from 1000 to 4200 kcal/kg, and approximately 79% has a lower calorific value below 2500 kcal/kg, making the majority of lignite used as fuel in thermal power plants (MERN 2025). Therefore, lignite plays a crucial role in ensuring a stable and sustainable energy supply by fueling many thermal power plants in Türkiye.

Coal is a sedimentary rock formed by the accumulation of plant and tree residues through the chemical and physical effects of millions of years. Volatile organic compounds, gases, and solid wastes, known as environmental pollutants, are inevitably formed as a result of coal combustion in thermal power plants. The most important of these solid wastes is fly ash. Approximately 99% of fly ash is collected by electrostatic precipitators and disposed of in wet or dry forms in ash heaps or landfills, while the remaining 1% is released into the atmosphere along with volatile and gaseous wastes (Turhan et al., 2010; Jayaranjan et al., 2014; Altıkulaç et al., 2022; Turhan and Jamasali, 2024). However, a significant amount of fly ash particles can be released into the atmosphere each year as a result of the combustion of billions of tons of coal. Coal contains varying trace amounts of naturally occurring radioactive materials (NORMs) such as radionuclides from the decay series of uranium (^{238}U) and thorium (^{232}Th) and radio-potassium (^{40}K), depending on its geological formation, geochemical structure, and organic matter composition (Turhan et al. 2010; Dinis et al. 2021; Turhan and Jamasali 2024). When coal is burned, while organic components are removed, these radionuclides and minerals accumulate

in the ash (bottom and fly ash) to levels 3–10 times greater than typical values for burned coal (Turhan et al. 2010; Turhan and Jamasali 2024).

Therefore, fly ash is referred to as technologically enhanced naturally occurring radioactive material (TENORM) as coal combustion technically leads to an increase in the concentration of these radionuclides in the fly ash (Janković et al. 2022; Turhan and Jamasali 2024). People's exposure to ionizing radiation occurs via two primary routes: external and internal (UNSCEAR 2000). Internal exposure results from inhalation and ingestion of primordial radionuclides. Inhalation doses arise from the presence of soil dust particles containing these radionuclides in the air. The predominant component of inhalation exposure is the short-lived decay products of radon. Ingestion doses arise primarily from the radionuclides, which are present in food and drinking water. The total annual effective dose from inhalation and ingestion of terrestrial radionuclides is 310 μSv. Of this, 170 μSv originates from ^{40}K and 140 μSv from long-lived radionuclides in the ^{238}U and ^{232}Th decay chains (UNSCEAR 2000). Assessing radiological risks from natural and artificial radioactivity is crucial for human and environmental health and requires continuous measurement, monitoring, and assessment of environmental radioactivity. The UNSCEAR report defines low doses as doses below 100 mSv. At doses above 100 mSv, there is strong epidemiological evidence of a causal relationship between radiation exposure and many diseases, including cancer. At lower doses (<100 mSv), human data are variable, and observed effects are extrapolated from higher doses and results from experimental studies.

This study is the first to assess the radiological health risk resulting from internal exposure caused by inhalation of soil dust and/or accidental ingestion of soil particles by workers working in agricultural fields around the Kangal lignite-fired thermal power plant located in Sivas province in Türkiye. For the radiological assessment, the annual effective doses due to the inhalation and ingestion of the radionuclides in soil collected from agricultural areas around Kangal lignite-fired thermal power plant and the corresponding lifetime cancer risks were estimated.

MATERIAL AND METHODS

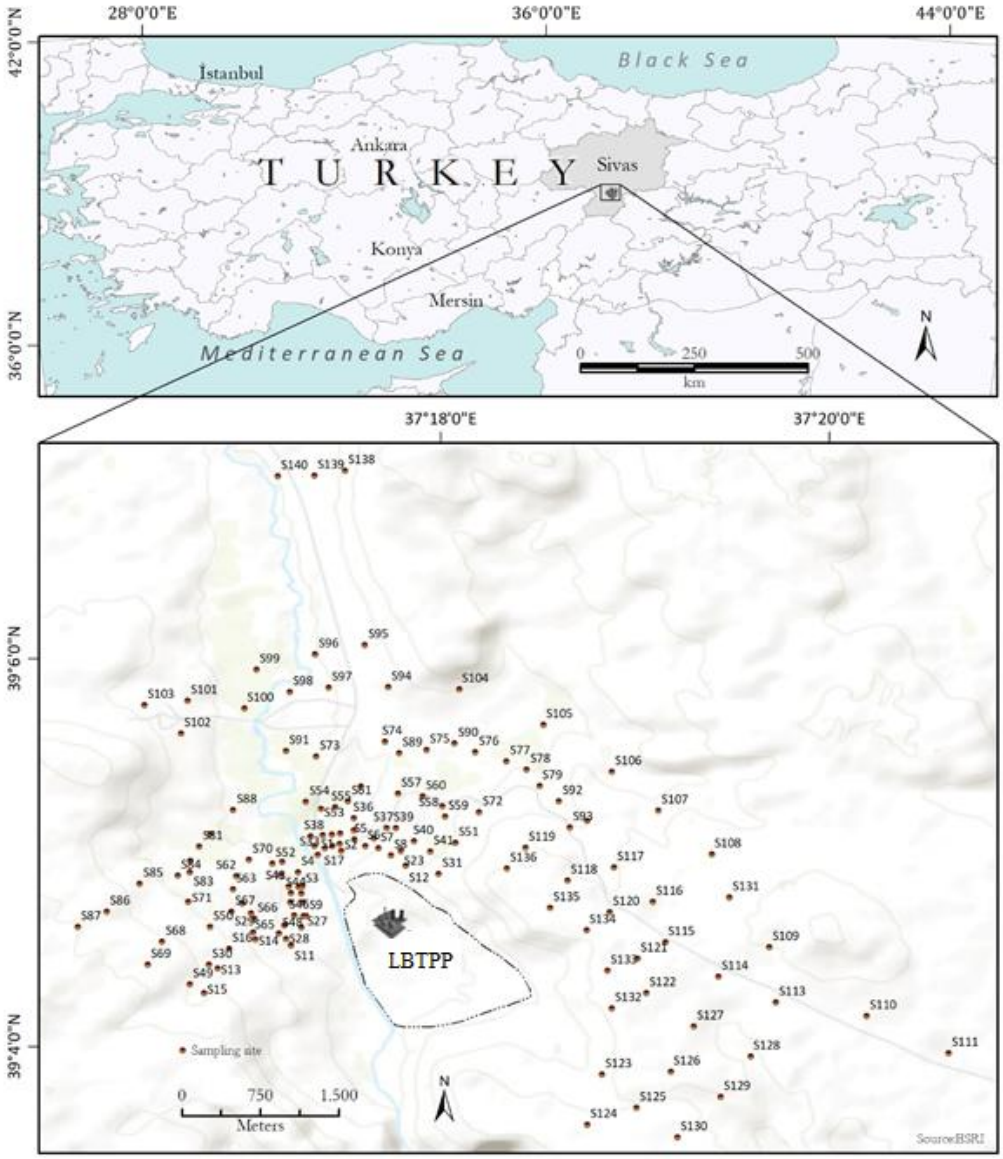
Collection, preparation, and analysis

Kangal is a district of Sivas Province in the Central Anatolia Region of Türkiye. The Kangal has been in production for 29 years, since 1989. The annual lignite coal consumption of the Kangal lignite-fired thermal power plant is approximately 6,832,889 tons. In 2015, it produced 1,423,843 tons of fly ash (Turhan 2020). Kangal lignite-fired thermal power plant has a total installed capacity of 457 MW and 1811 GWh gross production. The details of collection and preparation of the collection and preparation of 140 surface (0-5 cm) soil samples from Kangal lignite-fired thermal power plant, as shown in the map in Fig.1, and the determination of the concentration of PTEs by an energy-dispersive X-ray fluorescence (EDXRF) spectrometer were given in the study conducted by Turhan (2020).

In this study, the uranium, thorium, and potassium concentrations analyzed by Turhan (2020) were converted to activity concentration (A) using the following formula:

$$A(Bq/kg) = \frac{E_C \times \lambda_E \times N_{Av} \times IA_E}{AW_E \times f} \quad (1)$$

where E_C is the elemental concentration of uranium (mg/kg), thorium (mg/kg) and potassium (%) taken from Turhan (2020); λ_E is the decay constant (1/s), N_{Av} is Avogadro's number (6.023×10^{23} atoms/mol); IA_E is the atomic abundance of uranium (99.275%), thorium (100%) and potassium (0.0116%); AW_E is the atomic mass (kg/mol) and f is a factor with a value of 1,000,000 for ^{238}U and ^{232}Th and 100 for ^{40}K.



5. Fig. 1. Map of sampling sites (Turhan 2020)

Assessment of radiological health risk

Radiological health risks caused by the ionizing radiation emitted from the primordial radionuclides in the soil samples were assessed for adult agricultural workers, taking into account internal exposure. Internal exposures occur in the intake of the terrestrial radionuclides in the soil samples by inhalation and ingestion (UNSCEAR 2000). The annual effective dose (AED_{Inh}) due to the inhalation was estimated as follows (UNSCEAR 2000):

$$AED_{Inh}(\mu Sv/y) = \sum_i (A_i \times DC_{Inh}) \times V \times C \times T \quad (2)$$

where A_i is the activity concentration (Bq/kg) of ^{238}U, ^{232}Th and ^{40}K in soil samples, DC_{iInh} is the effective dose coefficient for adult agricultural workers and taken as 1.6, 42 and 0.003 μSv/Bq for ^{238}U, ^{232}Th and ^{40}K, respectively (ICRP 119); V is breath frequency (20 m^3/d), and C is the average soil dust concentration (50 μg/m^3) (UNSCEAR 2000) and T is the exposure time (25 y × 180 d/y).

Annual effective dose (AED_{Ing}) due to the ingestion was estimated as follows (UNSCEAR 2000):

$$AED_{Ing}\left(\mu Sv/y\right)=\sum_{i}(A_{i}\times DC_{iIng})\times AI \quad (3)$$

where DC_{Ing} is the effective dose coefficient for adult agricultural workers taken as 0.044, 0.23, and 0.0062 μSv/Bq for ^{238}U, ^{232}Th, and ^{40}K, respectively (ICRP 119), and AI is an annual intake of soil particles (100 mg/d ×180 d/y). Total annual effective dose (AED_{Total}) is calculated as follows:

$$AED_{Total}=AED_{Inh}+AED_{Ing} \quad (4)$$

The excess lifetime cancer risks CR_{Inh} and CR_{Ing} due to inhalation and ingestion were estimated as follows (ICRP 1990):

$$CR_{Inh}=AED_{Inh}\times\cdot LT\cdot R_{F} \quad (5)$$

$$CR_{Ing}=AED_{Ing}\times\cdot LT\cdot R_{F} \quad (6)$$

where AED_{inh} and AED_{Ing} are the inhalation and ingestion annual effective dose given in Eq. (2) and Eq. (3), respectively, LT is the average lifetime (70 y), and R_F is the cancer risk factor of 0.057/Sv (ICRP 1990). The total excess lifetime cancer risk (CR_{Total}) is calculated as follows:

$$CR_{Total}=CR_{Inh}+CR_{Ing} \quad (7)$$

RESULTS AND DISCUSSION

Some descriptive statistical information of the activity concentrations of ^{40}K, ^{232}Th, and ^{238}U analyzed in the soil samples is presented in Table 1. The activity concentrations of radionuclides ranged from 78 to 505 Bq/kg with a mean of 207 Bq/kg (^{40}K), 12 to 52 Bq/kg with a mean of 23 Bq/kg (^{232}Th), and 4 to 152 Bq/kg with a mean of 18 Bq/kg (^{238}U). The average activity concentrations of these radionuclides are lower than the current worldwide mean values of 412 Bq/kg (^{40}K), 45 Bq/kg (^{232}Th), and 33 Bq/kg (^{238}U).

The values of radiological parameters estimated for adult workers are given in Table 2. It can be seen from Table 2 that the values of the AED_{Inh} ranged from 2.31 to 10.6 μSv/y with a mean of 4.56 μSv/y, which is lower than the world average annual effective dose of 5.8 μSv/y from inhalation of ^{238}U and ^{232}Th series radionuclides in air (UNSCEAR 2008). The values of the AED_{Ing} ranged from 0.08 to 0.30 μSv/y with a mean of 0.13 μSv/y, which is significantly lower than the world average annual effective dose of 290 μSv/y from the ingestion of primordial radionuclides (UNSCEAR 2008). The values of AED_{Total} ranged from 2.39 to 10.37 μSv/y with a mean of 4.69 μSv/y, which is significantly lower than the world total average annual effective dose of 296 μSv/y from internal exposure due to the primordial radionuclides.

Table 1. Some descriptive statistical information on radionuclide activity concentrations

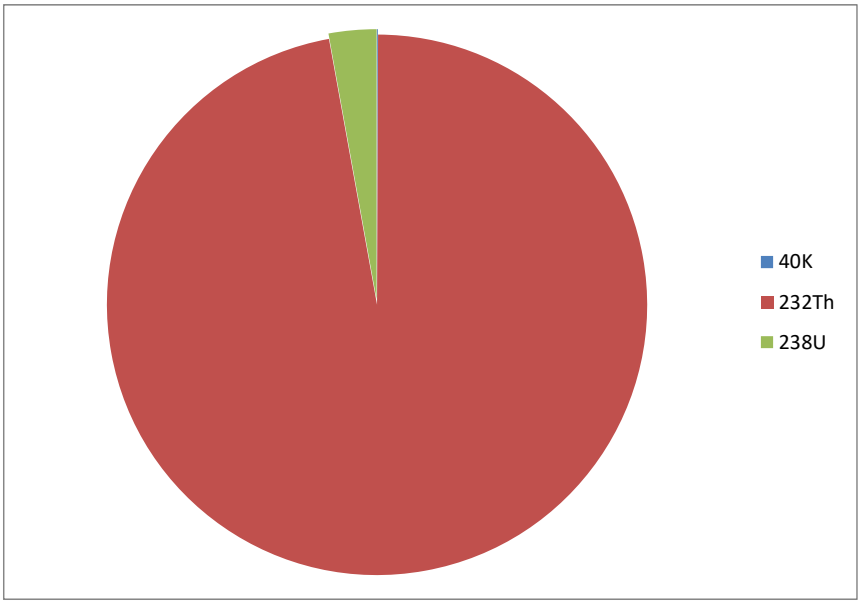
	Activity concentration (Bq/kg)		
	^{40}K	^{232}Th	^{238}U
Mean	207.1	23.4	18.0
Standard error	6.7	0.7	1.4
Median	184.0	21.5	12.3
Mode	181.8	22.7	12.3
Standard deviation	79.4	8.3	16.8
Sample variance	6308.2	69.6	281.0
Kurtosis	2.1	2.1	32.8
Skewness	1.6	1.5	4.9
Range	427.1	39.8	148.1
Min	77.6	11.8	3.7
Max	504.7	51.5	151.8
Total	28992.5	3277.7	2525.7
Number of samples	140	140	140

Table 2. The values of radiological parameters estimated for workers

	Radiological parameter		
	AED_{Inh}	AED_{Ing}	AED_{Total}
Mean	4.56	0.13	4.69
Standard error	0.14	0.004	0.14
Median	4.17	0.12	4.30
Standard deviation	1.62	0.05	1.66
Sample variance	2.62	0.002	2.77
Kurtosis	2.28	2.94	2.30
Skewness	1.52	1.78	1.52
Range	7.75	0.23	7.98
Min	2.31	0.08	2.39
Max	10.06	0.30	10.37

The contribution of each radionuclide to the total annual effective dose is shown in Fig. 2. The contributions of radionuclides ^{40}K, ^{232}Th, and ^{238}U to the inhalation annual effective dose are 0.1%, 97.1% and 2.9%, respectively. The contributions of radionuclides ^{40}K, ^{232}Th, and ^{238}U to the ingestion annual effective dose are 17%, 72% and 11%, respectively.

a)



b)

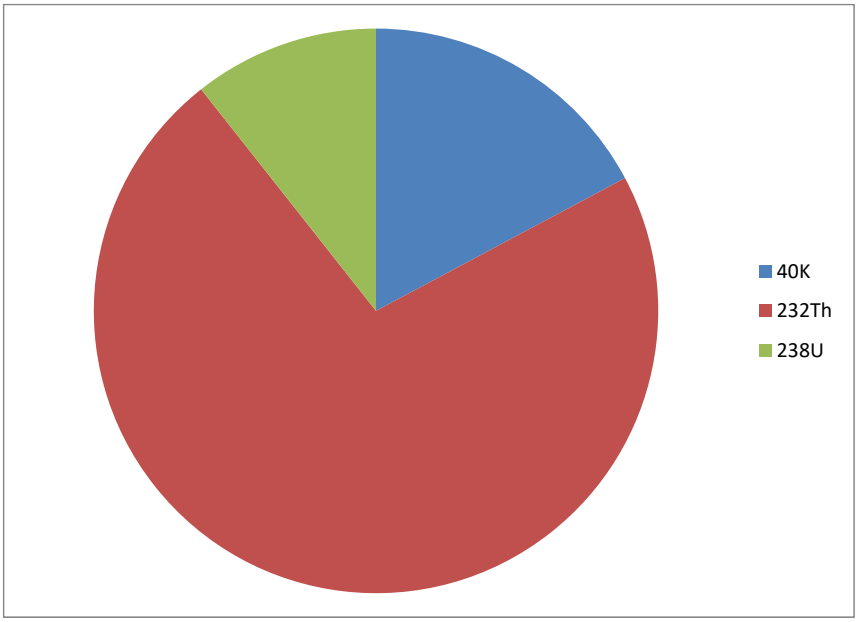


Fig. 2. The contribution of each radionuclide to the total annual effective dose. a) Inhalation and b) Ingestion

The values of the CR_{Total} varied from 9.5×10^{-6} to 4.1×10^{-5} with a mean of 1.9×10^{-5}. The CR_{Total} is significantly lower than the world average value of 1.2×10^{-3}.

CONCLUSIONS

This study assessed for the first time the radiological health risk of agricultural workers in fields around the Kangal lignite-fired thermal power plant in Türkiye due to exposure to soil dust or particles. The results revealed that the radiation dose to which the workers were exposed was low. However, it is recommended that workers take radiation protective measures to minimize radiation exposure.

REFERENCES

Altıkulaç A, Turhan Ş, Kurnaz A, Gören E, Duran C, Hançerlioğulları A, Uğur FA. (2022). Assessment of the enrichment of heavy metals in coal and its combustion residues. ACS Omega, 7(24), 21239–21245.

Dinis MdL, Fiúza A, Góis J, de Carvalho JS, Meira Castro AC. (2021). Assessment of natural radioactivity, heavy metals and particulate matter in air and soil around a coal-fired power plant—an ıntegrated approach. Atmosphere, 12, 1–20.

ICRP 119. (2012). Compendium of dose coefficients based on ICRP Publication 60. Ottawa.

Janković MM, Todorović DJ, Nikolić JD. (2011). Analysis of natural radionuclides in coal, slag and ash in coal-fired power plants in Serbia. Journal of Mining and Metallurgy, 47(2), 149–155.

ICRP (1990). Recommendations of the International Commission on Radiological Protection, vol. 212, No.1-3, publication 60.

Jayaranjan MLD, van Hullebusch ED, Annachhatre AP. (2014). Reuse options for coal fired power plant bottom ash and fly ash. Reviews in Environmental Science and Biotechnology, 13, 467–486.

MENR (Ministry of Energy and Natural Resources), (2025) Web page: https://enerji.gov.tr/infobank-energy-electricity.

Turhan Ş, Parmaksız A, Köse A, Yüksel A, Arıkan İH, Yücel. B (2010). Radiological characteristics of pulverized fly ashes produced in Turkish coal-burning thermal power plants. Fuel 89(12), 3892–3900.

Turhan Ş. (2020). Evaluation of agricultural soil radiotoxic element pollution around a lignite-burning thermal power plant. Radiochimica Acta, 108 (1), 77–85.

Turhan Ş, Jamasali Y-den. (2024). Evaluation of radiological health risk caused by the use of fly ash in cement and concrete production and its storage. International Journal of Environmental Health Research, 34(9), 3256–3271.

UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation). (2000). Sources and effects of ionizing radiation. United Nations Publication, New York, USA, 2000.

UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation). (2008). Sources and effects of ionizing radiation. United Nations Publication, New York, USA, 2010.

DESIGN AND EVALUATION OF A REAL-TIME DRIVER MONITORING SYSTEM USING LANDMARK-BASED AND DEEP VISUAL FEATURES

Duygu ARAS

Turkish German University, Faculty of Engineering, Department of Mechatronics,

Istanbul, Turkey

ORCID ID: https://orcid.org/0009-0005-1985-2507

Asst. Prof. Dr. Merve TEKE BUDAKLI

Turkish German University, Faculty of Engineering, Department of Mechatronics,

Istanbul, Turkey

ORCID ID: https://orcid.org/0000-0002-5792-1228

ABSTRACT

This study presents a real-time, multi-modal driver monitoring system designed to detect fatigue and distraction in truck drivers. The system evaluates personalized behavioral metrics such as eye closure ratio (EAR), mouth opening ratio (MAR), head pose, and phone usage under realistic conditions. The aim is to support accident prevention in fleet operations by recognizing risky driver states early.

Developed in Python, the system combines OpenCV, Dlib, MediaPipe, and YOLOv5s. Haar Cascade was chosen for its low-computation frontal face detection to enable fast initialization. Detected regions were passed to Dlib for 68-point facial landmark extraction. EAR and MAR thresholds were dynamically determined via a 5-second personalized calibration (EAR_thresh = μ - 0.25σ, MAR_thresh = μ + 2σ) over 150+ frames. Head orientation was estimated using six reference points from MediaPipe FaceMesh and OpenCV's solvePnP() algorithm; continuous yaw deviations greater than ±30° for over 4 seconds were flagged as distraction. For phone use, YOLOv5s (input: 640×480) and MediaPipe Hands (21 landmarks) were combined, marking "hand-on-phone" states longer than 5 seconds as risky.

Performance testing showed that MediaPipe FaceMesh achieved an average detection time of 9.32 ms with a 100% detection rate, while MediaPipe FaceDetection followed with 3.61 ms, also reaching 100% accuracy. Dlib performed with an average of 71.73 ms and a 97.1% detection rate, whereas HaarCascade had the slowest average at 91.65 ms, ranging up to 357.8 ms, with a detection rate of 97.1%. Statistical comparison using the Mann-Whitney U test confirmed that most differences between methods were statistically significant ($p < 0.05$), except between MediaPipe FaceMesh and HaarCascade ($p = 0.092$), suggesting comparable performance under certain conditions. Additionally, personalized calibration reduced false positive alerts by 38% compared to fixed-threshold approaches. Although HaarCascade demonstrated higher latency and lower frame rate (10.9 FPS), it was selected for its simplicity, low computational demand, and reliable frontal face detection in embedded systems, making it a practical and effective choice for real-time modular integration.

Each algorithm was selected based on a performance-accuracy trade-off. HaarCascade was favored for its low resource usage and initialization speed. MediaPipe methods offered

excellent accuracy and real-time capability, while Dlib ensured robust landmark detection. The integration forms a modular, efficient system suitable for embedded fleet safety applications.

Key Words: Driver Monitoring, EAR, MAR, Haar Cascade, Dlib, YOLOv5s, MediaPipe, Real-Time Processing

Introduction

Driver-related accidents in commercial transportation, especially during long-distance trips, pose a significant safety issue. Fatigue and distraction are among the primary causes of accidents in the logistics sector. In Turkey alone, 924 individuals were injured or killed in truck-related traffic accidents in 2024. When including tractor-trailers and other heavy vehicles, this number exceeds 2,200[1]. This situation demonstrates that driver monitoring systems are no longer optional but have become a necessity.

Traditional CAN-Bus-based fleet management systems typically focus solely on the technical status of the vehicle while neglecting the driver's condition. The system developed in this study offers an integrated solution capable of monitoring both the vehicle and the driver simultaneously. Parameters such as the driver's facial region, eye and mouth movements, head position, and phone usage are analyzed via camera input, and the resulting data are presented in real-time through a Python-based graphical user interface (GUI).

One of the unique aspects of the system is its ability to perform personalized calibration. Recognizing that each driver has a different eye structure, facial ratio, or mimic profile, the system improves performance by setting individual threshold values at the start of each driving session. This approach not only reduces the false alarm rate but also enables the system to respond more accurately.

To enhance the scientific validity of the developed system, various facial detection algorithms were comparatively evaluated. In driver monitoring solutions designed for embedded systems, both detection time (in milliseconds) and accuracy rate (%) are critical parameters.

Accordingly, widely used methods such as Haar Cascade, Dlib, MediaPipe FaceDetection, and MediaPipe FaceMesh were tested under controlled conditions and analyzed in terms of processing time, detection accuracy, and statistical significance. The performance of the algorithms was demonstrated not only theoretically but also through real-time graphical and numerical outputs. These comparative analyses enabled an objective evaluation of the algorithms, allowing the identification of the most suitable one along with the rationale for its selection.

Development

To address the challenges of driver fatigue and distraction in long-haul transportation, this study presents the development of a real-time, camera-based driver monitoring system. The following sections outline the system's structure, hardware and software architecture, and key functional components.

System Structure and Components

The system developed in this study is a computer vision-based monitoring module specifically designed to detect driver fatigue and distraction by analyzing facial features. The architecture operates on real-time processing of behavioral indicators such as eye openness, mouth movement, head orientation, and phone usage.

Hardware Architecture

The system is built on a compact embedded platform, the Raspberry Pi 5, and is supported by a Raspberry Pi v3 camera module for capturing driver-oriented visual data. The camera is positioned to optimally cover the driver's entire facial region, with a diagonal field of view of 79°. This configuration enables high-accuracy detection of facial contours, eye and mouth movements, and head orientation.

Software Architecture and Tracking

The software architecture was entirely developed using the Python programming language, with integration of the following libraries:

- OpenCV: Used for image preprocessing and visual data capture.
- Dlib: Provides a 68-point facial landmark model, primarily used for calculating EAR (Eye Aspect Ratio) and MAR (Mouth Aspect Ratio).
- MediaPipe Face Mesh: Utilized for 468-point facial mesh analysis, particularly for tracking head pose and facial orientation.
- YOLOv5s: Employed for fast and accurate object detection, specifically for identifying smartphone presence.
- MediaPipe Hands: Detects hand movement and interaction with handheld devices, such as phone usage.

This architecture enables the system to infer fatigue and distraction signals specific to individual drivers based solely on visual input. For each new driver, the system performs a personalized calibration at the start of the driving session, automatically determining driver-specific threshold values.

The graphical user interface (GUI) is a visual panel developed using PyQt6. It provides real-time feedback on driver status, such as "fatigued," "attentive," or "phone usage detected", through a combination of icons, color indicators, and textual labels. These visual outputs allow the system to be interpreted without the need for human intervention.

Driver Monitoring Method

The visual driver state recognition is based on a combination of Haar Cascade face detection and Dlib's 68-point facial landmark model. Using this setup, parameters such as the Eye Aspect Ratio (EAR) and Mouth Aspect Ratio (MAR) are calculated in real time to detect signs of fatigue, including drowsiness and yawning.

At the beginning of each driving session, an automatic calibration is performed to determine individual threshold values for EAR, MAR, and LIP. These thresholds serve as the basis for a personalized fatigue analysis. Additionally, the system attempts to visually identify the driver. All relevant data are displayed and continuously updated within the Driver Information module.

Haar Cascade for Face Detection

The Haar Cascade algorithm is based on so-called "Haar-like features," which are rectangular filters used to identify specific object structures such as eyes, nose, and facial contours. These

features exploit the contrast between light and dark regions to detect characteristic visual patterns.

Such a feature is calculated as follows:

$$Value = \sum_{x,y \in bright\ region} I(x,y) - \sum_{x,y \in dark\ region} I(x,y) \quad (1)$$

where I(x,y) denotes the pixel intensity at position (x,y). The feature value is derived by subtracting the sum of pixel intensities in the darker region from that in the brighter region.

The computed value is then compared to a predefined threshold. If it exceeds this threshold, it is assumed that the target object is located at that position.

To enable efficient computation of these features, the **integral image** method is employed. This approach allows the sum of pixel intensities within any arbitrary rectangular region to be calculated in constant time, with a computational complexity of $O(1)^2$.

For each pixel, the sum of all pixel values located to the left and above that point is computed. This enables rapid evaluation of even large image regions, which is essential for real-time processing in vehicle environments.

Training a Haar Cascade classifier generally requires a large set of normalized grayscale images labeled as positive and negative samples. However, in this study, no custom training was performed; instead, a pre-trained model provided by OpenCV was used. The greater the diversity of training images, the higher the detection accuracy tends to be. The objective is to utilize a Haar Cascade function capable of detecting similar or identical objects across various images.

To reduce computational time, it is not necessary to evaluate all features for every image; instead, features are checked sequentially. If a given feature yields a negative result, indicating its absence, the image is immediately classified as negative, and the algorithm proceeds to the next image in the dataset. This sequential evaluation significantly streamlines the process. The system output is either “face not detected” or “face detected,” corresponding to a negative or positive classification.

Figures 3.1 through 3.3 illustrate examples of Haar-like features: edge features (e.g., for detecting light-dark transitions), line features (used to identify symmetric structures), and four-rectangle features (for more complex pattern recognition). These rectangular feature masks act as filters that allow efficient extraction of relevant visual information from the image.

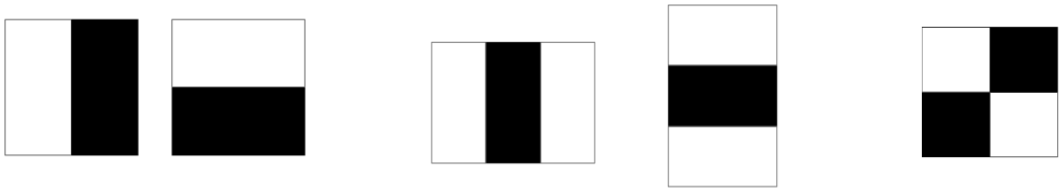


Fig 3.1: Features a) Edge, b) Line, c) Four-Rectangle

In contrast to conventional summation methods, where each pixel value would need to be accumulated individually, the integral image is based on a preprocessing step. In this step, the sum of all pixel values located above and to the left of a given point, including the point itself, is calculated for each pixel.

This can be formally described as follows:

$$II(x,y) = \sum_{i=0}^{x} \sum_{j=0}^{y} I(i,j) \quad (2)$$

where:

- I(x,y) represents the original grayscale intensity of the pixel at point (x,y)
- II(x,y) denotes the corresponding value in the integral image[3,4].

As a result, the integral image method enables extremely fast computation of rectangular sums, with a complexity of O(1), which are necessary for detecting specific patterns in an image using Haar features. In practice, this allows Haar features to be applied efficiently even on systems with limited processing power, such as a Raspberry Pi. Consequently, the algorithm is well suited for execution on embedded platforms.

In the Haar Cascade algorithm, each image region passes through a predefined chain of classifiers known as the cascade. This chain is composed of so-called weak classifiers. At each stage, the algorithm checks whether the corresponding region meets specific criteria. If a region fails any of these checks, it is immediately discarded, thus avoiding unnecessary computations.

Dlib 68-Point Facial Landmark Detection

In this study, facial position was initially detected using the Haar Cascade method. For more precise analysis of specific facial regions the 68-point landmark model from Dlib was subsequently employed. This model is based on a pre-trained regression approach that identifies key points on the human face, including six points per eye and twenty points around the mouth.

Accurate localization of the eye and mouth landmarks is essential for calculating the metrics used in this study, such as the Eye Aspect Ratio (EAR) and Mouth Aspect Ratio (MAR). The figure below illustrates the indexed reference points corresponding to specific anatomical regions of the human face:

- Eyes: left eye (points 37–42), right eye (points 43–48)
- Mouth: outer region (points 49–60), inner region (points 61–68)
- Eyebrows: left eyebrow (points 18–22), right eyebrow (points 23–27)
- Nose: (points 28–36)
- Jawline/Face contour: (points 1–17)

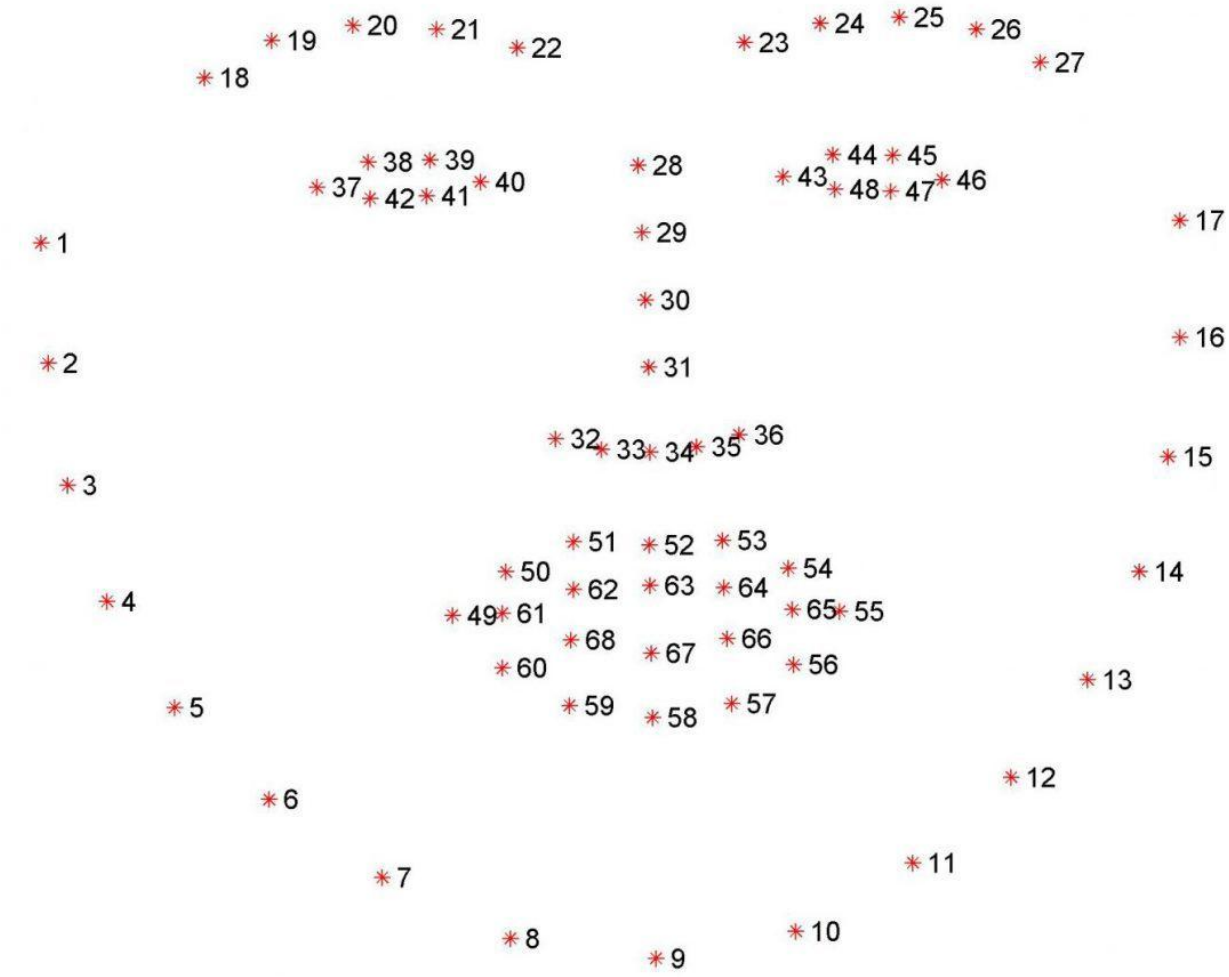


Fig. 3.2: Facial Feature Detection Using Dlib's 68-Point Model[5]

By leveraging Dlib's 68-point facial landmark model, the positions of the eyes and mouth could be reliably detected in each video frame, enabling real-time analysis of fatigue-related indicators. Key metrics such as the Eye Aspect Ratio (EAR), based on points 37–42 and 43–48, and the Mouth Aspect Ratio (MAR), derived from points including 49, 55, 52, 58, 61, and 67, were extracted consistently. This allowed the system to monitor subtle facial changes associated with drowsiness, without the need for extensive computational resources.

EAR (Eye Aspect Ratio) and MAR (Mouth Aspect Ratio)

Blinking is a natural reflex in which the eyelid briefly closes and reopens. Two primary muscle groups are involved in this process: the musculus orbicularis oculi, responsible for closing the eye, and the musculus levator palpebrae superioris, which controls eyelid elevation. In addition to protecting the eye from foreign particles, blinking also serves essential functions such as moisturizing and cleaning the ocular surface [6].

The early detection of driver fatigue plays a crucial role in reducing the risk of serious traffic accidents. A widely adopted approach for fatigue detection involves the analysis of blink behavior, as fatigue often manifests through an increased blink frequency or prolonged eyelid closures. In this context, the Eye Aspect Ratio (EAR) method has proven to be effective.

EAR describes the ratio between the vertical and horizontal dimensions of the eye opening and is calculated based on specific facial landmarks that can be automatically localized using the

Dlib library. When the eyes are closed, the calculated EAR value drops significantly, serving as a reliable indicator of drowsiness.

This method functions independently of head orientation or distance from the camera. It is particularly well suited for in-vehicle applications due to its lightweight structure, rapid computation, and high effectiveness.

The Eye Aspect Ratio (EAR) is a dimensionless scalar value computed from six specific landmark points around the eye. These points are identified using a facial landmark model[7].

Table 1: Corresponding Landmark Indices for EAR in the Dlib 68-Point Model

Visualization (Point)	**Dlib-Index**		**Description**
P1	37 (left eye)	43 (right eye)	outer horizontal point
P2	38	44	upper outer vertical point
P3	39	45	upper inner vertical point
P4	40	46	inner horizontal point
P5	41	47	lower inner vertical point
P6	42	48	lower outer vertical point

The calculation is performed using the following formula: In the numerator, the vertical opening of the eye is measured. In close relation, the denominator represents the horizontal width of the eye[6].

Here, ||Pi - Pj|| denotes the Euclidean distance between points Pi and Pj. The EAR value for both open and closed eyes is calculated using the following equations[6]:

$$EAR = \frac{||P2 - P6|| + ||P3 - P5||}{2\,.\,||P1 - P4||} \quad (3)$$

$$AVGEAR = \frac{1}{2}\,(EAR_{Let} + EAR_{Rit}\,) \quad (4)$$

$$EAR_{open} = \frac{||P_2 - P_6||_{max} + ||P_3 - P_5||_{max}}{2\,.\,||P_1 - P_4||_{min}} \quad (5)$$

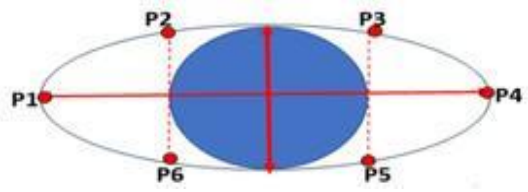


Fig. 3.3: Open Eye

$$EAR_{closed} = \frac{||P_2 - P_6||_{min} + ||P_3 - P_5||_{min}}{2 \,.\, ||P_1 - P_4||_{max}} \quad (6)$$

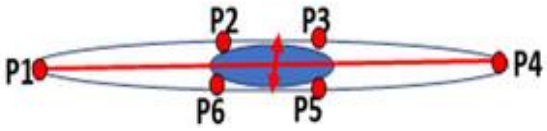


Fig. 3.4: Closed Eye

The final Modified EAR value is then computed as the average of both calculations, as expressed in the following equation:

$$Threshold_{modified} = \frac{(EAR_{closed} + EAR_{open})}{2} \quad (7)$$

The Eye Aspect Ratio (EAR) is used to determine the eye status. When the EAR value falls below a defined threshold, it is interpreted as an indication of closed eyes, whereas values above the threshold suggest that the eyes are open. A low EAR value, typically close to zero, signals eyelid closure, while open eyes correspond to higher EAR values. By continuously computing the EAR value in each video frame, blinking behavior and the driver's level of alertness can be monitored in real time. If the EAR remains below the threshold across several consecutive frames, it may indicate fatigue or reduced attentiveness.

Image acquisition was carried out using an original Raspberry Pi camera module, which is directly connected to the Raspberry Pi via the CSI interface. The camera provides video streams up to 60 frames per second at 1080p resolution, allowing precise real-time tracking of eye movements. Processing is performed locally on the Raspberry Pi 5 using OpenCV and Dlib libraries.

The EAR method enables continuous, real-time monitoring of the driver without requiring complex hardware or computationally intensive algorithms. This is especially important during long-haul truck driving, where continuous assessment of the driver's alertness and fatigue levels is crucial. The method relies on detecting patterns of eye opening and closure via a live video stream. When the system detects that the eyes remain closed for a predefined duration, it interprets this as a sign of drowsiness or microsleep. In such cases, the integrated alert system is activated to warn the driver through visual or auditory signals.

This early warning can be critical in monotonous driving conditions, at night, or during poor visibility, helping prevent potential accidents. In such situations, the system acts as a supportive tool by drawing the driver’s attention to their current state of fatigue and helping them maintain control.

Another key advantage of the EAR method lies in its relatively low computational demand. The formulas used for calculation are simple yet flexible enough to adapt to various eye shapes and facial structures. This makes the method highly efficient for real-time in-vehicle systems, where processing speed and energy efficiency are essential.

Moreover, the EAR method is robust to minor head movements and varying camera angles. This means that the camera does not need to be positioned directly in front of the driver's face. Even when mounted at the side window or dashboard with a lateral viewing angle, the system can still reliably detect fatigue. This increases flexibility in camera placement within the vehicle cabin and improves the practicality of the system in real-world use.

In summary, the EAR method provides a practical solution for fatigue detection that can be effectively integrated into existing driver assistance systems and significantly enhance road safety.

In parallel, for precise analysis of the mouth region, this study also utilizes the Dlib 68-point facial landmark model. This model identifies standardized facial points, including the outer and inner contours of the mouth. To detect yawning, the Mouth Aspect Ratio (MAR) is calculated as a ratio between selected vertical and horizontal point pairs within the inner mouth region.

The figure below illustrates the vertical and horizontal distances, along with the corresponding landmark indices from the Dlib 68-point model, which are used in the computation of the MAR value.

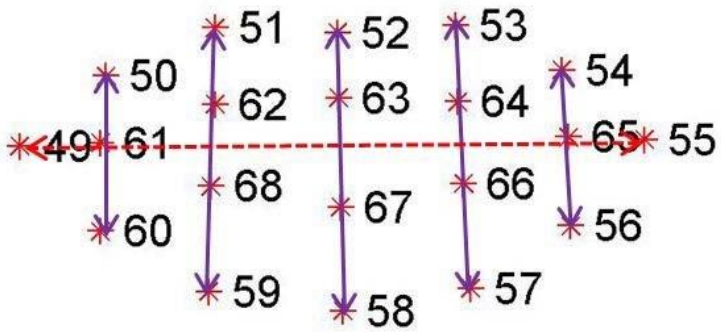


Fig. 3.5: Mouth Landmarks in the Dlib 68-Point Model[8]

The figure below illustrates the point assignments (p1–p8) used to calculate the Mouth Aspect Ratio (MAR), where vertical and horizontal distances within the inner mouth region are measured:

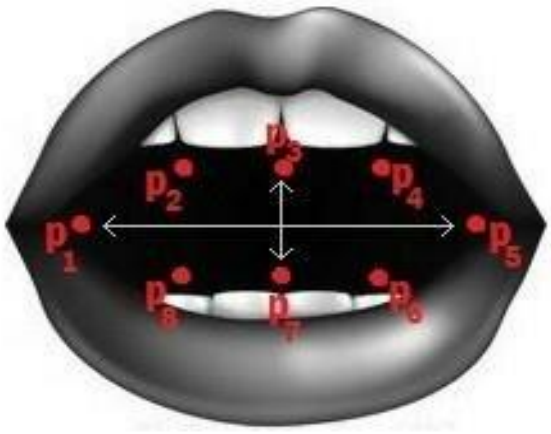


Fig. 3.6: Point Assignments for Calculating the Mouth Aspect Ratio (MAR)[8]

As shown in the figure, eight specific points are used. Their corresponding indices in the Dlib model are as follows:

Table 2: Corresponding Landmark Indices for MAR in the Dlib 68-Point Model

Visualization (Point)	Dlib-Index	Description
P1	61	Left inner horizontal point
P2	62	Upper left inner point
P3	63	Upper center inner point
P4	64	Upper right inner point
P5	67	Right inner horizontal point
P6	66	Lower right inner point
P7	65	Lower center inner point
P8	68	Lower left inner point

The formula for calculating the MAR is accordingly given as:

$$MAR = \frac{\left||P2 - P8|\right| + \left||P3 - P7|\right| + \left||P4 - P6|\right|}{2\,.\,||P1 - P5||} \quad (8)$$

A MAR value exceeding an individually calibrated threshold and sustained for at least 0.6 seconds is classified as a yawn by the system.

Calibration Process (Personalized Thresholds)

A key distinguishing feature of the developed fatigue detection system is the implementation of a personalized calibration procedure tailored to the biometric characteristics of each individual driver. Unlike static thresholds, the decision boundaries for fatigue and yawning are dynamically determined through a one-time calibration process.

Prior to calibration, the system performs automated driver identification based on facial features, which are extracted using a pre-trained embedding model and compared with a local profile database.

If a known driver is recognized, the system automatically loads the previously stored EAR and MAR thresholds for that driver. If no profile is found or the driver is not recognized, a new calibration is initiated and subsequently linked to a newly assigned driver ID.

The calibration is conducted under the assumption that the driver is in a neutral, alert state. Over a five-second period, each video frame is used to record both the Eye Aspect Ratio (EAR), based on landmark points 37 to 42 and 43 to 48, and the Mouth Aspect Ratio (MAR), based on points 60 to 68. These measurements are stored in two separate lists and, upon completion of the calibration phase, subjected to statistical analysis to establish individual reference values for further evaluation [9].

The calculation of the individual thresholds is performed according to the following formulas[10]:

$$EAR_{\text{Threshold}} = \mu(EAR) - 0{,}25\ x\ \sigma(EAR) \quad (9)$$

$$MAR_{\text{Threshold}} = \mu(MAR) + 2\ x\ \sigma(MAR) \quad (10)$$

Here, μ represents the mean and σ the standard deviation of the corresponding measurement set. These personalized threshold values are then used in the ongoing detection process for classifying fatigue and yawning behavior.

Through this adaptive method, the system can account for individual physiological differences (such as eye shape or eyelid tension), significantly reduce the false alarm rate, and adapt to various drivers without requiring manual fine-tuning.

Calibration is performed once per driver profile and is firmly integrated into the system workflow. Upon successful initialization, the computed threshold values are stored in the system state and applied automatically. If needed, the user can restart the calibration to account for changed conditions, such as fatigue levels or lighting.

Head Pose Detection and Warning Algorithm for Yaw Angle Monitoring

One of the essential criteria for safe driving is the driver's continuous visual focus on the road. If the driver’s head turns to the left or right for an extended period without any traffic-related reason, this may indicate distraction. Therefore, a warning algorithm was developed within the scope of this project to detect such head movements in real time. The core of this method is the calculation of the yaw angle, which represents the horizontal deviation of the driver’s head from the forward-facing direction.

To implement this, the MediaPipe Face Mesh library was used, which detects 468 three-dimensional facial landmarks in real time. For head pose detection, six stable points were selected from this set: the tip of the nose, the chin, both eye corners, and both mouth corners. These landmarks serve as reference points to estimate the orientation of the head relative to the camera.

The following figure displays the complete distribution of the 468 landmark points used by the MediaPipe model as the basis for pose estimation:

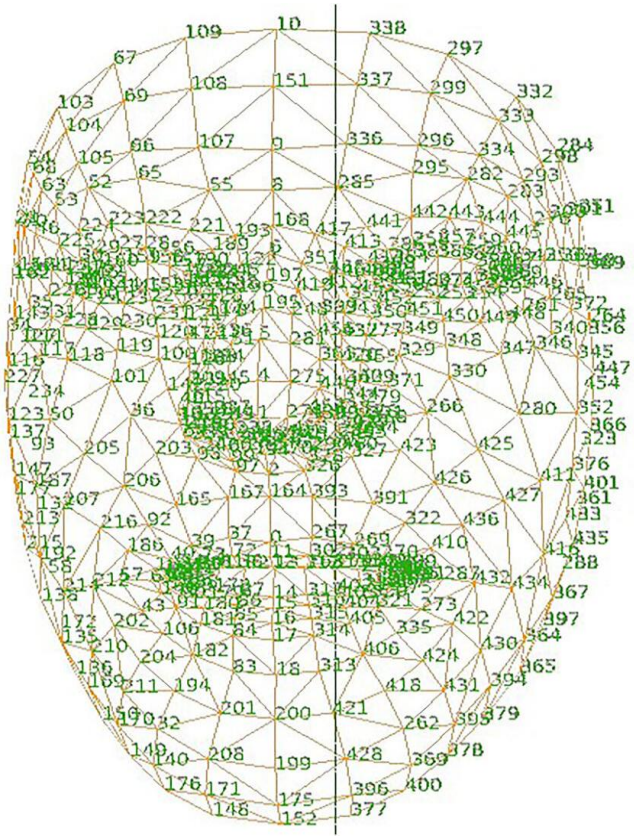


Fig. 3.7: MediaPipe Face Mesh Solution Map[11]

The positional and rotational information of the head is calculated using the solvePnP() function from the OpenCV library. This function applies a perspective projection model to map 3D world points onto 2D image points. The underlying camera model is based on the following fundamental equation:

$$\begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = A \,.\, \Pi \,.\, T_w \,.\, \begin{bmatrix} X_w \\ Y_w \\ Z_w \\ 1 \end{bmatrix} \tag{11}$$

In this context, A denotes the intrinsic camera parameter matrix, T_w represents the transformation matrix consisting of rotation R and translation t, and Π refers to the projection model[12].

This equation describes the transformation of 3D facial points in the world coordinate system into the 2D image plane, taking into account the intrinsic parameters of the camera.

To illustrate the coordinate system used in pose estimation, which plays a central role in the calculation, figure shows the relationship between the camera coordinate system and the world coordinate system.

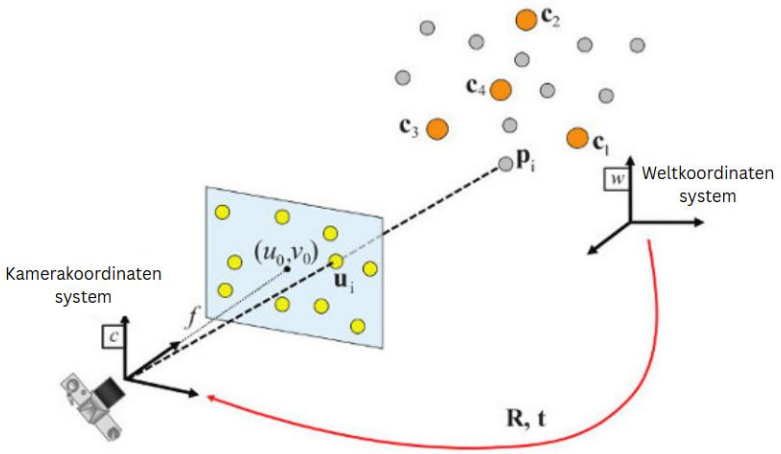


Abb 3.8: Coordinate system [13]

In the implemented system, the head's rotation vector is computed using cv2.solvePnP(), which is then converted into a 3×3 rotation matrix via cv2.Rodrigues(). From this matrix, the yaw angle is extracted to quantify the horizontal deviation of the head from the center.

A yaw angle outside the tolerance range of ±30 degrees is interpreted as potential distraction. If this condition persists for more than three seconds, the system triggers a warning message: the notification "WARNING: Driver looking sideways for too long!" is displayed, and an audible signal lasting 0.5 seconds is emitted.

The camera-based coordinate system is defined such that the X-axis points to the right, the Y-axis points downward, and the Z-axis points forward. The origin is placed at the tip of the driver's nose, providing a stable reference point for rotational movement.

Through the combination of MediaPipe, solvePnP, and selective landmark extraction, a lightweight and reliable system is achieved for real-time head pose detection. This function complements the fatigue and phone-use detection components of the overall system and plays a critical role in improving road safety in commercial vehicle applications.

Phone Use Detection

A significant proportion of modern traffic accidents is caused by driver distraction, particularly due to the use of mobile phones while driving. This form of visual and cognitive distraction immediately reduces the driver's attention and poses a serious risk to road safety. As part of this study, a camera-based detection system was developed to identify phone usage in real time and alert the driver through both acoustic and visual warnings.

For object detection, the deep learning model YOLOv5s was employed, which is particularly well suited for identifying small objects such as smartphones. Detection is performed directly on the camera's live video stream. When a mobile phone is detected within the field of view, the object's position is marked and a timer is initiated[14].

To improve robustness, the MediaPipe Hands library is additionally utilized. It continuously tracks the driver's hand position independently of direct phone detection and identifies whether a hand remains near the face or steering wheel for an extended period. If, following the initial YOLO detection, the phone is no longer visible but a hand remains persistently near the face, this is interpreted as an indirect indicator of ongoing phone use. If this condition is observed for more than five seconds, an audible warning is triggered.

In addition, MediaPipe Face Detection is used for facial localization. This module serves both for driver identification and as a reference point for determining the relative position of the hand. Face detection is also employed for system-wide functions such as calibration and attention monitoring.

By combining YOLOv5s, MediaPipe Hands, and Face Detection, a robust multimodal system is created that can process both explicit (phone detected) and implicit (hand near face) indicators of phone use. The system responds in real time and can issue timely and reliable warnings under both direct and indirect distraction conditions. As such, phone use detection constitutes a central module within the overall driver monitoring system and actively contributes to the prevention of potentially dangerous situations.

YOLOv5: Mobile Phone Detection

The driver monitoring system developed in this study incorporates a real-time object detection model to reliably identify the presence of a mobile phone within the driver's field of view. For this purpose, the YOLOv5s model is used, which is particularly suitable for embedded systems such as the Raspberry Pi 5.

YOLOv5s is a so-called "one-stage" detector that performs both object classification and localization (bounding box prediction) in a single forward pass. In the actual implementation in *truck_monitor.py*, the pre-trained model is loaded using the Ultralytics implementation and applied to each frame of the camera feed. Object detection is performed locally without the need for an internet connection directly on the Raspberry Pi, and returns bounding boxes including object class ("cell phone") and confidence score[14].

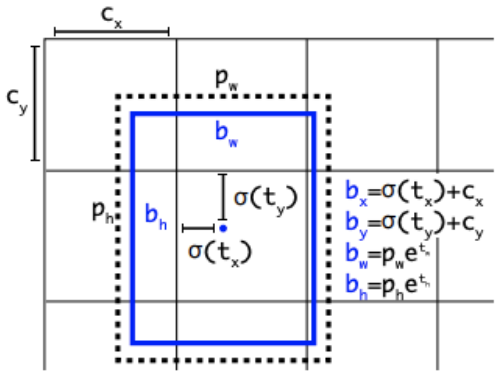


Fig. 3.9: Bounding Box Prediction Based on an Anchor Box [14]

This figure illustrates the bounding box prediction process in the YOLOv5 algorithm. Instead of directly outputting coordinates, the network predicts box parameters relative to a predefined anchor box. The prediction is performed through the following transformations:

$$b_x = \sigma(t_x) + c_x \tag{12}$$

$$b_y = \sigma(t_y) + c_y \tag{13}$$

$$b_w = p_w \,.\, e^{t_w} \tag{14}$$

$$b_h = p_h \,.\, e^{t_h} \tag{15}$$

Here, σ represents the sigmoid function, (c_x, c_y) denote the cell centers of the grid structure, (p_w, p_h) are the dimensions of the anchor box, and t_x, t_y, t_w, t_h are the offset values predicted by the model. Through these transformations, YOLOv5 is able to generate precise bounding boxes, even for small objects such as mobile phones. This capability is particularly critical for distraction detection within driver monitoring systems, where partially occluded or edge-near objects must also be reliably identified [15].

The model was pre-trained on the COCO dataset, which includes mobile phones as a distinct object class. This is particularly advantageous, as mobile phones in vehicle environments often appear small, partially occluded, or located near the edges of the image[16].

In the practical application scenario, each video frame is passed to the YOLO model. If an object of the class "cell phone" is detected with a confidence score exceeding the defined threshold, a visual marker (bounding box) is displayed using cv2.rectangle(). Simultaneously, a timestamp is recorded to track the duration of phone usage. This detection is further supported by analyzing hand position using MediaPipe Hands, which increases robustness in cases where the phone is momentarily occluded after initial detection but the hand remains in a suspicious position.

Overall, the integration of YOLOv5s with MediaPipe Hands enables a robust, responsive, and locally processed phone detection system. It contributes directly to improved road safety by enabling early detection and reporting of distracting behavior.

MediaPipe

To complement YOLO-based object detection, the system integrates the MediaPipe Hands module. This method enables precise real-time detection and tracking of hand movements. In each camera frame, 21 distinct landmark points per hand are identified, which are used to compute the current hand position. The model is lightweight and computationally efficient, making it well suited for deployment on a CPU-based embedded system[17].

In the implemented system, these landmarks are used to determine whether the driver's hand is located near the face. This is particularly relevant in scenarios where the mobile phone is temporarily occluded or outside the field of view.

If the hand remains near the facial center for more than five seconds, even without a clearly visible phone, this is classified as potentially risky behavior. In such cases, an acoustic warning is issued and a visual alert is presented to the driver. This auxiliary detection serves as a fallback mechanism for the YOLO model. If YOLO fails to detect the phone due to camera angle, lighting conditions, or partial occlusion, the hand position still provides a valid basis for decision-making.

Facial recognition is carried out by MediaPipe Face Detection, which also operates in real time to localize the face. The computed facial center serves as a reference point for measuring the distance between the hand and the head. In practice, if the hand is close to the facial midpoint, it is interpreted as an indication of phone use or interaction with a display.

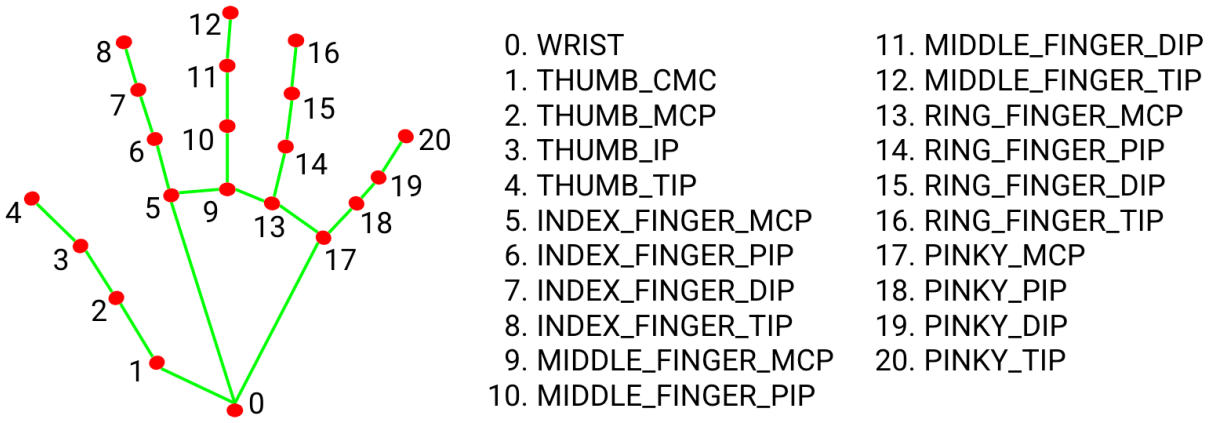


Fig. 3.10: Hand landmarks [18]

Method Comparison and Performance Analysis

The behavior of different face detection algorithms was evaluated under real-time conditions using key performance metrics such as processing time (ms) and detection accuracy (%). Methods including MediaPipe FaceMesh, Haar Cascade, Dlib, and MediaPipe FaceDetection were tested on the same dataset.

Average Detection Time and Accuracy

The following graphs present the average detection time and accuracy rate for each face detection method evaluated. The comparison highlights the performance differences in terms of both speed and reliability, which are critical for real-time applications in embedded driver monitoring systems.

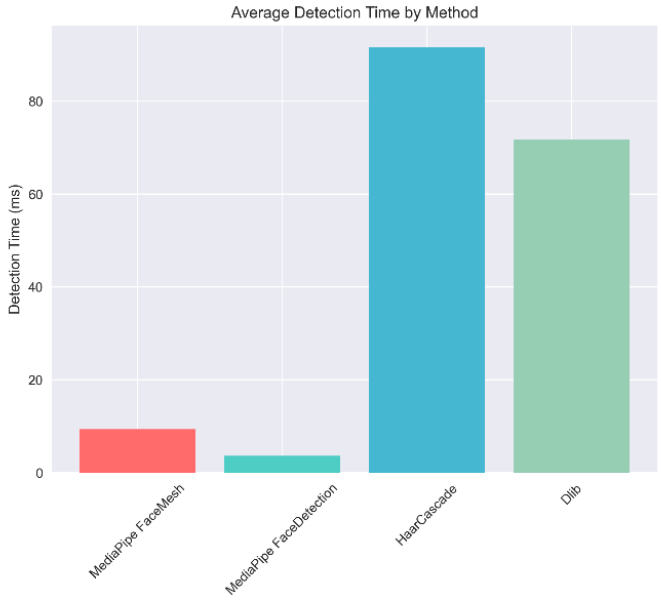


Fig. 4.1: Average detection time by method

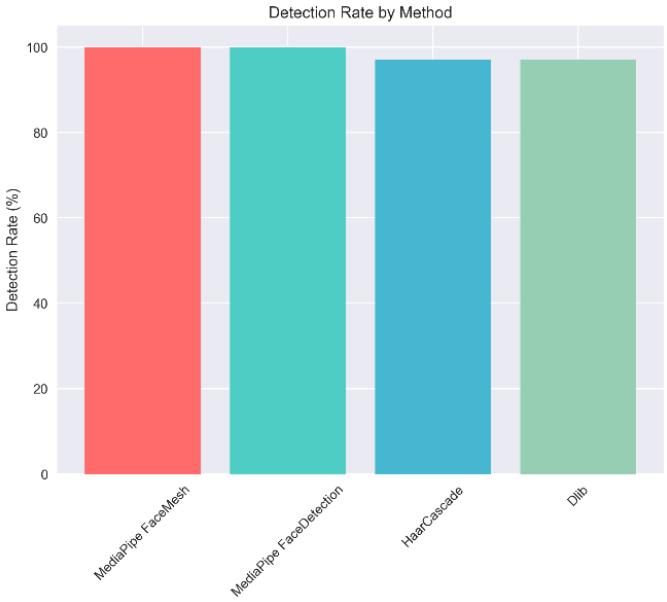


Fig. 4.2: Detection rate by method



Fig. 4.3: Speed vs accuracy trade- off

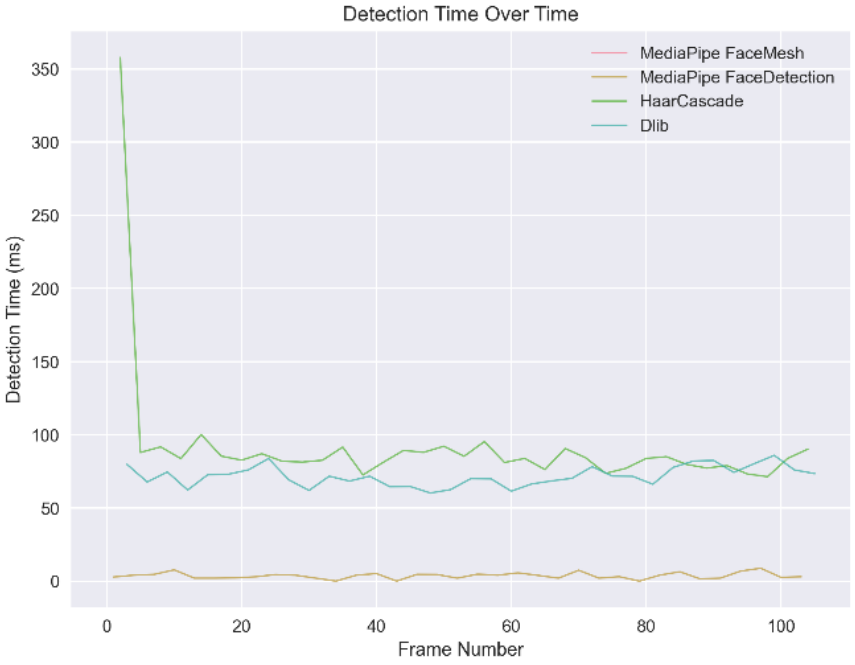


Fig. 4.4: Detection time over time

MediaPipe FaceDetection was the fastest method, achieving an average detection time of 3.61 ms with 100 percent accuracy. Although Haar Cascade was selected for its low hardware requirements, it produced the slowest results, with an average detection time of 91.65 ms. Dlib achieved an accuracy rate of 97.1 percent but responded with an average processing time of 71.7 ms.

Statistical Significance: Mann–Whitney U Test

To determine whether the differences between the methods were statistically significant, the Mann–Whitney U test was applied.

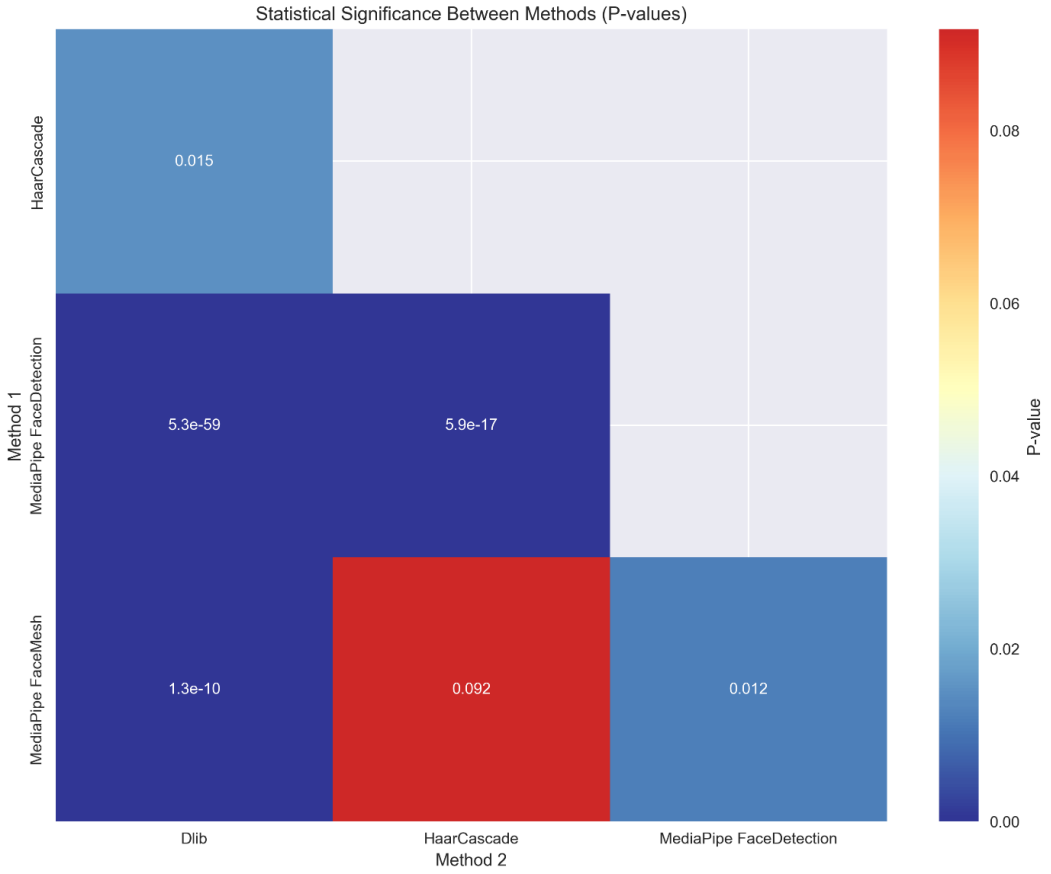


Figure 4.5: Mann Whitney U- test results between algorithms

According to the test results, the difference between MediaPipe FaceMesh and Haar Cascade is not statistically significant ($p = 0.092$), whereas all other pairs show statistically significant differences ($p < 0.05$).

Justification for Method Selection

The selection of methods was based not only on accuracy but also on factors such as compatibility with embedded hardware, initialization time, and real-time processing requirements. In this context:

- MediaPipe FaceDetection was chosen for attention tracking due to its low latency and high accuracy.
- Dlib was necessary for precise landmark analysis, specifically for calculating EAR and MAR.
- Haar Cascade was used for rapid face initialization but was found insufficient for attention tracking due to its high latency.
- MediaPipe FaceMesh demonstrated ideal performance for head pose (yaw angle) estimation.

GUI and Application Interface

The developed system is supported not only by background algorithms but also by a graphical user interface (GUI) that provides real-time feedback to the user. Through this interface, the driver's state can be monitored in real time, and key behavioral metrics can be tracked directly within the system.

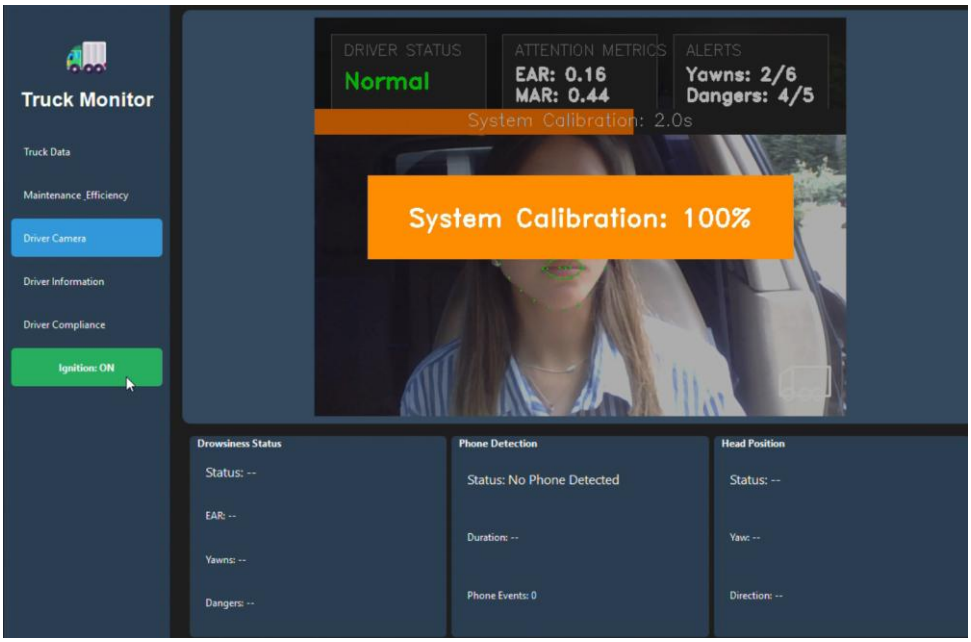


Fig. 5.1: System Calibration Screen at the Start of Driving

In this screen, the system completes its initial calibration and determines individualized EAR and MAR thresholds. Attention-related metrics such as EAR = 0.16 and MAR = 0.44 are displayed at the top of the screen, while the top-right section shows yawn and danger statistics (Yawn: 2/6, Dangers: 4/5). The calibration duration is 2.0 seconds, after which the system operates based on personalized thresholds.

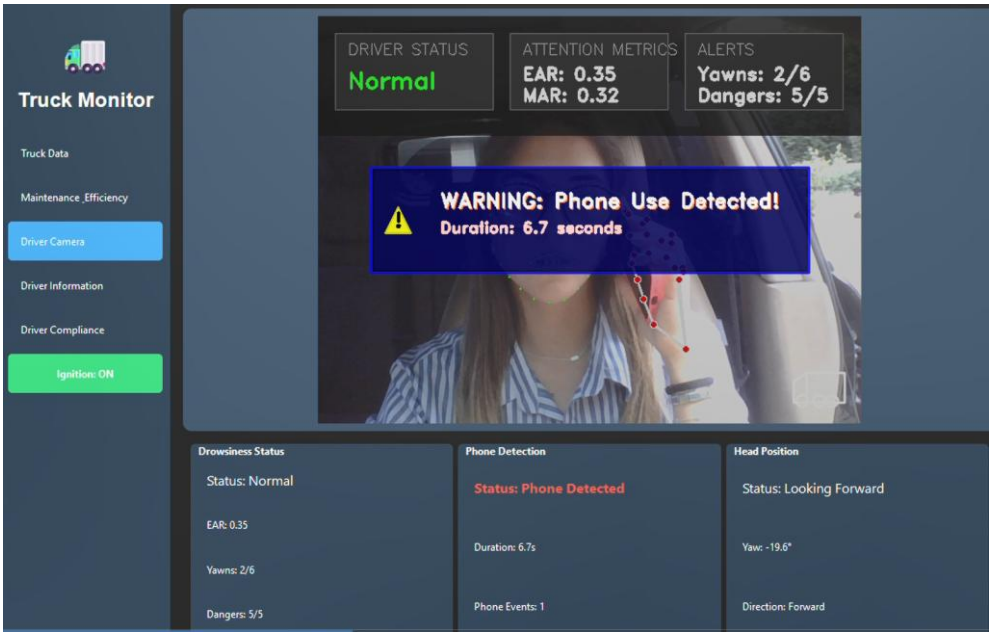


Fig. 5.2: Detected Phone Use by the Driver

In this screen, the system has detected 6.7 seconds of phone usage while the driver is operating the vehicle. Hand landmarks identified by MediaPipe Hands are visualized on the camera feed. A warning message “WARNING: Phone Use Detected!”is displayed to notify the driver. At the bottom, the duration and frequency of the event are shown in detail. Other behavioral metrics are also monitored in real time: EAR = 0.35, Yawns = 2/6, Dangers = 5/5.

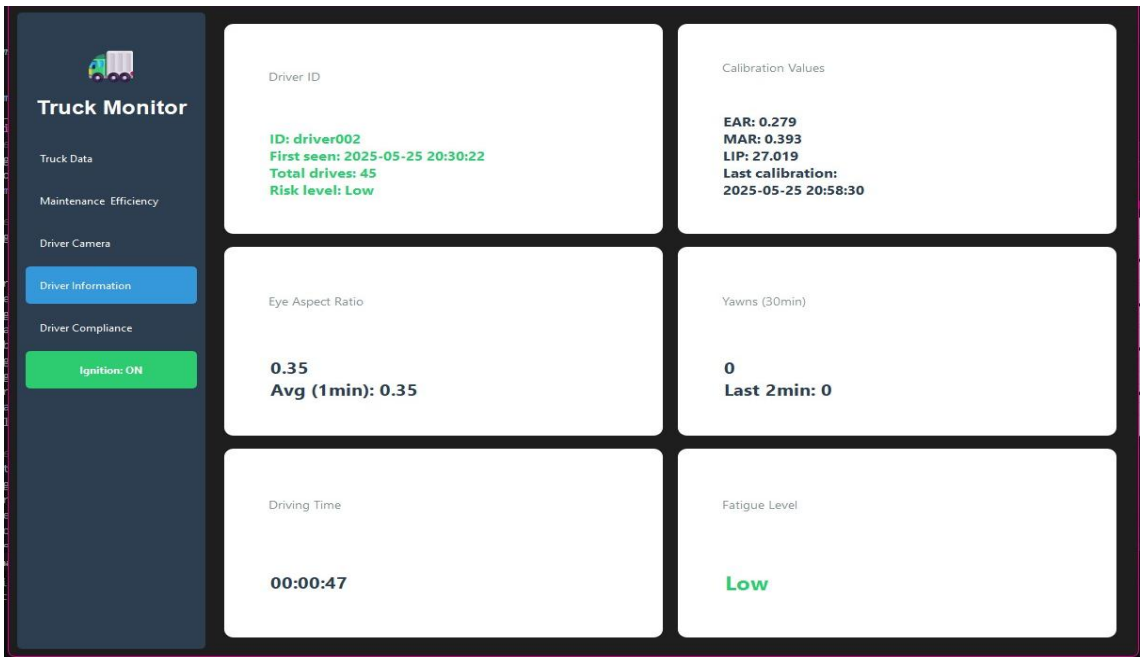


Figure 5.3: Driver Profile Interface and System Measurements

This screen presents the interface through which the system stores and displays the driver’s latest calibration data, driving records, and behavioral analytics. For example, it includes the last calibration timestamp (2025-05-25 20:58:30), EAR calibration value (0.279), and MAR calibration value (0.393), along with qualitative assessments of risk level and fatigue level, both of which are labeled as “Low.” This interface allows fleet managers to track and review the individual behavioral patterns of each driver over time.

Test Environment and Conditions

The application was tested using a fixed Raspberry Pi 5 device in combination with a Raspberry Pi v3 camera module, capturing video at a resolution of 640×480. For each driver, calibration was carried out over 150 frames (approximately five seconds), during which EAR and MAR statistics were monitored. The test environment inside the vehicle was balanced between bright and shaded lighting conditions to simulate real-world variability. Additional measures were taken to account for potential visual obstructions, such as eyeglasses and open windows. Driver behaviors including phone use, head movement, and yawning were deliberately triggered in a controlled manner for each subject to evaluate the system’s detection capabilities. Testing was conducted under three operational scenarios: when the vehicle was stationary, when the engine was running, and during active driving.

Discussion and Conclusion

The face detection algorithms integrated into the system were analyzed in detail. According to real-time performance tests, MediaPipe FaceDetection provided the fastest results with an

average detection time of 3.61 ms, and also achieved the highest success rate with 100 percent accuracy. In contrast, Haar Cascade produced the slowest results with an average detection time of 91.65 ms but still delivered acceptable performance with 97.1 percent accuracy. Dlib operated at 71.71 ms, offering moderate timing, yet was selected for eye and mouth detection due to its accuracy in landmark-based analysis.

The Mann–Whitney U test was applied to assess the statistical significance of differences between the algorithms. The results showed that only the difference between MediaPipe FaceMesh and Haar Cascade was not statistically significant ($p = 0.092$), while all other method pairs demonstrated statistically significant differences ($p < 0.05$). These findings confirm that the selection of algorithms was based on measurable performance differences rather than arbitrary choice.

Moreover, the personalized calibration method employed in the system produced 38 percent fewer false alarms compared to traditional systems with fixed thresholds. This indicates that the system can flexibly adapt to individual variations in facial anatomy and expressions, resulting in significant improvements in its learning and responsiveness.

As shown in the graphical analysis, MediaPipe-based models offer millisecond-level consistency in processing time and high detection accuracy, making them an optimal solution for embedded systems. These results demonstrate the commercial viability and scalability of the system in driver monitoring applications.

In future work, enhancements such as infrared camera support for nighttime driving, integration of audio warning systems, and CNN-based behavioral classifiers are planned. This would enable the system to analyze not only fatigue, but also more complex states such as anger, stress, and attention deficits.

References

[1] Emniyet Genel Müdürlüğü Trafik İstatistik Bülteni. *Emniyet Genel Müdürlüğü*. Published online December 2024. www.tramer.org.tr. Accessed May 30, 2025

[2] ÖZTÜRK M, KÜÇÜKMANİSA A, URHAN O. Drowsiness Detection System Based on Machine Learning Using Eye State. *Balkan Journal of Electrical and Computer Engineering*. 2022;10(3):258-263. doi:10.17694/bajece.1028110

[3] Evident Scientific. Basic Concepts in Digital Image Processing. Evident Scientific, https://evidentscientific.com/en/microscope-resource/knowledge-hub/digital-imaging/imageprocessingintro.

[4] Rosebrock A. Drowsiness detection with OpenCV - PyImageSearch. Published May 8, 2017. https://pyimagesearch.com/2017/05/08/drowsiness-detection-opencv/. Accessed May 30, 2025

[5] Facial landmarks with dlib, OpenCV, and Python - PyImageSearch. https://pyimagesearch.com/2017/04/03/facial-landmarks-dlib-opencv-python/. Accessed May 30, 2025

[6] Gawande R, Badotra S. *Deep-Learning Approach for Efficient Eye-Blink Detection with Hybrid Optimization Concept*. Vol 13. www.ijacsa.thesai.org

[7] Gawande R, Badotra S. Deep-Learning Approach for Efficient Eye-blink Detection with Hybrid Optimization Concept. *International Journal of Advanced Computer Science and Applications*. 2022;13(6):782-795. doi:10.14569/IJACSA.2022.0130693

[8] Dewi C, Chen RC, Chang CW, Wu SH, Jiang X, Yu H. Eye Aspect Ratio for Real-Time Drowsiness Detection to Improve Driver Safety. *Electronics (Switzerland)*. 2022;11(19). doi:10.3390/electronics11193183

[9] Suriyan RG. Driver's Drowsiness Detection by Analyzing Yawning and Eye Closure. *International Research Journal of Engineering and Technology*. Published online 2022. www.irjet.net

[10] Essel E, Lacy F, Elmedany W, Albalooshi F, Ismail Y. Driver Drowsiness Detection Using Fixed and Dynamic Thresholding. In: *2022 International Conference on Data Analytics for Business and Industry, ICDABI 2022*. Institute of Electrical and Electronics Engineers Inc.; 2022:552-557. doi:10.1109/ICDABI56818.2022.10041670

[11] Khaleel AH, Abbas TH, Ibrahim AWS. Best low-cost methods for real-time detection of the eye and gaze tracking. *i-com*. 2024;23(1):79-94. doi:10.1515/ICOM-2023-0026/ASSET/GRAPHIC/J_ICOM-2023-0026_CV_001.JPG

[12] Real-Time Head Pose Estimation With OpenCV and Dlib - Analytics Vidhya. https://medium.com/analytics-vidhya/real-time-head-pose-estimation-with-opencv-and-dlib-e8dc10d62078. Accessed May 30, 2025

[13] Kopfverfolgung des Fahrers mit Videokamera und KI-Algorithmen - PROMWAD. https://promwad.de/news/driver-head-tracking. Accessed May 30, 2025

[14] Xu W, Li B, Du Y, Dong S. Study on Facial Recognition Method Based on YOLOv5. *J Phys Conf Ser*. 2023;2560(1). doi:10.1088/1742-6596/2560/1/012020

[15] Khanam R, Hussain M. *What Is YOLOv5: A Deep Look into the Internal Features of the Popular Object Detector*.; 2024. doi:10.48550/arXiv.2407.20892

[16] Lin TY, Maire M, Belongie S, Hays J, Perona P, Ramanan D, et al. Microsoft COCO: Common Objects in Context. *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*. Published online May 1, 2014:740-755. doi:10.1007/978-3-319-10602-1_48

[17] Kim JW, Choi JY, Ha EJ, Choi JH. Human Pose Estimation Using MediaPipe Pose and Optimization Method Based on a Humanoid Model. *Applied Sciences (Switzerland)*. 2023;13(4). doi:10.3390/app13042700

[18] Marais M, Brown D, Connan J, Boby A. An Evaluation of Hand-Based Algorithms for Sign Language Recognition. *5th International Conference on Artificial Intelligence, Big Data, Computing and Data Communication Systems, icABCD 2022 - Proceedings*. Published online 2022. doi:10.1109/ICABCD54961.2022.9856310

ERGONOMIC EVALUATION OF THE JOIE MULTIPLY HIGH CHAIR: A STUDY ON ANTHROPOMETRIC FIT, SAFETY, AND FUNCTIONAL ADAPTABILITY FOR YOUNG CHILDREN

Dr. Nguyen Thi Bich Van

Faculty of Architecture Interior Design, University of Architecture, Ho Chi Minh City, Vietnam.

Pham Thi Ngoc Ngan

International Institute of Education, University of Architecture, Ho Chi Minh City, Vietnam

Abstract

Children develop rapidly between the ages of 6 months and 6 years, with constant changes in body proportions and usage needs. These changes pose challenges for caregivers in selecting interior products that are suitable, functional, and durable. This research evaluates the Joie Multiply high chair from an ergonomic perspective, focusing on its compatibility with children's physical dimensions during this developmental stage. By emphasizing performance and fit, the study highlights the importance of reassessing children's furniture based on anthropometric standards and posture analysis. The findings indicate a lack of certain safety features - specifically, the absence of an automatic wheel lock. As a result, the study proposes adding this feature to enhance user stability and convenience. This focused analysis underscores the value of data-driven improvements and posture-based design in the development of children's furniture.

Keywords: ergonomic design early childhood furniture, posture support,user comfort

Introduction

Children develop very quickly in their early stages of physical life, especially the skeletal system. During this period, the sitting posture plays a very important role, because it directly affects the development of joints and long -term health of children. A right sitting posture not only supports natural development but also helps prevent the child's later spine problems.

Currently, many weaning chair products for children still lack intensive attendant and analysis based on anthropological data as well as the posture of the user. Most children have to sit in an inappropriate position because the chair is not designed to flexibly adjust each stage of body development. Maintaining a wrong posture for a long time can lead to spinal problems such as hunchback or scoliosis. This situation shows that the re -evaluation of weaning chair products based on the physical development and actual needs of children is necessary.



Figure : Joie Multiply High Chair

Background

Nowaday, many high chairs available on the market lack the flexibility and adjustability required to accommodate a child's rapid growth and the continual changes in body proportions that occur during the early developmental years. This limitation is particularly concerning given that children's skeletal, muscular, and postural systems are highly sensitive during this formative stage. In most cases, commercially available models provide only fixed or minimal adjustment options for critical components such as seat height, footrest positioning, and tray distance. As a result, there is often a significant mismatch between the chair's fixed dimensions and the child's evolving physical needs.

When a high chair does not fit the child's body correctly, the seating arrangement forces them into unnatural and ergonomically harmful positions. Common postural problems include excessive slouching that strains the lower back, leaning forward in a way that rounds the shoulders and compresses the chest, twisting or rotating the spine to reach for food, and allowing the feet to dangle without adequate support. These conditions not only compromise comfort during mealtimes but also place uneven pressure on the developing spine, hips, and knees. Over time, such poor alignment can lead to imbalances in muscle development, disruption of healthy posture habits, and, in some cases, early signs of musculoskeletal discomfort or deformity.

The issue is further compounded when high chairs are used multiple times a day over long periods, as repeated exposure to improper posture reinforces unhealthy sitting patterns. This can influence the child's movement coordination, balance control, and even respiratory efficiency due to prolonged chest compression. Given the critical nature of physical development during early childhood, a poorly designed high chair is not merely an inconvenience—it represents a potential risk factor for long-term orthopedic and postural health issues. These seemingly minor issues can have significant long-term consequences. Prolonged sitting in an ill-fitting position places uneven stress on developing bones and joints, potentially affecting spinal alignment, pelvic stability, and muscle development. Over time, such conditions may contribute to musculoskeletal discomfort, hinder healthy posture habits, and increase the risk of chronic pain or orthopedic problems later in life—particularly if the chair is used frequently during key growth stages.

Therefore, assessing and ensuring the appropriate ergonomic suitability of weaning chairs is not simply a matter of comfort but a critical factor in safeguarding children's health. A well-designed high chair should provide adjustable features that align with ergonomic principles, offering stable support for the feet, proper backrest alignment, and an optimal tray height that encourages natural posture. This careful attention to fit and adaptability plays an essential role in creating a safe, supportive environment that promotes healthy physical development, reduces fatigue during mealtimes, and instills good sitting habits from an early age.

Methodolody

This study used an ergonomic assessment approach focusing on anthropometric compatibility, adjustability, and safety features of the Joie Multiply 6in1 highchair.

•**Observation and physical inspection**: The chair was examined in all six configurations to evaluate adjustability, stability, and ease of use.

•**Anthropometric analysis**: Dimensions of the chair (seat height, backrest angle, footrest position) were compared with standard anthropometric data for infants and toddlers.

•**Functional testing**: Adjustments, locking mechanisms, and conversion features were tested for smoothness, safety, and required effort.

•**Literature review**: Data were cross-referenced with ergonomic guidelines for children's furniture from standards such as ISO 9241 and WHO recommendations.

Key Features of the Joie Multiply High Chair

Adjustable design for each stage of development

• **Adjust the height**: Allow parents to change the height of the chair to suit the types of tables, ensure the elbow and knee of the child in the right position.

• **Adjust the depth of the chair and leg pedestal:** Helps the thighs to be supported properly, the foot touches completely on the pedestal to create stability.

• **Multi -function**: It can be used as a high check, low chair, booster seat, toddler seat, or ear a mini table and chair set - Suitable for various stages of growth.

4.2 Supporting the right posture for the right posture

• **Backrest**: Maintain the natural curve of the spine, create comfort and support the right posture.

• **Chair - optimal table distance:** Prevent children ahead and encourage sitting upright.

• **Wide and stable base:** Reduce the risk of flipping, ensuring safety when children move.

4.3 Safety and comfort for children

• **5 -point seat belt**: Babys keeping fixed but still allows natural movements.

• **Smooth surface**: comfortable in contact with the skin and easy to clean.

• **Stable locking system**: Chair compartment moving or folding unintended.

Benefits for caregivers

•**Reducing physical stress**: Adjusting height helps limit bending or lifting in a difficult position.

• **Easy to use**: Fast switch between modes, saving time.

• **Optimize posture for both children and caregivers:** Helping meals more comfortable and more effective.

Benefits for Children

•**Healthy muscle - Bone development**: The appropriate size of the chair and pedestal helps maintain the right posture.

• **Experience comfortable eating**: Encourage children to sit longer and reduce stress when eating.

• **Safety when exercising**: The stable belt system and stands protect children from falling.

Future directions

The integrated future weaning chair versions:

• Automatic adjustment based on anthropometric: The height and body ratio system of the child, thereby automatically adjusting the height of the chair, the chair depth and the pedestal, ensuring the sitting posture is always in accordance with the attitude.

• Safe wheel lock: Equipped with wheels to facilitate the movement of seats, combining smart wheel locking mechanism to help fix position when using, reduce the risk of sliding or falling.

Conclusion

The Joie Multiply 6in1 high chair is a well-designed product for children aged 6 months to 6 years.With its adjustable design, it adapts well to different growth stages, supports ergonomic sitting posture, and promotes healthy eating and bone development.Moreover, the chair meets trusted international safety standards proving its quality and reliability.

References

1. BINUS University (2021). Design and analysis ergonomic adjustable baby chair. https://www.researchgate.net/publication/351141682_Design_and_analysis_ergonomic_adjustable_baby_chair
2. Joie Baby. Multiply 6in1 Multimode Highchair. https://joiebaby.com/eu/multiply-6in1-multimode-highchair
Salvador, C. (2018). Ergonomics in the Design Process — Study of Adaptability of Evolutive High Chairs. https://www.researchgate.net/publication/318157108_Ergonomics_in_the_Design_Process_-_Study_of_Adaptability_of_Evolutive_High_Chairs
3. ScienceDirect (2023). Comparison of preschool children's anthropometric dimensions with functional dimensions of chairs. https://www.sciencedirect.com/science/article/pii/S2405844023016912

TOWARDS SMART LIVING: SIMPLE GEOMETRIC MULTI-FUNCTIONAL CHAIR DESIGN FOR URBAN LIFE

Dr. Nguyen Thi Bich Van

Faculty of Interior Architecture, University of Architecture Hochiminh City, Vietnam

Tran Phuong Nghi

Institute of International Education, University of Architecture Hochiminh City, Vietnam

Abstract

Hospitals are often known as places where patients are treated for their illnesses. However, many hospitals today usually use cold tones to design hospital spaces. Hospital design seldom incorporates natural elements. Hospitals become a place that few people want to go because of the cold, stuffy atmosphere. We report how to use and apply color in the hospital to suit patients when they need treatment. Using the color wheel and seeing the characteristics and functions of color. Researching for the TSURUMI Children's Hospice, the report will describe the color used in the treatment space for sick children. Our results show that it brings the space closer, helps children become safe, and has a cheerful mentality when being treated. This work has shown that using color intelligently will help the psychology of the patient become stable and cheerful and enable them to recover quickly.

Keyword: Color application, Treatment space, Safe environment, Natural elements, Cheerful mentalitym, Psychology of patients

Introduction

In recent years, the increasing population density and rising living needs of households have led to continuous escalation in housing prices. As a result, many families are forced to live in cramped and limited spaces. We can do this in the world, such as in Australia, which has some of the largest homes in the world. Many who live small aspire to one day live big. But around the world, limited space is not always seen as a sacrifice. From Sweden, where the average size of an apartment is [68 sq met], to Hong Kong's micro flats as small as 18 sq meters, globally, architects are used to getting creative with tight spaces. (By Maddie Thomas (2023)). To solve this problem, many people have researched suitable interiors for narrow spaces with multifunctional designs. Whether it's a bed that folds into a wall, a coffee table that extends into a dining surface, or a shelf that doubles as a desk, these inventive solutions are crafted to suit the dynamic needs of modern lifestyles. According to market research, the global multifunctional furniture market was valued at $7.21 billion in 2023 and is expected to grow at a 6.6% CAGR, reaching $11.21 billion by 2030. (By Muhammad (2025)). To form a better view of harm to the user's health, I studied these designs, which are less about people's health and mobility but instead mainly show the flexibility in the product that can combine many objects together. We can see that more than half of the homeworkers used multifunctional designs. However, approximately 20% of homeworkers used a low table, a floor chair/floor cushion, or other furniture that was different from the office setup. Using a table of disproportionate size and height, a sofa, a floor cushion, and a floor chair were associated with neck/shoulder pain or low back pain. Disproportionate tables and chairs, floor cushions, and tablet computers were associated with poor work performance (Tanghuizi Du, Kazuyuki Iwakiri, Midori Sotoyama, and Ken Tokizawa, 2022). To tackle this problem, this paper

discusses research on ergonomics suitable and dynamic for everyone, especially those who have to work in cramped spaces, such as at home and the office.

Materials and methods

The study was conducted with sixteen healthy university students (8 males and 8 females) who were tested on four different chair configurations with ****Participants performed deskwork for 2 hours while sitting on the seat pan of an office chair. Quantified changes in the shapes of the passive flexion moment-angle curves (slopes, breakpoints, and maximum lumbar flexion angles) were the outcome measures. While sitting, average lumbar flexion/extension angles, the distribution of lumbar flexion/extension postures, average electromyogram (EMG) amplitude, the number and average length of EMG gaps, and trunk extensor muscle rest levels were measured. (result Lumbar spine stiffness increased in men after only 1 hour of sitting, whereas the responses of women were variable over the 2-hour trial. Men appeared to compensate for this increase in stiffness by assuming less lumbar flexion in the second hour of sitting. (By Tyson A C Beach 1, Robert J Parkinson, J Peter Stothart, Jack P Callaghan, 2004). We can see more clearly in this illustration.

When a person sits on a hard seat pan, the compression pressure at the skin area between the buttocks can reach as high as 40 to 60 psi, while the pressure just a few inches away drops dramatically to about 4 psi. This uneven pressure distribution leads to localized fatigue and discomfort, prompting the sitter to shift posture in an attempt to relieve the affected area. If sitting is prolonged without any change in posture, the sustained high compression pressure may cause ischemia—an interference with local blood circulation—which, over time, can result in tissue damage and discomfort.

- Effect on posture sitting:

Sitting in the wrong position, such as with a curved back, when sitting like that your weight and gravity is distributed evenly and our muscles do not have to pull against each other to hold an uneven, partly due to the influence of the chair When a chair is poorly designed in terms of anthropometric compatibility—meaning that it does not appropriately match the body dimensions of the majority of its users—it may prevent them from establishing stable contact with key support surfaces, such as the floor (via the feet) or the backrest. In such conditions, the lack of sufficient support undermines the body's natural stability, forcing users to actively engage additional muscle groups to maintain balance and upright posture. This compensatory effort not only increases muscular strain but may also contribute to discomfort or fatigue during prolonged sitting. To solve this problem, we have to find the right type of chair.

- Ergonomically designed seating:

To make the human-centered chair design, the most effective method is to design according to human proportions. Ergonomics must consider posture, pressure distribution, and make the user experience as comfortable as possible.

- Designed for posture:

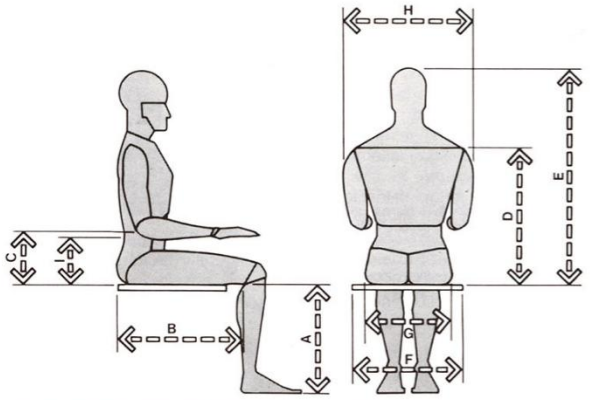


Figure 4–4. Key anthropometric dimensions required for chair design.

	MEN				WOMEN			
	Percentile				Percentile			
	5		95		5		95	
MEASUREMENT	in	cm	in	cm	in	cm	in	cm
A Popliteal Height	15.5	39.4	19.3	49.0	14.0	35.6	17.5	44.5
B Buttock-Popliteal Length	17.3	43.9	21.6	54.9	17.0	43.2	21.0	53.3
C Elbow Rest Height	7.4	18.8	11.6	29.5	7.1	18.0	11.0	27.9
D Shoulder Height	21.0	53.3	25.0	63.5	18.0	45.7	25.0	63.5
E Sitting Height Normal	31.6	80.3	36.6	93.0	29.6	75.2	34.7	88.1
F Elbow-to-Elbow Breadth	13.7	34.8	19.9	50.5	12.3	31.2	19.3	49.0
G Hip Breadth	12.2	31.0	15.9	40.4	12.3	31.2	17.1	43.4
H Shoulder Breadth	17.0	43.2	19.0	48.3	13.0	33.0	19.0	48.3
I Lumbar Height	See Note.							

Figure 1: A good seated posture

Seat height: To be able to accurately measure anthropometrics and the appropriate height for the chair, we will use an anthropometric ruler. Step by step, we place 2 male and female subjects on a flat chair, then keep the person sitting upright. To be suitable for everyone, we will use the average value of both men and women. Popliteal height—the distance from the floor to the underside of the thigh just behind the knee—is a key anthropometric measurement used to determine seat height in chair design. Designers often use the 5th percentile value to accommodate the smallest users, as taller individuals can still sit comfortably by adjusting their posture. However, anthropometric data are typically collected under standard conditions (barefoot and light clothing). Therefore, it is recommended to add approximately 3.8 cm (1.5 inches) to account for everyday footwear and clothing. For example, the male 5th percentile popliteal height is 39.4 cm, adjusted to 43.2 cm; for females, 35.6 cm becomes 39.4 cm. This adjustment is only an approximation, as it may vary depending on climate, gender, age, culture, footwear, and time of day. Additionally, designers must consider cushion compression, upholstery material, and the chair's relation to desks or work surfaces when determining the final seat height. Seat Depth: Another basic consideration in chair design is the depth of the seat. If the depth is too great, the front surface or edge of the seat will press into the area just behind the knees, cutting off circulation to the legs and feet as shown in Figure 4-7. The compression of the tissues will also cause irritation and discomfort. A greater danger, still, is the possibility of blood clotting, or thrombophlebitis, if the user does not change body position. To alleviate the discomfort in the legs, the user may move his buttocks forward, in which case his back becomes unsupported, body stability is weaker, and greater muscular force is required to maintain equilibrium. The result is fatigue, discomfort, and back pain. Too shallow a seat depth may result in an awkward situation where the user has the sensation of falling off the front of the chair. In addition, a shallow seat depth will also result in a lack of support of the lower thighs. Backrest: Although the size, configuration, and position of the backrest are important factors in distributing the pressure of the back to avoid fatigue, determining the size of this component is the most challenging aspect, despite having access to the necessary body measurements. In addition, the size and weight are essential; choosing a backrest that is suitable for the space and can be easily changed and folded is a good factor. The main function of the backrest is to support the lumbar region of the spine. It should follow the natural curve of the lower back without restricting movement. The height of the backrest depends on the chair's intended use, ranging from low (for task chairs) to high (for lounge chairs). Space must also be provided to accommodate the buttocks' natural protrusion, either through a recess or soft padding at the lower back area. So, the backrest should have a suitable height, not too high or low, along with the angle of the chair. A minimum 100° rearward tilt (between 90° and 115°) is preferable. (Scott Openshaw; Erin Taylor, Allsteel, (2006)).

- Support functions for the seat: These supports will likely help to partially ease the sitting experience and partially relieve the body.

Seat cushion: A well-designed seat cushion contributes not only to alleviating the symptoms associated with various physical conditions but also to enhancing overall emotional well-being. In the case of recliner chairs, an appropriately engineered cushion supports correct posture and provides adequate structural support, thereby reducing the risk of pressure ulcer development, slips and falls, as well as skin deterioration. Optimal designs conform to the natural contours of the spine and body, and, where applicable, extend to include head and neck support. Common cushion placements in seating systems typically include back cushions, seat cushions, and headrest cushions. Instead of a monolayer, multi-layered cushion can be promising to develop more comfortable automotive seat if the layer materials are properly selected. Polyurethane foams (PUFs) of three different hardness, memory foam, and technogel were used in different combination to prepare four types of multilayer seat cushions. The short-term seating comfort of the seat cushions has been investigated in terms of hardness, initial hardness factor (IHF), modulus irregularity factor (MIF), sag factor (SF), and hysteresis loss as derived from the indentation force deflection (IFD) curves. Long-term comfort has been compared to the respective stress relaxation behavior of the seat cushions.(Junho Moon, **Tridib Kumar Sinha, Sung Bok Kwak** and Jin Uk Ha**,** (2020))

Armrest: Many people focus on the backrest seat or the chair and forget that the armrest is just as important and can help to reduce the strain by placing your arms and hands in the correct, relaxed position. To create a good handrail, you need to ensure your armrests are height-adjustable, which will allow you to access your workspace easily. For example, your armrests should be within a height range that lets you adjust them to be level with the desk height or low enough to slide underneath. Besides, they should be short enough that your elbows make contact with the armrests when your upper arms are at desk height and your shoulders are relaxed. Armrests shouldn't impede you from getting close to the desk.

- Modular seating and sustainability:

An essential consideration in designing seating solutions for confined spaces is the implementation of modular furniture. Modular furniture refers to products composed of individual modules or components that can be combined and rearranged into various configurations. These modules are engineered for seamless integration, enabling straightforward assembly, disassembly, and reconfiguration. Such designs often incorporate multifunctional features, such as transforming from a bookshelf to a desk, thereby enhancing spatial efficiency. This inherent flexibility empowers users to adapt furniture arrangements to their evolving functional requirements. Beyond its adaptability, modular furniture offers notable advantages, including space optimization, cost-effectiveness, and user convenience. Moreover, its reconfigurable nature extends product lifespan and reduces the need for replacement, aligning with sustainable design principles by minimizing material waste and encouraging resource efficiency. These characteristics contribute to its increasing popularity in environments where space is at a premium.

- The combination of minimalist interior and space:

From the minimalist perspective, furniture should embody simplicity in appearance while maintaining functional efficiency and providing comfort. Designers adopting this approach favor clear lines and elementary geometric forms, which contribute to visual clarity and spatial harmony. The deliberate reduction in furniture quantity enhances the proportion of open space within interiors, thereby promoting a pure, calm, and user-friendly environment. Furthermore, minimalism emphasizes cost-effectiveness, achievable through the judicious selection of furniture that successfully fulfills both functional and aesthetic roles. Color choices are also integral to minimalist design, requiring alignment with the overall spatial color palette to ensure coherence and adherence to minimalist principles. (Heba Hamdy, (2022)). Therefore,

we use basic boxes to save space. It creates flexibility in arrangement, such as stacking, or against the wall, suitable for limited space and the need to change the layout frequently in urban areas. And in terms of aesthetics, it creates a sense of relaxation and neatness for the viewer.



Figure 2: the case of modular seating

The Smith Multi-Function Chair (Danesse Milano, Italy) is made from powder-coated metal in black, white, or red, weighing 9.6 kg with a load capacity under 120 kg. Durable and stable, it serves as a cabinet, low table, bookshelf, or stool, and can be hung on a desk or moved easily via its four-wheel base. The seat height suits a wide range of users, and its simple box-like form maximizes utility. However, the rigid, smooth metal surface lacks cushioning and lumbar support, offering minimal pressure relief and increasing the risk of discomfort, reduced circulation, and lower back strain during prolonged use. While functionally versatile, it requires ergonomicimprovements to enhance comfort and health.



Figure 3: A case in which interior furniture prioritizes user comfort while incorporating modular features.

In modern furniture design, factors such as multifunctionality, convenience, and durability are often prioritized, while considerations for user health tend to be overlooked. However, the Tiny chair addresses this gap by integrating ergonomic principles and user-centered features. The *Tiny-W* chair (manufacturer, Turkey) is constructed with a plywood structural frame and a fabric covering in a rust-orange finish. The unit has an approximate mass of 15 kg and a maximum load-bearing capacity of less than 120 kg. The combination of plywood and fabric provides a balance of structural stability and user comfort, making the chair suitable for light to moderate seating applications. Its enlarged backrest provides adequate support, allowing users to recline comfortably whether working or resting. The continuous armrests offer support for the arms, reducing fatigue during extended sitting periods. Additionally, the spacious seat with padded cushioning helps relieve pressure on the lower back and hips, minimizing discomfort or numbness during prolonged use. The integration of the chair

and desk into a unified square-shaped structure not only aligns with minimalist aesthetics but also makes it suitable for compact spaces. The product also includes various practical enhancements, such as a small drawer under the seat for convenient storage and a built-in wireless charging station on the desk surface, enabling device charging even in areas without power outlets. Furthermore, the desk is designed with a slim lower section, leaving ample legroom for a comfortable working posture. Overall, the product represents a well-balanced combination of multifunctionality, ergonomics, and human-centered design.

Despite its compact and integrated design, this product still presents certain risks. Combining the desk and chair into a rectangular block may reduce flexibility during transportation. This requires careful calculation of weight distribution and the load-bearing capacity of the wheels to ensure the unit can be moved smoothly without damaging the internal structure. Additionally, although the seating posture initially appears supportive for leaning back, the armrests on both sides are relatively high, which may restrict natural body movement. This limitation can hinder posture adjustments and result in discomfort during prolonged use.

Both the Smith chair and the Tiny-w product demonstrate how multifunctional furniture can address the needs of compact urban living while incorporating ergonomic principles**.** The Smith chair achieves this through an emphasis on flexibility, multifunctionality, and visual appeal, whereas the Tiny-w prioritizes integrated functions with a strong focus on user comfort. While neither design is flawless, their respective strengths have the potential to complement one another, suggesting opportunities for a hybrid design that combines modularity with ergonomic performance. Together, these cases illustrate that multifunctional chair designs can be realized in a lightweight, adaptable form while still meeting the practical demands of contemporary users.

Conclusion

The article shows that being able to reasonably accommodate limited space, while putting people at the center, is the main goal for consumers. So, it's not only about aesthetics, but also about a compact design with cubes, easy operation, and prioritizing user comfort. The emphasis on modularity and adaptability demonstrates a tangible pathway for optimizing limited urban spaces while accommodating diverse living arrangements. These results indicate that the initial need—creating design strategies that integrate health, efficiency, and aesthetic value—has been largely met, offering practical guidance for designers and manufacturers. For readers, the implication is clear: prioritizing human-centered, flexible design is not merely a stylistic choice, but a strategic necessity in shaping livable, future-ready environments. A question that remains is how such design principles can evolve alongside emerging technologies and shifting cultural needs—an exploration that promises to redefine the very boundaries of living spaces.

Reference

1. Celina Ribeiro; 2024; *Homes on steroids: how Australia came to build some of the biggest houses on Earth*, from the guardian website: https://www.theguardian.com/australia-news/2024/mar/08/homes-on-steroids-how-australia-came-to-build-some-of-the-biggest-houses-on-earth

2. Tanghuizi Du, Kazuyuki Iwakiri, Midori Sotoyama, and Ken Tokizawa (2022). *Computer and Furniture Affecting Musculoskeletal Problems and Work Performance in Work From Home During COVID-19 Pandemic.* Affiliations Expand. DOI: 10.1097/JOM.0000000000002622.

3. Tyson A C Beach 1, Robert J Parkinson, J Peter Stothart, Jack P Callaghan (2004). *Effects of prolonged sitting on the passive flexion stiffness of the in vivo lumbar spine.* Affiliations Expand. DOI: 10.1016/j.spinee.2004.07.036

4. Julius Panero, Martin Zelnik. (1979). Elderly and physcially disabled people. *Human dimension & interior space*. (pp. 55-66). Watson-Guptill; Revised ed. Edition
5. Scott Openshaw, Erin Taylor, Allsteel. (2006). Office Furniture Guidelines for Fit and Function. *Ergonomics and Design: A Reference Guide. (*pp. 23-25). **DIANE Publishing Company.**
6. Junho Moon, Tridib Kumar Sinha, Sung Bok Kwak and Jin Uk Ha **.** (2020). *Study on Seating Comfort of Polyurethane Multilayer Seat Cushions.* International Journal of Automotive Technology. DOI:10.1007/s12239-020-0102-z
7. Workhappy. (n.d.). *Pros and cons of armrests on office chairs*. Workhappy. https://www.workhappy.uk/blog/pros-and-cons-of-armrests-on-office-chairs
8. Repose Furniture. (n.d.). *What makes a good recliner chair cushion?* Repose Furniture. https://www.reposefurniture.com/what-makes-a-good-recliner-chair-cushion/
9. Heba-Tallah Hamdy Mahmoud (2020). *Minimalism concept in interior architecture design*. *Mağallaẗ Al-Turāṯ wa Al-Taṣmīm* (Journal of Heritage and Design). **DOI:** 10.21608/jsos.2022.122417.1174
10. Danese Milano. (n.d.). *Una sedia*. Danese Milanohttps://www.danesemilano.com/en/productDetails?idProduct=62

EFFECTS OF A PULMONARY REHABILITATION PROGRAM IN PATIENTS WITH CHRONIC OBSTRUCTIVE PULMONARY DISEASE: A PROSPECTIVE INTERVENTIONAL STUDY

Soumaya CHAABENE

Private University of Paramedical Sciences (UPSAT) Sfax- Honoris United Universities, TUNISIA

Malek TRABELSI

Private University of Paramedical Sciences (UPSAT) Sfax- Honoris United Universities, TUNISIA

INTRODUCTION

Chronic Obstructive Pulmonary Disease (COPD) is a progressive respiratory condition and a major global public health issue. In 2019, it was the third leading cause of death worldwide, responsible for over 3.2 million deaths, and ranked seventh in disability-adjusted life years (DALYs) (1,2).

According to the 2023 Global Initiative for Chronic Obstructive Lung Disease (GOLD), COPD is characterized by persistent respiratory symptoms such as dyspnea, cough, and sputum production, resulting from airway abnormalities including bronchitis, bronchiolitis, and emphysema, leading to airflow limitation (3). As the disease progresses, it affects multiple systems, leading to functional limitations driven by dyspnea, muscle dysfunction, reduced activity, and anxiety (4).

COPD significantly impairs quality of life and contributes to a cycle of physical deconditioning. Although incurable, symptoms can be managed through smoking cessation, environmental control, vaccination, medication, oxygen therapy, and pulmonary rehabilitation (5). The latter plays a key role in improving exercise tolerance and quality of life and involves physical training, education, and airway clearance techniques—areas where physiotherapists are particularly involved (6,7).

This study aimed to assess the impact of a pulmonary rehabilitation program on physical capacity, lung function, and quality of life in Tunisian patients with COPD.

METHODS

Study Design and Setting

An interventional study was conducted from January to May 2024 in the Rehabilitation Unit of the Pulmonology Department at Hédi Chaker Hospital, Sfax, Tunisia.

Participants

Eligible participants were male patients aged between 50 and 80 years with stable COPD who experienced difficulty in performing daily activities. Exclusion criteria included recent exacerbation of COPD, cardiovascular or neuromuscular comorbidities or musculoskeletal disorders. Patients were also excluded if they experienced chest pain or major dyspnea during sessions, unstable angina, recent myocardial infarction, or persistent oxygen saturation ≤ 85%.

Pulmonary Rehabilitation Program

The intervention consisted of a 6-week pulmonary rehabilitation program, with three supervised sessions per week. Each session included:

- Warm-up exercises
- Aerobic training using either an ergocycle or treadmill, adjusted according to the patient's tolerance and Borg scale feedback
- Muscle strengthening exercises using body weight, resistance bands, or weights
- Functional training incorporating activities of daily living

Physiological parameters (blood pressure, heart rate, and oxygen saturation) were monitored before, during, and after each session.

Outcome Measures

Pre- and post-intervention assessments included:

- **Dyspnea**: The modified Medical Research Council (mMRC) scale measures breathlessness on a 0 to 4 scale, with higher scores indicating more severe dyspnea that limits daily activities. A change of 1 point is clinically significant.
- **Pulmonary function**: Peak Expiratory Flow (PEF) measures the maximum speed of expiration in liters per minute, reflecting airway obstruction severity. Higher values indicate better lung function. Oxygen saturation (SpO_2) was also assessed. Values above 95% are normal; increases reflect improved oxygenation.
- **Endurance**: The 1-minute chair stand test counts how many times a patient can stand up and sit down from a chair in one minute, assessing lower limb strength and endurance. More repetitions mean better functional capacity.
- **Fatigue**: The modified Borg scale from 0 (no fatigue) to 10 (maximal fatigue), used to assess perceived exertion or tiredness during activity. Lower scores after intervention indicate reduced fatigue.
- **Health status**: The COPD Assessment Test (CAT), validated in Arabic, is a simple questionnaire scoring from 0 to 40; higher scores mean worse symptoms and quality of life. A change of about 2 points is considered clinically meaningful.
- **Quality of life**: The St. George's Respiratory Questionnaire (SGRQ) scores range from 0% to 100%, with higher percentages indicating poorer respiratory health-related quality of life. A 4–5% decrease in SGRQ score reflects a significant clinical improvement. CAT and SGRQ scores help quantify how much a patient's daily life improves after treatment.

All instruments used for assessment, including mMRC, PEF, Borg scale, CAT, and SGRQ, are validated tools widely used in COPD research and recommended in clinical practice.

Ethical Considerations

Informed consent was obtained from all participants prior to enrollment. Participants' confidentiality and rights were ensured throughout the study.

RESULTS

Eight male patients with stable COPD completed the 6-week pulmonary rehabilitation program. Improvements were observed in all assessed parameters after the intervention **(Table 1)**.

Table 1. Changes in Clinical and Functional Outcomes Pre- and Post-Rehabilitation (n=8)

Outcome Measure	Pre-Rehabilitation (Mean ± SD)	Post-Rehabilitation (Mean ± SD)
Dyspnea (mMRC score)	2.7 ± 0.7	1.5 ± 0.5
Peak Expiratory Flow (PEF, L/min)	183.7 ± 29.3	258.3 ± 47.4
Oxygen Saturation (SpO_2, %)	93.63 ± 1.4	94.69 ± 1.2
1-Minute Chair Stand Test (repetitions)	17.7 ± 4.2	24.3 ± 3.9
Fatigue (Borg scale)	3.6 ± 1.2	2.3 ± 1.0
CAT score	19.7 ± 3.5	14.1 ± 2.8
SGRQ total score (%)	47.5*	33.5*

*SD = Standard Deviation; mMRC = modified Medical Research Council; CAT = COPD Assessment Test; SGRQ = St. George's Respiratory Questionnaire; % = percent; *: no SD.*

DISCUSSION

This study demonstrated that a 6-week pulmonary rehabilitation program improved multiple dimensions of health in patients with stable COPD, as measured by validated clinical tools. These results align with existing evidence supporting the role of exercise and respiratory therapy in the management of COPD, even alongside optimal pharmacological treatment (8).

The substantial decrease in dyspnea, quantified by the mMRC scale, from 2.7 to 1.5, reflects a clinically meaningful reduction in breathlessness that directly translates to improved capacity to perform daily activities. Since a 1-point change in mMRC is recognized as significant, these results indicate a true improvement in respiratory symptoms and patient function. De Souza et al. demonstrated the clinical relevance of pulmonary rehabilitation on dyspnea as measured by the mMRC scale (9). The role of exercise in reducing breathlessness is well-documented and constitutes a cornerstone of pulmonary rehabilitation (10).

Pulmonary function assessed by PEF increased markedly, suggesting enhanced airway patency and respiratory muscle performance. Similar improvements were reported by Won et al., who found a significant increase in PEF after 12 weeks of rehabilitation in a post-burn population (11). Complementing these findings, the modest but relevant rise in SpO_2 reflects improved gas exchange and oxygen delivery, both critical factors for reducing hypoxemia-related complications in COPD. While modest, this increase is clinically relevant for patients whose oxygenation is often compromised. Previous studies have also noted improved SpO_2 levels following pulmonary rehabilitation (12,13).

Fatigue levels, assessed with the modified Borg scale, decreased from 3.6 to 2.3, supporting the role of enhanced muscular strength and endurance in reducing exertional fatigue (14). In contrast, Griffiths et al. found minimal changes in Borg scores, potentially due to higher session intensity and longer durations (15).

Endurance, as measured by the 1-minute chair stand test, showed a notable increase in repetitions, reflecting improved lower limb strength and functional exercise capacity. This improvement is important, as better physical endurance is directly associated with greater

independence and quality of life in COPD patients. Beaumont et al. similarly reported significant improvements in chair stand test scores after rehabilitation (16).

Quality of life, as measured by CAT and SGRQ scores, improved meaningfully. CAT scores dropped from 19.7 to 14.1, and SGRQ scores from 47.5% to 33.5%, both exceeding the minimal clinically important difference. These complementary tools capture the multidimensional impact of COPD on patients' lives and validate the clinical relevance of the intervention. Similar improvements were reported by Greulich et al. and Alharbi et al., confirming the positive effects of rehabilitation on patients' perceived health status (13,17).

These results confirm that pulmonary rehabilitation offers multidimensional benefits, improving clinical and functional outcomes as well as overall patient well-being. The combination of objective indicators and validated quality-of-life measures reinforces the value of such programs. However, this study has limitations. The small sample size and limited equipment (only one ergocycle and one treadmill) constrained participation and limit the generalizability of the findings. Future studies should include larger samples and longer intervention periods to validate and extend these results.

CONCLUSION

This study demonstrated that a structured pulmonary rehabilitation program significantly improves pulmonary function, endurance, and quality of life in COPD patients, regardless of disease severity. Regular, personalized exercise sessions effectively enhance clinical and functional outcomes. These findings highlight the importance of including pulmonary rehabilitation as part of comprehensive COPD management. Further research is needed to identify the most effective training approaches for different patient profiles and to evaluate the long-term impact on disease progression and quality of life.

REFERENCES

1. Gauthier R, Vassail J, Croutaz JP, Raspaud C. Thérapies actives du mouvement corps-esprit et réadaptation respiratoire dans la BPCO. Rev Mal Respir. 2022;39(3):258-69.
2. Neto Silva I, Monnin D. Quelles stratégies utiliser pour promouvoir l'activité physique chez les patients atteints de BPCO ? Kinésithér Rev. 2021;21(232):29-30.
3. Agustí A, Celli BR, Criner GJ, Halpin D, Anzueto A, Barnes P, et al. Global Initiative for Chronic Obstructive Lung Disease 2023 Report: GOLD Executive Summary. Eur Respir J. 2023;61(4):230-239.
4. Medrinal C, Bonnevie T. La kinésithérapie en per- et post-exacerbation immédiate de BPCO. Rev Mal Respir. 2022;39(4):386-97.
5. Proffit M, Magni M, Huck O, Karsandi K, Abdellaoui A, Pichon R. Kinésithérapie respiratoire libérale : intérêts et modalités de prescription. Revue des Maladies Respiratoires. 2024;41(3):248-256.
6. Beaumont M, Latiers AC, Prieur G. Le rôle du kinésithérapeute dans l'évaluation et la gestion de la dyspnée. Revue des Maladies Respiratoires. 2023;40(2):169-87.
7. Koné S, Kanouté T, Soumaré D, Ouattara K, Sanogo FB, Traoré M, et al. Impact de la kinésithérapie chez les patients atteints de BPCO. Rev Mal Respir Actual. 2024;16(1):98-9.
8. Selleron B, Billet D. Parcours de soins BPCO : les guides et outils de la HAS. Kinésithér Rev. 2013;13(135):16-21.
9. De Souza Y, Da Silva KM, Condesso D, Figueira B, Noronha Filho AJ, Rufino R, et al. Use of a Home-Based Manual as Part of a Pulmonary Rehabilitation Program. Respir Care. déc 2018;63(12):1485-91.
10. Institut national de la santé et de la recherche médicale (INSERM). Activité physique: prévention et traitement des maladies chroniques [Internet]. Paris: INSERM; 2019 [cité 11 avr

2024]. Disponible sur: https://www.inserm.fr/wp-content/uploads/2019-02/inserm-ec-2019activitephysiquemaladieschroniques-synthese.pdf
11. Won YH, Cho YS, Joo SY, Seo CH. The Effect of a Pulmonary Rehabilitation on Lung Function and Exercise Capacity in Patients with Burn. Journal of Clinical Medicine. 2020;9(7):2250.
12. Theodorakopoulou EP, Gennimata SA, Harikiopoulou M, Kaltsakas G, Palamidas A, Koutsoukou A, et al. Effect of pulmonary rehabilitation on tidal expiratory flow limitation at rest and during exercise in COPD patients. Respiratory Physiology & Neurobiology. 2017;238:47-54.
13. Greulich T, Koczulla AR, Nell C, Kehr K, Vogelmeier CF, Stojanovic D, et al. Effect of a Three-Week Inpatient Rehabilitation Program on 544 Consecutive Patients with Very Severe COPD: A Retrospective Analysis. Respiration. 2015;90(4):287-292.
14. Beaumont M, Péran L, Berriet AC, Le Ber C, Philippe E, Courtois Communier E, et al. Effet du mode de renforcement musculaire des membres supérieurs sur la dyspnée, dans la BPCO: REHABSUP. Revue des Maladies Respiratoires Actualités. 2024;16(1):32.
15. Griffiths T, Burr M, Campbell I, Lewis-Jenkins V, Mullins J, Shiels K, et al. Results at 1 year of outpatient multidisciplinary pulmonary rehabilitation: a randomised controlled trial. Lancet. 2000;355(9201):362-8.
16. Beaumont M, Ruelland C. Impact du genre sur les effets de la réadaptation respiratoire chez les patients atteints de BPCO. Revue des Maladies Respiratoires Actualités. 2024;16(1):25-6.
17. Alharbi MG, Kalra HS, Suri M, Soni N, Okpaleke N, Yadav S, et al. Pulmonary Rehabilitation in Management of Chronic Obstructive Pulmonary Disease. Cureus. 2021;13(10):e18414.

ASSESSMENT OF RADIATION EXPOSURE IN NUCLEAR MEDICINE PROCEDURES IN ALBANIA: DIAGNOSTIC AND THERAPEUTIC IMPLICATIONS

Margarita KUQALI

Polytechnic University of Tirana, Faculty of Mathematics Engineering and Physics Engineering, Department of Physics Engineering, Tirana, Albania

ORCID ID: https://orcid.org/0009-0007-2428-1408

Kostandin DOLLANI

University of Tirana, Institute of Applied Nuclear Physics, Tirana, Albania

ORCID ID: https://orcid.org/0009-0007-5036-9745

Ylli KAÇIU

University Clinical Center of Kosovo, Nuclear Medicine, Clinical Service, Pristina, Kosovo

ORCID ID: https://orcid.org/0000-0002-3657-1871

ABSTRACT

Background: This study aims to analyze the applications of nuclear medicine in Albanian hospitals. More precisely the analysis will focus on the diagnostic and therapeutic effectiveness while assessing the associated radiation exposure risks. Nuclear medicine has been present in Albania for over four decades and is currently applied in three main hospitals where up to date equipments are used. The aim of this study was to assess radiation doses in nuclear medicine practices and evaluate the possible risks.

Materials and Methods: The main sources of data gathering were 3 hospitals in Albania which perform nuclear medicine. The main radiopharmaceuticals used were Tc-99m for diagnostics and I-131 for diagnostics and therapy. The Medical Internal Radiation Dose [MIRD] methodology was employed in order to estimate absorbed and effective doses in patients undergoing different nuclear medicine procedures.

Results and Discussion: The absorbed doses varied significantly depending on the procedure, with diagnostic procedures generally resulting in low effective doses (0.5–4.2 mSv), while therapeutic I-131 procedures led to significantly higher doses (up to several sieverts). An estimated collective dose of 730 man·Sv was calculated, which corresponds to about 36 projected cancer cases and one hereditary case per year due to these procedures.

Conclusion: These findings highlight the importance of radiation protection, especially in paediatric patients. The study confirms that nuclear medicine offers substantial diagnostic and therapeutic benefits, but on the other hand it emphasizes the importance of radiation safety and dose optimization practices enhancement. Therefore, the establishment of a national dose registry and development of stricter radiation safety protocols, especially for high-dose treatments, is a must.

Keywords: Nuclear medicine, Tc-99m and I-131, MIRD and patient safety.

INTRODUCTION

Nuclear medicine is a specialized field of medical imaging and therapy that makes use of radiopharmaceuticals to diagnose and treat a variety of diseases. Unlike conventional-traditional radiology or external beam radiation therapies, which apply radiation externally, nuclear medicine includes the administration of unsealed radioactive compounds that concentrate in specific organs or tissues, enabling in this way, both functional imaging and localized radiotherapy [1]. Diagnostic applications generally use gamma-emitting isotopes such as Tc-99m and I-131, which, when bound to organ-specific pharmaceutical kits, allow for the evaluation of physiological processes in the thyroid, kidneys, skeleton, lungs, and other systems [2,3]. Therapeutically, beta-emitting isotopes like I-131 are used to ablate hyper functioning thyroid tissue or eradicate residual thyroid cancer cells following thyroidectomy.

In Albanian context, nuclear medicine has been present for over four decades and is currently provided by three medical centers in Tirana: the University Hospital Center "Mother Teresa" [UHCMT], Hygeia Hospital (HH), and the American Hospital (AH). These facilities operate with modern dual-head gamma cameras and maintain a continuous supply of Mo-99/Tc-99m generators and I-131 capsules, supporting both diagnostic and therapeutic services [4]. However, despite these improvements, national-level data on patient dosimetry, radiation risk, and procedural frequency remain limited. This lack of data presents challenges in radiation protection oversight and long-term epidemiological planning.

The objective of this study is to meticulously evaluate patient exposure from nuclear medicine procedures being implemented in Albania using the Medical Internal Radiation Dose [MIRD] methodology [5]. Specifically, the study aims to quantify organ-absorbed doses, effective doses, and collective doses across major diagnostic and therapeutic applications, and to estimate associated stochastic risks such as radiation-induced cancers and hereditary effects using International Commission on Radiological Protection [ICRP] risk coefficients [6–8]. The hypothesis underpinning this work is that while nuclear medicine procedures in Albania follow international practices in terms of radiopharmaceutical selection and equipment, there may be gaps in dose optimization, patient monitoring, and regulatory enforcement, particularly in vulnerable groups such as pediatric patients [9]. Addressing these gaps is essential for improving radiation safety, developing a national patient dose registry, and aligning Albania's nuclear medicine practices with international safety standards.

MATERIAL AND METHODS

This study was conducted across the three primary Nuclear Medicine Clinics [NMCs] in Albania: UHCMT, HH, and AH, between 2017 and 2024. Data collection focused on the following aspects: patient numbers, radiopharmaceutical types and activity levels, procedural protocols, and equipment characteristics. Radiation doses were assessed using the MIRD methodology, allowing for standardized assessment of absorbed and effective doses across diagnostic and therapeutic procedures.

Radiopharmaceuticals and Procedures

While approximately 30 radioisotopes are used in nuclear medicine worldwide, in Albanian context clinical practice is limited to only two: Tc-99m and I-131. These isotopes are selected based on their physical and radiological properties, with Tc-99m primarily used for diagnostic imaging and I-131 for therapeutic applications. To support the continuous operation of nuclear medicine procedures, NMCs of UHCMT, HH and AH maintain a stable radiopharmaceutical supply chain. This includes:

- Mo-99/Tc-99m generators, which enable the production of Tc-99m in hospitals [4]. In Albania, these generators typically have activities in the range of tens of GBq. Each unit is

usually used for about two weeks, after which a new one must be imported due to the decay of Mo-99 activity.

- Sodium iodide (NaI) capsules, with activity levels ranging from 370 MBq to 3700 MBq.

To conduct diagnostic procedures with the Tc-99m isotope, it is first eluted from the chromatographic column where molybdenum atoms are fixed in the Mo-99/Tc-99m generator. A sterile saline solution (NaCl) is used to serve this purpose, which, when passed through the column, washes out and produces a solution of sodium pertechnetate ($NaTc\text{-}99mO_4$). This solution can be used directly for intravenous injections to examine the thyroid gland or be radio chemically combined with cold kits for diagnosing various organs. These are chemical compounds that, once introduced into the human body, accumulate in specific organs. When combined with the radioisotope Tc-99m, they form a "hot kit" or radiopharmaceutical. To enable the diagnosis of different organs, specialized kits are formulated to ensure the targeted uptake of Tc-99m in the corresponding tissues [2]. Table 1 presents the diagnostic procedures currently performed in Albania, along with the corresponding radiopharmaceuticals employed for each application. On the other hand, the radioactive isotope of iodine (I-131) is imported by nuclear medicine clinics in the chemical form of sodium iodide (NaI) in two types of capsules, with initial activities of 3700 MBq and 370 MBq. Capsules with high activity (3700 MBq) are used for treating thyroid cancer after surgical removal of the gland. In this case, patients are hospitalized for a 24-hour period, after which they may return home. According to national regulations, a patient may be discharged only when the amount of radioactive iodine in their body is no more than 1100 MBq. Low-activity capsules (370 MBq) are used for the treatment of hyperthyroidism of the thyroid gland. The amount of radioactive iodine administered to patients for hyperthyroidism treatment in NMCs ranges between 370 MBq and 1100 MBq. This treatment does not necessarily require hospitalization and can be carried out on an outpatient basis.

After injection, the behavior of the radioactive Tc-99m in the target organ is monitored using gamma cameras [3]. These facilities are equipped with gamma cameras, which are essential for capturing images of radiopharmaceutical distribution in the body. They create detailed images of the distribution of these tracers in organs or tissues, helping in the diagnosis and monitoring of various conditions such as thyroid disorders, bone diseases, etc.. The gamma cameras in use meet modern technological standards and are subject to regular maintenance and calibration to ensure optimal performance and accuracy. At UHCMT, the gamma camera is of the AnyScan type, produced by the Hungarian company “MEDISO,” and it was installed in 2011 by this company. This gamma camera is composed of 56 scintillation detectors and is mounted on a gantry system that allows it to rotate at a 360-degree angle. The scintillation detectors of this gamma camera are hexagonal in shape with high stability and are characterized by high performance and good optical and mechanical properties. The gamma camera has dimensions of 530 mm × 390 mm. The scintillation crystal is NaI with dimensions of 585 mm × 470 mm and is shielded from light with a layer of aluminized foil. Additionally, the gamma camera is protected on top by a lead-glass sheet with a thickness of 12 mm. An important part of the gamma camera is the gantry system, which ensures the rotation of the system and acquisition of 3-dimensional images. The energy range detected by the scintillation detectors is from 40 to 600 keV.

All NMCs in Albania use activity calibrators as well, to measure the radioisotope activity before patient injection. These devices consist of a cylindrical ionization chamber connected to an electrometer controlled by a microprocessor, ensuring accurate measurements for various radioisotopes. The NMC at QSUT is equipped with a Capintec calibrator, capable of measuring activities from 1 MBq to 100 GBq and detecting 20 different isotopes.

Additionally, each NMC is equipped with a specially designed ventilated steel hood where the Mo-99/Tc-99m generator is placed, ensuring radiation protection during handling.

UHCMT, HH and AH implement strict radiation safety protocols, including shielded storage areas for radioactive materials, controlled handling procedures, and continuous personnel monitoring to comply with international radiation protection standards.

To conduct a comprehensive assessment of nuclear medicine practices in Albania, data was collected from all three hospitals that practice nuclear medicine. The data collection process involved:

- Reviewing hospital records to obtain the number of patients undergoing nuclear medicine procedures.
- Gathering procedural details, including administered radiopharmaceuticals, activity levels, and imaging protocols.
- Assessing hospital supply chains, including the frequency of Mo-99/Tc-99m generator replacements and I-131 capsule availability.
- Consulting nuclear medicine specialists and medical physicists to understand procedural workflows, patient selection criteria, and radiation safety measures.
- Examining equipment maintenance records to ensure that gamma cameras and radiation detection instruments meet operational standards.

The collected data was categorized into diagnostic and therapeutic procedures to analyze patient exposure levels and associated radiation risks.

Dosimetric Approach

Several methods are available for calculating doses from incorporated radioisotopes, including Monte Carlo simulations that model the interactions of thousands of virtual gamma rays with human tissue. However, the most widely adopted and standardized approach is the MIRD method. Developed in collaboration with ICRP, the MIRD method offers improved accuracy in estimating absorbed and effective doses [7]. In this study, we employed the MIRD methodology to evaluate radiation doses, following its systematic framework for internal dosimetry [10]: In accordance with the recommendations provided in ICRP Publication 128, which offers updated dose coefficients and guidance for radiopharmaceutical administration in diagnostic and therapeutic nuclear medicine, the MIRD methodology was applied to ensure consistency with current international standards [12].

1. Determine the initial activity, A_{S0} of the administered radioisotope [MBq].
2. Calculate the cumulated activity, $\tilde{A}_s$ in a given organ [MBq · h].
3. Calculate the dose commitment, D_t that is, the total dose absorbed by the target organ due to the complete decay of the deposited radionuclide.
4. Estimate the effective dose, E incorporating tissue weighting factors.

For a given organ receiving an initial activity A_{S0}, the cumulated activity is the time integral of the deposited radioactivity:

$$\tilde{A}_s = \int_0^\infty A_s(t)dt = A_{S0}\int_0^\infty e^{-\lambda_E t}dt = \frac{A_{S0}}{\lambda_E} \qquad (1)$$

where $A_s(t)$ is the activity at time t, andλ_E is the effective decay constant.

The dose commitment to the target organ due to the complete decay of the deposited radionuclide, is then calculated as:

$$D_t = \tilde{A}_s \cdot S(t,s) \qquad (2)$$

where $S(t,s)$[mGy/MBq · h] is the absorbed dose per unit cumulated activity, whose values are tabulated for numerous target organs and for numerous radionuclides of interest [5]. For example, value of S for thyroid gland during thyroid imaging with Tc-99m, is $S = 1.03 \times 10^{-2}$ mGy/MBq ·h, while value of S for thyroid gland during hyperthyroidism therapy with I-131 is $S = 6.12$ mGy/MBq · h. On the other hand, the effective dose, E accounts for radiation exposure across the entire body, incorporating tissue weighting factors, w_T, and is then calculated as [11]:

$$E = D_t \cdot w_T \qquad (3)$$

RESULTS AND DISCUSSION

Both diagnostic and therapeutic applications were analyzed to assess radiation exposure and its potential health effects. The findings are discussed in relation to patient volume, procedural distribution, and projected stochastic risks, providing insight into current practices and identifying areas for improved radiation safety.

Organ Dose Estimation via MIRD

Based on the activities of radiopharmaceuticals used in nuclear medicine procedures in NMCs of the three hospitals, we have calculated the doses received by different organs because of diagnostic and therapeutic procedures. Below, we present the dose calculation for two procedures: one diagnostic and one therapeutic, both involving the thyroid gland.

- Thyroid Diagnostic Procedure (Tc-99m Pertechnetate, 120 MBq)

For thyroid imaging, Tc-99m Pertechnetate is administered with initial activity, A_{S0} of 120 MBq. Given an effective half-life, λ_E of 6 hours [10], the cumulated activity in the thyroid, calculated by substituting A_{S0} and λ_E into (1), is equal to 1036.8 MBq · h.

With a value of $S = 1.03 \times 10^{-2}$ mGy/MBqh [5], the dose commitment to the target organ, the thyroid, using (2), is $10{,}68\ mGy$. The effective dose, E [11] using (3), is: $E = 10.68$ mGy · $0.05 = 0.53$ mSv.

- Hyperthyroidism Treatment (I-131 Sodium Iodide, 370 MBq)

For the treatment of hyperthyroidism (Graves' disease), I-131 sodium iodide is administered with $A_{S0} = 370$ MBq. The radioactive half-life, T_R of I-131 is 8.01 days, while its biological half-life, T_B in the thyroid is 10.8 days. This makes the effective half-life, $T_E = \frac{T_R \times T_B}{T_R + T_B} =$ 4.59 days [10].

Assuming 25% of the administered $I-131$ accumulates in the thyroid, the cumulated activity in the thyroid is:$0.25\frac{A_{S0}}{\lambda_E} = 1.47\text{x}10^4$MBq · h.

With an S-factor of 6.12 mGy/MBq · h [5] the absorbed dose in the thyroid, D_t is 89.9 Gy:

The effective dose, E [11] is:$E = D_t \cdot w_T = 89.9$ Gy · $0.05 = 4.49$ Sv

Table 1 summarizes the typical administered activity for each nuclear medicine procedures performed in Albania in a year, the corresponding absorbed dose, effective dose and patient volumes. The values presented there indicate that doses of internal radiation from Tc-99m diagnostic procedures range from 0.5 mSv (lung scan) to 4.2 mSv for skeleton scan. In contrast, higher doses are observed in therapeutic applications of I-131 for hyperthyroidism, where the absorbed dose in the thyroid reaches approximately 90 Gy, and the effective dose is 4.5 Sv; and for thyroid cancer treatment the absorbed dose in the thyroid reaches approximately 2.4 Gy, and the effective dose is 0.283 Sv.

Table 1. Absorbed and effective doses from selected nuclear medicine procedures in Albania

Type of Exposure	Radiopharmaceutical	Administred Activity, A_{s0}, (MBq)	Dose, D_t , (mGy)	Effective Dose, E, (mSv)	No. of patients
Thyroid Gland	Tc-99m Pertechnetate	120	10,7	0.53	7200
Skeleton	Tc-99m MDP	740	46	4,2	960
Lungs	Tc- 99mMAA	120	4.9	0.5	240
Kidneys (Dynamic)	Tc-99mDTPA	185	9.3	2,2	240
Kidneys (Static)	Tc-99mDMSA	111	7,1	1,7	240
PET/CT	F-18 FDG	400	16	16	1200
Thyroid Gland	I-131NaI	370	89900	4490	150
Thyroid Gland	I-131NaI	3700	2357	283	100

Collective Dose Estimation and Projected Stochastic Effects

The investigation conducted across the NMCs of three hospitals in Albania assessed the diagnostic and therapeutic procedures performed, as well as the average number of patients treated per month. The findings revealed that, collectively, the three clinics import approximately 70 Mo-99/Tc-99m generators annually, along with radioactive iodine based on clinical demand. The most frequently performed procedures include organ imaging and therapies for hyperthyroidism and thyroid cancer following surgical thyroidectomy. Table 1 presents an overview of the procedures performed and the corresponding patient volumes:

- The examination of the thyroid gland is performed using technetium pertechnetate through intravenous injection, with an activity of 120 MBq. This procedure accounts for the largest number of examinations conducted in all three NMCs in the country. According to clinical data, the total number of examinations conducted is 600 patients per month, or 7,200 per year.

- The skeletal examination is performed by combining the technetium isotope with an activity of 740 MBq with the MDP kit. The total number of examinations across the three clinics is 80 patients per month or 960 per year.

- The lung examination is performed by combining the technetium isotope with an activity of 120 MBq with the MAA kit. The total number of examinations across the three clinics is 20 patients per month or 240 per year.

- The dynamic kidney examination is performed by combining the technetium isotope with an activity of 120 MBq with the DTPA kit. The total number of examinations across the three clinics is 20 patients per month or 240 per year.

- The static kidney examination is performed by combining the technetium isotope with an activity of 120 MBq with the DMSA kit. The total number of examinations across the three clinics is 20 patients per month or 240 per year.

- PET/CT diagnostics are performed only at HH, and the number of patients is 100 per month, or 1,200 per year.

Regarding therapeutic nuclear medicine procedures conducted in Albania, all three NMCs perform hyperthyroidism therapy, whereas thyroid cancer treatments after thyroid removal are carried out in only two of the NMCs.

- For hyperthyroidism treatment, sodium iodide solution with an activity of 370 MBq is administered orally to the patient. The number of patients undergoing this therapy is 150 per year.
- For thyroid cancer treatment after thyroid removal, sodium iodide solution with an activity of 3700 MBq is again used and administered orally. The number of patients undergoing this therapy is 100 per year.

To determine expected health effects, the effective dose, E, must be analyzed, as it relates to stochastic effects (e.g., cancer and hereditary mutations), while the absorbed dose from a certain organ is relevant for deterministic effects, occurring only when a threshold dose is exceeded.

From the analysis of the number of patients undergoing diagnostic and therapeutic nuclear medicine treatments in our country, it is evident that diagnostic procedures constitute the majority, with approximately 10,100 examinations per year. In contrast, the number of patients undergoing therapeutic procedures is limited to approximately 250 per year.

Regarding the values of effective doses, it is observed that these doses are low, in the millisievert range, for diagnostic examinations, while they are high, in the Sievert range, for therapeutic treatments.

To numerically quantify the expected stochastic effects, the most significant of which are the occurrence of tumors and hereditary effects, it is necessary to calculate the collective dose received by the group of patients undergoing diagnostic and therapeutic nuclear medicine treatments over a year.

For this purpose, we will sum up the products of the number of patients undergoing a specific treatment with the effective dose for that treatment. The formula to be used for the collective dose is:

$$S_C = \sum_i n_i \cdot E_i \qquad (4)$$

where n_i is the number of patients undergoing a specific procedure, and E_i is the effective dose for that procedure.

By performing the calculations according to (4), based on the data from Table 1 regarding effective doses and the number of patients undergoing a specific type of treatment, the collective dose S_C [man $\cdot$ Sv] for medical exposures conducted in Albania is equal to 729.9 man $\cdot$ Sv .

To determine the expected stochastic effects, we must consider the risk coefficients for the occurrence of these effects, as defined by the ICRP. According to this commission, the following values for risk coefficients have been established [8]:

- The risk coefficient for the occurrence of a tumor is $\mathrm{K}_1 = 5 \cdot 10^{-2}\ \mathrm{Sv}^{-1}$.
- The risk coefficient for the occurrence of a hereditary effect is $\mathrm{K}_2 = 0.2 \cdot 10^{-2}\ \mathrm{Sv}^{-1}$.

The expected damage of both types will be determined as the product of the collective dose, $S_C$and the respective risk coefficients defined by the ICRP.

Expected number of tumor cases:

$$\mathrm{N}_1 = S_C \cdot \mathrm{K}_1 = 729.9\ \text{man} \cdot \text{Sv} \cdot 5 \cdot 10^{-2}\mathrm{Sv}^{-1} = 36\ \text{man}$$

Expected number of hereditary effects:

$$\mathrm{N}_2 = S_C \cdot \mathrm{K}_2 = 729.9\ \text{man} \cdot \text{Sv} \times 0.2 \times 10^{-2}\ \mathrm{Sv}^{-1} = 1.46\ \text{man}$$

According to these calculations, for all procedures performed in nuclear medicine in Albania, there will be an additional 36 cases of tumors and 1 case of hereditary effects among the group of people treated with nuclear medicine procedures.

CONCLUSION

This study made an evaluation of the radiation doses associated with nuclear medicine procedures in Albania, by making use of the MIRD methodology in order to estimate organ-specific absorbed doses, effective doses, and collective doses based on actual clinical practice of the three national centers. The findings showed that diagnostic procedures are the ones which dominate, with a quantity of over 10,000 examinations annually, with relatively low effective doses (0.5–4.2 mSv). On the other hand, therapeutic procedures, though less frequent, reflect higher doses, particularly for I-131 therapies. The calculated collective dose of 729.9 man·Sv corresponds to an estimated 36 additional cancer cases and one hereditary effect annually.

These results confirm the diagnostic and therapeutic value of nuclear medicine while highlighting the significance of dose optimization and enhanced radiation protection, particularly for radiosensitive populations such as children. The implementation of strategies such as the use of non-ionizing alternatives where possible, appropriate radiopharmaceutical selection, strict procedural protocols, and comprehensive staff training are needed to minimize unnecessary exposure.

In summary, this study provides the first systematic national level dosimetric assessment of nuclear medicine in Albania, providing a foundation for regulatory planning and patient protection strategies.

Further research is, however, important in order to evaluate long-term outcomes, establish a national patient dose registry, and explore the potential role of advanced technologies, including artificial intelligence, in improving dosimetry accuracy and clinical decision-making. Future endeavors should also focus on epidemiological studies to investigate associations between cumulative exposures and health outcomes in high-risk groups, including pediatric and oncology patients

REFERENCES

1. International Atomic Energy Agency, Nuclear Medicine Physics: A Handbook for Teachers and Students, IAEA, Vienna, 2014.

2. International Atomic Energy Agency, Technetium-99m Radiopharmaceuticals: Status and Trends, IAEA Radioisotopes and Radiopharmaceuticals Series No.1, IAEA, Vienna, 2009.

3. International Atomic Energy Agency, Human Health Series No. 6: Quality Assurance for SPECT Systems, IAEA, Vienna, 2009.

4. International Atomic Energy Agency, Design and Principle of Mo-99/Tc99m Generator, IAEA, Vienna, 2006.

5. MIRD Pamphlet No.11, Radiation Absorbed Dose per Unit Cumulated Activity for Selected Radionuclides and Organs, Society of Nuclear Medicine, 1975.

6. MIRD Pamphlet No. 23, Quantitative SPECT for Patient Specific 3-Dimensional Dosimetry in Internal Radionuclide Therapy, Society of Nuclear Medicine, 2012.

7. International Commission on Radiological Protection, Radiation Doses to Patients from Radiopharmaceutical, Publication 53, ICRU, 1988.

8. International Commission on Radiological Protection, The 2007 Recommendations of the International Commission on Radiological Protection, ICRP Publication 103, 2007.

9. International Atomic Energy Agency, Radiological Protection for Medical Exposure to Ionizing Radiation, Safety Standards Series No. RS-G-1.5, IAEA, 2002.

10. Loevinger P, Budinger T.F, Watson E. MIRD Primer for Absorbed Dose Calculations, Revised Edition. New York, The Society of Nuclear Medicine, 1991.

11. Mettler F, Huda Ë, Yoshizumi T, Mahesh M, Effective doses in radiology and diagnostic nuclear medicine: A catalog. Radiology 248(1):254-263; 2008.

12. International Commission on Radiological Protection, Radiation Dose to Patients from Radiopharmaceuticals: A Compendium of Current Information Related to Frequently Used Substances, ICRP Publication 128, Ann. ICRP 44(2S), 2015.

COMMUNITY-BASED CARBON MANAGEMENT: ASSESSMENT IN TERMS OF RURAL DEVELOPMENT AND FORESTRY

Prof. Dr. Ersin GÜNGÖR

Bartın University, Faculty of Forestry, Department of Forestry Engineering, Bartın, Turkey

ORCID ID: https://orcid.org/0000-0002-0844-4656

Res. Assist. Dr. Yağmur YEŞİLBAŞ

Bartın University, Faculty of Forestry, Department of Forestry Engineering, Bartın, Turkey

ORCID ID: https://orcid.org/0000-0002-6611-9069

ABSTRACT

Forests are among the most efficient natural systems capable of storing carbon in the atmosphere on a long-term basis and play an important role in combating climate change. Carbon management practices, especially with the participation of communities living in rural areas, not only provide environmental benefits, but also bring development opportunities at the local level. In this study, the "Community-Based Carbon Management" approach was evaluated in terms of rural development and forestry policies; A'WOT (SWOT integrated with Analytic Hierarchy Process) method was applied to systematically analyze strengths, weaknesses, opportunities and threats. The material of the study was the data obtained from the opinions of 10 experts who have knowledge in the field of carbon management and rural development. The factors identified by SWOT analysis were weighted using the AHP method and prioritized by strategic prioritization. A'WOT findings show that active participation of rural communities in carbon markets is effective in both achieving carbon reduction targets and improving rural living standards. In the study, it was determined that increasing local capacity, disseminating community-based forest management models and strengthening public support are among the priority strategies. In conclusion, community-based carbon management is considered as a strategic tool for developing sustainable forestry policies that support rural development. This approach strengthens community integration into environmental processes and contributes to maintaining social, economic and ecological balance.

Keywords: Community-Based Carbon Management, Rural Development, A'WOT Analysis, Sustainable Forestry, Carbon Markets

INTRODUCTION

In today's world, climate change has become a global problem with not only environmental but also economic and social dimensions. Carbon emissions, one of the main causes of greenhouse gas accumulation in the atmosphere, disrupts the balance of natural ecosystems and threatens sustainable development goals (IPCC, 2021). In this context, removing carbon from the atmosphere and storing it in the long term is a critical strategy to combat climate change. Forest ecosystems are recognized as one of the most effective natural sinks in this fight thanks to their capacity to sequester carbon through biomass and soil (FAO, 2020; Pan et al., 2011).

This function of forests not only generates environmental benefits, but also provides an

important opportunity for the development of socio-economic policies. Carbon management practices, especially by involving rural communities in forest management, contribute to increasing carbon stocks and serve local development goals (Agrawal et al., 2008; Shrestha et al., 2010). This double-win potential has led to the increasing importance of "community-based carbon management" (CBCM) approaches.

CBCM is a decentralized carbon management model based on the direct participation of rural people, taking into account local knowledge and needs. In this model, local communities are not only passive beneficiaries but also active decision makers and implementers. Therefore, the success of carbon management directly depends on the awareness, level of organization and economic motivation of local people (Chhatre & Agrawal, 2009). However, effective implementation of this process requires restructuring of forestry policies, development of public-private partnerships and in-depth analysis of socio-economic interactions.

Carbon management, in the broadest sense, is a holistic approach that includes planning, implementation and evaluation processes to reduce carbon emissions, increase carbon sinks and monitor carbon balance. This process is based on three main strategies: reducing carbon emissions (mitigation), removing carbon from the atmosphere (sequestration) and monitoring carbon stocks (monitoring-reporting-verification). Forests are at the center of carbon management in that they provide an integrated solution to all of these strategies (Brown et al., 2019).

However, the effectiveness of carbon management is not limited to the ecological dimension. In today's conditions where carbon has become a market product, the participation of economic and social actors in the process is inevitable. In this context, community-based carbon management stands out as a participatory model that encourages rural communities to take an active role in combating climate change (Boyd et al., 2007). CBCM practices increase the level of knowledge, skills and motivation of local people; reinforce a sense of ownership of forests and promote sustainable land use (Corbera & Brown, 2010).

Rural areas are fragile systems, both ecologically and socio-economically. Livelihoods based on agriculture, livestock, wood and non-wood forest products increase dependence on forests, making sustainable management of forest areas difficult. However, carbon management practices have the potential to create new sources of income for rural people. Villages taking part in voluntary carbon markets or publicly funded projects can generate direct income from the sale of carbon credits (Peskett et al., 2008).

In addition, carbon management provides multifaceted benefits such as sustainable forest management, erosion control, soil improvement, biodiversity conservation and water resource management, which in turn improves the quality of rural life and supports development dynamics (Angelsen et al., 2009). However, despite all these positive aspects, ensuring the effective and equitable participation of rural communities in this process poses serious governance and structural challenges.

For effective implementation of community-based carbon management, national forestry policies need to be structured in a flexible and participatory manner to support this approach. Centralized forestry structures often restrict local initiative and make it difficult for innovative practices such as carbon management to be adopted at the local level (Larson et al., 2010). Therefore, it is inevitable that the policy and legislative framework for carbon management should be revisited at both national and local levels.

In the case of Turkey, it is observed that carbon management policies have not yet evolved into a community-based structure. Existing practices are mostly carried out by the central government and the inclusion of rural communities in the process is limited. However, in line with both the European Union Green Deal and the goals of integration into international carbon markets, Turkey needs to move towards reforms that support community-based carbon

management (Ministry of Environment, Urbanization and Climate Change, 2023).

The main objective of this study is to make a holistic assessment of the community-based carbon management approach in terms of rural development and forestry policies. The study analyzed the applicability, local capacity, policy integration and governance dimensions, especially in the Turkish context. Using the A'WOT method, the strengths, weaknesses, opportunities and threats of community-based carbon management are systematically presented and a strategic priority ranking is presented to decision makers.

The unique contribution of this research is to develop feasible policy recommendations to increase the effectiveness of local communities in combating climate change. It also aims to contribute to the integration of Turkey forestry policies with climate goals and to bring a sustainability perspective to the rural development process.

CONCEPTUAL FRAMEWORK

This study aims to evaluate the concept of community-based carbon management in terms of rural development and forestry policies. CBCM is a governance model based on the participation of local people in combating climate change, aiming to reduce carbon emissions and support social development at the same time. The conceptual framework is based on sustainability, participatory governance and multi-stakeholder decision-making processes. In this context, the integrated consideration of environmental and socioeconomic components is placed at the center of the policy-making process.

The analytical infrastructure of the research is based on the A'WOT method, which is an integrated form of SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis and Analytic Hierarchy Process (AHP), one of the multi-criteria decision-making techniques. This method combines the qualitative aspect of classical SWOT analysis with the quantitative prioritization power of AHP, providing decision makers with a more systematic and objective analysis (Kurttila et al., 2000). The A'WOT approach enables comprehensive assessments that will contribute to strategic planning, especially in the fields of forestry, natural resource management and rural development.

In this framework, the conceptual basis of the study is built on an approach that encourages the active participation of local communities in decision-making processes, puts resource management on a fair and sustainable basis, and provides concrete strategic directions for policy makers. Thus, it is aimed to contribute to both the reduction of carbon emissions and the development of rural areas simultaneously.

METHODOLOGY

Data collection

The scope of the study includes Turkey's rural forest villages and the views of policy makers, practitioners and experts with academic knowledge in the field of carbon management. Forest villages in Turkey represent a population of approximately 7 million people and are directly and indirectly dependent on forest resources (OGM, 2023). These communities are both beneficiaries and implementers of carbon sequestration projects. In this context, the feasibility of community-based carbon management practices, their impact on rural development goals and their compatibility with forestry policies were evaluated. Data were collected from 10 experts with different areas of expertise in carbon management, rural development, participatory forest management and voluntary carbon markets. The experts were selected from different disciplines such as forestry, environmental sciences, rural development, carbon markets and public policy and had academic, technical and administrative experience.

Interviews were conducted through a structured questionnaire and participants were asked to make their assessments under four main headings (Strengths, Weaknesses, Opportunities, Threats) that make up the SWOT analysis. Each participant identified between 6-8 strategic factors according to his/her expertise perspective and these factors were then grouped and analyzed by the research team through thematic coding.

Analysis of the research problem

In the light of the data obtained, a classical SWOT matrix was first created. A total of 34 strategic factors obtained from the expert opinions were coded by content analysis and combined under common themes and a total of 16 factors were identified under 4 main headings (Strengths (G): 4 factors, Weaknesses (WE): 4 factors, Opportunities (F): 4 factors and Threats (T): 4 factors).

Following the creation of the SWOT matrix, each factor was weighted using the AHP method. At this stage, the experts were presented with a comparison matrix where they could evaluate the factors under the SWOT headings through pairwise comparisons. The comparisons were made using the 1-9 scale suggested by Saaty (1980) and the importance of each factor compared to the other was questioned.

The AHP process was carried out in the following stages:

1. Stage: Creation of pairwise comparison matrices,
2. Stage: Calculating consistency ratios for each matrix,
3. Stage: Determining the weights for each SWOT topic,
4. Stage: Extraction of the overall priority ranking.

The data received from the experts were analyzed with Excel and Expert Choice software. All matrices were analyzed so that the consistency ratio (CR) was below 10%. This was done to increase the reliability of the comparisons.

With the AHP results, the relative weights of each SWOT factor were determined and strategic priority ranking was made. In the light of the data obtained, it was analyzed which aspects of community-based carbon management should be strengthened, which risks should be managed as a priority, and which opportunities should be strategically exploited.

This assessment process involves both quantitative weighting and qualitative interpretation. In other words, the numerical importance levels of the factors were determined, and then these values were interpreted from the perspective of rural development and forestry policies and transformed into policy recommendations.

CONCLUSION AND DISCUSSION

Weighting SWOT Factors

Within the scope of the research, the SWOT matrix created with the data obtained from expert opinions was evaluated with the AHP and the relative weight of each factor was calculated. Through this analysis, which aspects should be prioritized in community-based carbon management practices were identified with numerical data. Tables 1-4 present the weighted factors and relative importance values of each SWOT dimension.

Table 1. Strengths and Weights for Community-Based Carbon Management

Factor Code	Factor Description	Weight (%)
G1	Traditional attachment of rural people to forests	31.2
G2	Existence of community-based forest management experience	27.5
G3	Local knowledge on natural resource management	23.8
G4	The potential of carbon management to create local jobs	17.5

Among the strengths identified in line with expert opinions, the traditional attachment of rural people to forests stands out (Table 1).

Table 2. Weaknesses and Weights for Community-Based Carbon Management

Factor Code	Factor Description	Weight (%)
Z1	Lack of local technical capacity and expertise	34.6
Z2	Lack of information on carbon markets	28.1
Z3	Lack of trust in volunteer projects	22.4
Z4	Regulatory and governance barriers	14.9

Lack of local technical capacity and lack of information on carbon markets emerged as the most dominant weaknesses (Table 2).

Table 3. Opportunities and Weights for Community-Based Carbon Management

Factor Code	Factor Description	Weight (%)
F1	Possibility of integration into international carbon markets	36.1
F2	EU Green Deal and climate finance opportunities	29.4
F3	Potential to encourage public-private partnerships	19.7
F4	Integrability of carbon management into rural development policies	14.8

In the opportunities dimension. especially the possibility of integration into international carbon markets has the highest strategic priority (Table 3).

Table 4. Threats to Community-Based Carbon Management and their Weights

Factor Code	Factor Description	Weight (%)
T1	Lack of sustainable financing for projects	33.8
T2	Lack of motivation for local people to participate in the process	30.6
T3	Natural disasters and ecological uncertainties (fire. drought, etc.)	21.2
T4	Central government's tendency to move away from participatory governance	14.4

The most important factor threatening the sustainability of the projects is the lack of financing (Table 4).

Weighting of SWOT Dimensions

As a result of the pairwise comparisons made with AHP, the overall strategic importance of the four SWOT dimensions is determined in Table 5.

Table 5. Comparative Priority Weights of SWOT Dimensions

SWOT Dimension	Priority Weight (%)
Opportunities (F)	34.7
Strengths (G)	27.3
Threats (T)	22.1
Weaknesses (Z)	15.9

According to Table 5. The "Opportunities" dimension has the highest strategic weight and is the area that should be considered as a priority in policy development processes. Strengths and threats also have considerable weights, while weaknesses have a relatively lower weight in strategic terms.

Strategic Priority Ranking (All Factors Overall Ranking)

AHP results. also revealed the overall priority ranking of all SWOT factors. The top 5 strategic factors (ST) are as follows:

1. ST: F1 - Possibility of integration into international carbon markets (12.5%).
2. ST: G1 - Traditional attachment of rural people to forests (10.4%).
3. ST: Z1 - Lack of local technical capacity and expertise (9.3%).
4. ST: T1 - Lack of sustainable financing for projects (7.5%).
5. ST: F2 - EU Green Deal and climate finance opportunities (6.8%).

This ranking shows that international integration is a top priority in developing carbon management strategies. Lack of local capacity and financing issues stand out as weaknesses and threats that directly affect the success of the process.

Lack of local capacity (Z1) and motivational issues (T2) directly threaten the viability of community-based carbon management. Therefore, capacity building and awareness raising activities should have strategic priority.

The traditional forest culture of rural people (G1). is seen as a factor that increases ownership of projects and it is recommended that this aspect be considered in public policies.

EU-based climate finance (F2) and public-private partnerships (F3) offer important opportunities to achieve both carbon and development goals. Project development capacities in these areas should be increased.

Community-based carbon management is considered as a multidimensional governance model that can simultaneously support both the participation of communities, especially those living in rural forest villages, in combating climate change and their socio-economic development. The findings of this study using the A'WOT method. The findings of this study provide important clues about the applicability, limitations and opportunities of community-based carbon management approaches in the Turkish context.

According to the findings. the factor with the highest strategic priority by the experts was identified as. "**possibility of integration into international carbon markets**" (12.5%). This situation. Turkey's potential to participate in global carbon markets can also be supported by community-based models. As a matter of fact, Bayrak & Marafa (2016) also reported similar findings and emphasized that especially for developing countries, taking an active role in carbon markets directly contributes to the socio-economic development of local communities. The fact that Turkey has not yet fully integrated into mandatory carbon markets creates an opportunity for community-based projects based on voluntary carbon markets. However, in order for this process to be sustainable, carbon crediting processes need to be transparent, traceable and designed in a way to gain the trust of local people (Corbera et al. 2007).

In the results of the analysis, "**the traditional attachment of rural people to forests**" has emerged as a high priority among the strengths. This finding suggests that rural communities have a sense of ownership of forest resources not only in terms of economic but also cultural and social values. Such local attachments are considered as the cornerstone of participatory forest management (Ostrom. 1990; Agrawal. 2001). However, in order to transform this ownership potential into effective carbon management, it is essential to increase institutional support and ensure the active participation of local people in governance processes. In Turkey, rural communities are not sufficiently involved in decision-making mechanisms, which causes this potential to remain at a limited level. The literature emphasizes that such practices are called "tokenism" and jeopardize the sustainability of the process (Pretty. 1995).

"**Lack of local technical capacity and expertise**", which was identified with the highest weight among the weaknesses, is an important problem that is in line with the literature. In many studies, it is stated that one of the most important reasons for the failure of community-based nature conservation and climate projects is the lack of technical capacity (Sunderlin et al. 2015; Minang et al. 2014). Especially in complex processes such as measuring, monitoring and

reporting carbon stocks, the lack of knowledge of local people makes it necessary to direct the process from the center and weakens the principle of participation. Therefore, technical trainings, guidance documents, local leadership programs and sustainable capacity building models are of strategic importance in the dissemination of community-based carbon management. It is also recommended to blend local knowledge with scientific processes through university-forest village collaborations and non-formal education activities.

The "**lack of sustainable financing**", which received the highest weight in the threats heading, stands out as a critical limiting factor in the success of carbon management projects. This finding. This finding supports the field research conducted by Boyd et al. (2009), where high initial investments and uncertainty of revenue streams in voluntary carbon market-based projects negatively affect the motivation of local people to participate. In the case of Turkey, the fact that community-based carbon management projects are largely dependent on international grants and support threatens the sustainability of the practices. At this point, strategically directing public resources and encouraging private sector investments may offer important opportunities for the financial sustainability of projects.

According to the research findings, "**centralized governance structure limiting participatory models**" was identified as a threat, albeit with a low weight. Forest management in Turkey is highly centralized and forest villagers are often only the implementers of the process. However, community-based carbon management is based on participatory governance principles (Larson et al. 2010). This constitutes a structural problem that hinders the democratization of not only carbon management but also rural development policies. However, programs such as FAO (2018) and UN-REDD define the participation of local people in decision-making processes in carbon sequestration projects as a sine qua non for the success of projects.

This study aims to evaluate carbon management practices, which are of strategic importance in combating climate change, in the context of rural development and forestry policies with a community-based approach. The findings obtained with the A'WOT method reveal that community-based carbon management can be considered as a holistic development tool with not only environmental but also social and economic dimensions.

One of the most important results of the research is that there is a high potential for rural communities to participate in carbon management practices. In particular, the traditional attachment of rural people to forests and local knowledge facilitate the ownership of projects and increase their sustainability. However, lack of local technical capacity, insufficient information and sustainable financing problems are among the main obstacles to the implementation process.

Ensuring integration into international carbon markets. Integration into international carbon markets is of great importance for Turkey to realize its climate commitments; in this process, community-based models stand out as an effective tool for carbon credit generation. However, this potential can be realized not only through economic incentives, but also through institutional transformation and strengthening local participation.

Based on the research results. The following recommendations have been developed that can be integrated into Turkey's forestry and rural development policies:

Capacity Building and Training: Carbon management training programs for local communities should be established. These programs should cover a wide range of topics from carbon measurement techniques to market mechanisms. Employment of village-based technical staff should be encouraged; joint capacity building programs should be carried out with local units of the forestry organization.

Institutional and Governance Reforms: To implement community-based carbon projects, semi-autonomous governance models should be developed in which forest villagers are actively involved in decision-making processes. Cooperatives. forest village associations and rural

development agencies should be supported as implementers and overseers of carbon management at the local level.

Financial Mechanisms: A national "Carbon Fund" should be established to support community-based carbon projects and should be used for initial financing of projects in voluntary carbon markets. Villages producing carbon credits should be eligible for an additional share of public subsidies (rural development grants. forest incentives, etc.).

Carbon Market Integration: It is essential for Turkey to develop a national voluntary carbon market infrastructure to provide a transparent and reliable framework for rural-based carbon projects. Public-university collaborations should be strengthened to increase the number of projects that comply with international certification systems (Verra. Gold Standard, etc.).

Database and Monitoring Systems: An open database on carbon sequestration projects carried out in rural areas should be created; this data should be used for both monitoring- evaluation and decision support processes. The development of low-cost MRV (measurement, reporting, verification) systems that can be used at the local level should be encouraged.

Social Participation and Awareness: Communication campaigns should be conducted to inform local people about carbon projects, with special support for the participation of women, youth and disadvantaged groups. Success stories should be shared in national media and social platforms, and a culture of environmental responsibility and participation should be promoted in society at large.

Community-based carbon management. Community-based carbon management should be considered as a strategic tool that can simultaneously contribute to rural development and sustainable forestry objectives in Turkey. This approach not only generates environmental benefits, but also stands out with its social outputs such as rural employment, income growth and social ownership. However, the success of this model depends on strengthening local capacity, making policy-making processes participatory and implementing governance reforms at the national level.

Consequently, decentralization of carbon management will democratize the fight against climate change and pave the way for rural communities to participate more effectively in a sustainable future.

REFERENCES

Agrawal A. Common property institutions and sustainable governance of resources. *World Development*. 2001;29(10):1649-1672.

Agrawal A. Chhatre A. Hardin R. Changing governance of the world's forests. *Science*. 2008;320(5882):1460-1462.

Angelsen A. Brockhaus M. Kanninen M. Sills E. Sunderlin WD. Wertz-Kanounnikoff S. eds. *Realising REDD+: National Strategy and Policy Options*. CIFOR; 2009.

Bayrak MM. Marafa LM. Ten years of REDD+: A critical review of the impact of REDD+ on forest-dependent communities. *Sustainability*. 2016;8(7):620.

Boyd E. Gutierrez M. Chang M. Small-scale forest carbon projects: Adapting CDM to low-income communities. *Global Environmental Change*. 2009;17(2):250-259.

Boyd E. May P. Chang M. Veiga F. Exploring socioeconomic impacts of forest based mitigation projects: Lessons from Brazil and Bolivia. *Environmental Science & Policy*. 2007;10(5):419-433.

Brown S. Zarin D. Symalla D. Reducing emissions from deforestation and forest degradation (REDD): Architecture. challenges. and opportunities. *Environmental Science and Policy for Sustainable Development*. 2019;61(6):4-15.

Chhatre A. Agrawal A. Trade-offs and synergies between carbon storage and livelihood benefits from forest commons. *Proceedings of the National Academy of Sciences*. 2009;106(42):17667-17670.

Corbera E. Brown K. Offsetting benefits? Analyzing access to forest carbon. *Environment and Planning A*. 2010;42(7):1739-1761.

Corbera E. Brown K. Adger WN. The equity and legitimacy of markets for ecosystem services. *Development and Change*. 2007;38(4):587-613.

Environment. Ministry of Urbanization and Climate Change. Updated NDC. 2023. Accessed August 2025. https://iklim.tccb.gov.tr/

FAO. *Global Forest Resources Assessment 2020: Main Report*. FAO; 2020.

FAO. *The State of the World's Forests 2018 - Forest Pathways to Sustainable Development*. FAO; 2018.

IPCC. *Climate Change 2021: The Physical Science Basis*. Cambridge University Press; 2021.

Kurttila M. Pesonen M. Kangas J. Kajanus M. Utilizing the analytic hierarchy process (AHP) in SWOT analysis-a hybrid method and its application to a forest-certification case. *Forest Policy and Economics*. 2000;1(1):41-52.

Larson AM. Cronkleton P. Barry D. Pacheco P. Tenure rights and beyond: Community access to forest resources in Latin America. *Forest Ecology and Management*. 2010;268:1- 5.

Minang PA. van Noordwijk M. Duguma LA. et al. REDD+ Readiness progress across countries: Time for reconsideration. *Climate Policy*. 2014;14(6):685-708.

OGM (General Directorate of Forestry). Turkey Forest Asset 2023. OGM Publications; 2023.

Ostrom E. *Governing the Commons: The Evolution of Institutions for Collective Action*. Cambridge University Press; 1990.

Pan Y. Birdsey RA. Fang J. et al. A large and persistent carbon sink in the world's forests.

Science. 2011;333(6045):988-993.

Peskett L. Huberman D. Bowen-Jones E. Edwards G. Brown J. *Making REDD Work for the Poor*. Poverty Environment Partnership (PEP); 2008.

Pretty J. Participatory learning for sustainable agriculture. *World Development*. 1995;23(8):1247-1263.

Saaty TL. *The Analytic Hierarchy Process: Planning. Priority Setting. Resource Allocation*. McGraw-Hill; 1980.

Shrestha RK. Alavalapati JRR. Kalmbacher RS. Exploring the potential for silvopasture adoption in south-central Florida: An application of SWOT-AHP method. *Agricultural Systems*. 2010;103(9):630-638.

Sunderlin WD. Larson AM. Cronkleton P. Forest tenure rights and REDD+: From inertia to policy solutions. In: Sills EO. Atmadja S. de Sassi C. Duchelle AE. Kweka D. Resosudarmo IAP. Sunderlin WD. eds. *REDD+ on the Ground: A Case Book of Subnational Initiatives Across the Globe*. CIFOR; 2015:47-64.

UN-REDD Programme. *About REDD+*. Accessed August 2025. https://www.un-redd.org/

ASSOCIATION BETWEEN DIGITAL NUTRITION LITERACY AND NUTRITION KNOWLEDGE LEVELS IN UNIVERSITY STUDENTS

Dr. Şeyma SÜNBÜL

Ankara University, Kalecik Vocational School, Food Technology Program, Ankara, Turkey[1]

ORCID ID: https://orcid.org/0000-00002-3333-7203

İlayda AKKAYA

Ankara University, Faculty of Health Sciences, Department of Nutrition and Dietetics, Ankara, Turkey

ORCID ID: https://orcid.org/0009-0001-5945-8871

Prof. Dr. Alev KESER

Ankara University, Faculty of Health Sciences, Department of Nutrition and Dietetics, Ankara, Turkey

ORCID ID: https:// orcid.org/0000-0003-2620-6747

ABSTRACT

Introduction and Purpose: This study aims to examine the relationship between the digital nutrition literacy of university students' their ability to evaluate nutrition-related information encountered in digital environments and their general nutrition knowledge. Specifically, the study will investigate how accurately students assess online health and nutrition information, to what extent to which this influences their basic nutrition knowledge and food preferences.

Materials and Methods: This cross-sectional study included 122 students (46 males and 76 females) from Kalecik Vocational School, Ankara University. Participants were asked to complete a questionnaire containing sociodemographic questions and two scales: the "e-Healthy Nutrition Literacy Scale (e-HDLQ)" to assess electronic healthy nutrition literacy, and the "Nutrition Knowledge Level Scale for Adults" to assess nutritional knowledge. Body mass index (BMI) was calculated based on self-reported weight and height data. Data were analyzed using SPSS version 24.0. Descriptive statistics, independent samples t-tests, and Pearson's correlation analyses were conducted. Statistical significance was set at $p<0.05$.

Results: The mean BMI of the students was found to be 23.8±4.5 kg/m². The mean e-HDLQ score of female students (39.3±6.7) was significantly higher than that of male students (35.4±8.8) ($p<0.05$). Regarding the subdimensions of the Nutrition Knowledge Level Scale for Adults, the average score for basic nutrition knowledge was modarete (52.6±7.7), while the score for food preference was good (36.5±6.3). Additionally, a positive and statistically significant correlation was observed between e-HDLQ scores and food preference scores ($r=0.33$, $p<0.001$).

Discussion and Conclusion: As students' digital literacy regading healthy eating increases, they become more aware of their food preferences and make healthier choices. Expanding nutrition education and nutrition literacy education is crucial for promoting healthy eating behaviors.

Key Words: E-healthy nutrition literacy; Nutrition knowledge level; Healthy nutrition; Food preferences

INTRODUCTION

The university period is a critical phase for individuals to develop enduring nutritional habits. The nutritional attitudes and behaviors acquired during this period can determine lifestyle choices in later years and impact the risk of chronic diseases such as obesity, diabetes, and cardiovascular disease (Gao T., 2023).

Adopting holistic approaches that consider healthy food consumption and environmental factors together is crucial for reducing noncommunicable diseases and their associated morbidity rates (Cammock et al., 2021). In this context, increasing nutritional literacy and nutritional knowledge levels at the societal level stands out as one of the fundamental strategies for protecting public health. Nutrition literacy and adequate nutritional knowledge are critical determinants for the adoption and maintenance of healthy eating behaviors (McNamara et al., 2020).

Healthy nutrition literacy is defined as the ability of individuals to obtain, evaluate, and understand information about nutrition and diet, and to access the necessary services to make appropriate decisions based on this information (Vettori et al., 2019). With the proliferation of digital environments, the concept of "e-healthy nutrition literacy" has also gained a place in the literature. This concept refers to individuals' ability to access, understand, evaluate, and apply information about healthy nutrition in daily life through electronic resources (Onbaşı & Türker, 2023).

Today, individuals can easily access a wealth of information through social media and various digital platforms. Mobile apps, online health communities, and social media-based information channels have become powerful educational tools due to their ability to reach large audiences, their low cost, and their ability to interact with users (Van Duong et al., 2021). It has been observed that individuals frequently use the internet to obtain information, particularly on health-related topics, and conduct online research on food safety and healthy nutrition (Franklin et al., 2020).

With the influence of technological advances, the concepts of "e-health literacy" and "e-healthy nutrition literacy" have become more frequently discussed in recent years (Aktaş & Özdoğan, 2020). Research shows that nutrition education provided digitally is more effective on nutrition literacy, especially when compared to traditional methods such as brochures and computer games (Silk et al., 2008). However, the diversity and sometimes contradictory nature of information sources available in the digital environment can make it difficult for individuals to access reliable and scientifically based information. This has made digital nutrition literacy a critical area not only for accessing information but also for distinguishing its accuracy (Van Duong et al., 2021).

Thanks to individuals with a nutritional literacy awareness, societies can gain a significant advantage in raising healthy future generations. In this context, it is crucial for university students to have adequate nutritional knowledge and literacy. The purpose of this study is to determine the relationship between university students' e-healthy nutrition literacy levels and their nutritional knowledge.

METHODS

This cross-sectional study was planned and conducted between January and March 2025 with adult individuals studying at Ankara University Kalecik Vocational School. Approval for the research was obtained from Ankara University "Non-Clinical Research on Human Subjects"

Ethics Committee dated 11.11.2024 and decision number 12/163. The study included 122 individuals over the age of 18 who read and approved the "Informed Voluntary Consent Form" and agreed to participate in the study. Data were collected through a questionnaire using face-to-face interview method. "General Information Form" was used to determine the general information and socio-demographic characteristics of the individuals, "e-Healthy Nutrition Literacy Scale (e-HDLQ)" was used to evaluate the level of electronic healthy nutrition literacy, and "Nutrition Knowledge Level Scale for Adults" was used to determine the level of nutrition knowledge.

Anthropometric Measurements

Since there was no suitable environment for anthropometric measurements in the study, body weight and height measurements were taken based on the declaration of the individuals. BMI values of the individuals were calculated using the equation body weight (kg)/height (m^2).

E-Healthy Nutrition Literacy Scale (e-HDLQ)

The "e-Healthy Nutrition Literacy Scale (e-HDLQ)" scale was developed by Van Duong and colleagues in 2021 to measure the ability of adults to access, evaluate and use healthy diet information in digital environment. This measurement tool consists of 5 factors and includes 15 items in total (Van Duong et al., 2021). The scale in question was adapted into Turkish by Onbaşı in 2022. Similar to the original, the Turkish form consists of 5 factors and 15 items. The scoring system of the scale is structured differently for each sub-dimension. The statements in the first subdimension are graded between "never" (1) and "every day" (5). In the second subdimension, 5 points were given for each statement answered correctly and 1 point was given for statements marked as incorrect or "don't know". In the third sub-dimension, participants' opinions were scored between "strongly disagree" (1) and "strongly agree" (5). In the fourth sub-dimension, the frequency level was scored between "never" (1) and "always" (5). In the fifth subdimension, a score between "very difficult" (1) and "very easy" (4) was given according to the degree of difficulty. The sum of the scores obtained from all sub-dimensions reflects the individual's e-healthy nutrition literacy level. A high total score obtained from the scale means that the individual's literacy level in this area is also high (Onbaşı, 2022).

Nutrition Knowledge Level Scale for Adults

In this study, the "Nutrition Knowledge Level for Adults " scale was used to determine the participants' level of knowledge about nutrition. This scale was developed by Batmaz (2018) and a validity and reliability study was conducted. This measurement tool consists of two main parts; the first part consists of 20 questions aiming to measure basic nutrition knowledge and the second part consists of 12 questions about individuals' food preferences. The questions in these two sections, which consist of 32 questions in total, are evaluated with a 5-point Likert scale as strongly agree, agree, neither agree nor disagree, disagree, strongly disagree. The maximum score that can be obtained in the basic nutrition subdimension of the scale is determined as 80. According to the scores obtained from this subdimension, the knowledge levels of individuals are categorized as follows: 45 points and below indicates "low", 46-55 points indicates "moderate", 56-65 points indicates "good" and above 65 points indicates "very good" level of nutrition knowledge. On the other hand, the highest score that can be obtained from the second section on food preferences is 48. When the score distribution in this section is examined; scores of 30 and below reflect "low", 31-36 points reflect "moderate", 37-42 points reflect "good" and values above 42 points reflect "very good" food preference behaviors (Batmaz, 2018).

Statistical Evaluation of Data

Statistical analyses of the data collected within the scope of the study were conducted using the SPSS 24.0 package program. Frequency (n), percentage (%), mean ($\bar{X}$) and standard deviation (SD) were used for descriptive data. The conformity of the data to normal distribution was examined using the Kolmogorov-Smirnov Test. The Independent Samples t-Test was used for the analysis of categorical data, while Pearson Correlation Analysis was employed to evaluate the relationships among the data. Statistical values were evaluated at $p<0.05$ significance level.

RESULTS

Table 1. Distribution and averages of students according to socio demographic characteristics and anthropometric measurements

Variables	**$\bar{x}$±SS**	
Age (years)	20.9±2.9	
Body weight (kg)	69.1±16.0	
Height (cm)	169.9±10.3	
Body mass index(kg/m^2)	23.8±4.4	
Variables	**n**	**%**
Gender		
Female	7	26.9
Male	11	42.3
Smoking status		
Yes	46	37.7
No	76	62.3
Alcohol use status		
Yes	49	40.2
No	73	59.8
Use of nutritional supplements		
Yes	31	25.4
No	91	74.6
Any health problem		
Yes	20	16.4
No	102	83.6
Nutrition education status		
Yes	30	24.6
No	92	75.4

A total of 122 students, 46 (37.7%) males and 76 (62.3%) females, with a mean age of 20.9±2.9 years, participated in the study. The mean BMI values were 23.4±4.8 kg/m^2 for female students and 24.4±3.8 kg/m^2 for male students. The majority of the students did not smoke (62.3%) and did not consume alcohol (59.8%). A total of 83.6% of the participants reported having no health problems and then 74.6% they did not use vitamin or mineral supplements. 24.6% of the students stated that they had received nutrition education before (Table 1).

The relationship between participants' BMI values, e-healthy nutrition literacy and nutrition knowledge level scores is shown in Table 3. There was a positive and moderate relationship between e-HDLQ score and food preference scores ($r=0.331$, $p<0.01$), and a positive and strong relationship between basic nutrition knowledge level score and food preference score ($r=0.621$, $p<0.01$).

Table 2. Evaluation of nutrition knowledge and e-healthy nutrition literacy levels of students according to gender

Variables	Male (n:46)	Female (n:76)	p
BMI (kg/m^2)	24.4±3.8	23.4±4.8	0.234
e-HDLQ score	35.4±8.8	39.3±6.7	**0.007***
Nutrition Knowledge Level Scale for Adults	51.3±7.5	53.4±7.7	0.147
Basic nutrition score	35.8±6.4	36.9±6.3	0.370
Food preference score			

*p<0.05, independent sample t-test. BMI: Body mass index; e-HDLQ: E-Healthy Nutrition Literacy Scale

Table 3. The relationship between students' e-healthy nutrition literacy and nutrition knowledge level scores

Parameters	BMI	e-HDLQ	Basic nutrition score	Food preference score
BMI (kg/m^2)	**1**	.039	.063	.060
e-HDLQ score		**1**	.174	.331**
Nutrition Knowledge Level Scale for Adults			**1**	.621**
Basic nutrition score				**1**
Food preference score				

**p<0.01 Pearson correlation analysis; BMI: Body mass index; e-HDLQ: E-Healthy Nutrition Literacy Scale

When the e-healthy nutrition literacy and nutrition knowledge level scores of the participants were compared according to their nutrition education status, a significant difference was found between the groups only in terms of e-HDLQ scores (p = 0.023). The mean e-HDLQ score of individuals who received nutrition education (40.6 ± 8.5) was statistically significantly higher than the mean score of individuals who did not receive nutrition education (36.9 ± 7.3) (p<0.05). There was no statistically significant difference between the groups in other variables (p>0.05).

Table 4. Evaluation of nutrition knowledge and e-healthy nutrition literacy levels of students according to their nutrition education status

Variables	Receiving Nutrition Education (n:30)	No Nutrition Education (n:90)	p
e-HDLQ score	40.6±8.5	36.9±7.3	**0.023**
Nutrition Knowledge Level Scale for Adults			
Basic nutrition score	53.1±6.9	52.5±8.0	0.733
Food preference score	36.1±5.7	36.6±6.5	0.691

*p<0.05 Independent Samples t-Testi. e-HDLQ: E-Healthy Nutrition Literacy Scale

DISCUSSION

The proliferation of internet-based healthy eating platforms has made digital healthy eating literacy increasingly important. Such digital platforms offer advantages such as reaching large audiences, cost-effectiveness and influencing consumer behavior. However, it is noted that the information provided on these platforms can often be biased, incomplete, misleading or commercially motivated (Van Duong et al., 2021). Nutrition literacy has been shown to play a decisive role in individuals' healthy or unhealthy food choices (Taylor et al., 2019). According to the findings of the study, the e-healthy nutrition literacy levels of female students (39.3 ± 6.7) were higher than those of male students (35.4 ± 8.8). Similarly, in a study conducted by Köse (2025) with university students, it was determined that female students had higher levels of e-HDLQ. However, in a study conducted with students from the Faculty of Sports Sciences, no significant difference was found between e-HDLQ scores according to gender (Aydın et al., 2024). In some studies conducted in different populations, it was found that female had higher levels of e-healthy nutrition literacy compared to male (Yeşildemir, 2023; Kaçar & Türker, 2024).

It was found that there was a positive and moderately significant relationship between electronic nutrition literacy and food preference scores of the university students participating in the study ($r=0.331$, $p<0.01$). It is seen that as the e-nutrition literacy level of the students increases, they tend to change their food preferences in a healthier direction. Similarly, Yeşildemir (2023) found a positive correlation between e-HDLQ total score and basic nutrition and food preference scores ($p<0.05$). Van Duong et al. (2020) also found that higher digital healthy eating literacy scores were associated with healthier eating behavior. In general, college students with higher e-health literacy exhibit more positive health-promoting behaviors (Yang et al., 2017; Britt et al., 2017). This result reveals that individuals' ability to access and understand accurate and reliable nutrition information has an impact on their ability to make healthy food choices.

The mean e-HDLQ score of students who received nutrition education (40.6 ± 8.5) was statistically significantly higher than that of students who did not receive nutrition education (36.9 ± 7.3) ($p = 0.023$). This result shows that nutrition education is effective in increasing students' ability to access, evaluate and use digital health and nutrition information. Students' ability to interpret health information presented in digital media more accurately and transform this information into healthy eating behaviors is an important skill that can be developed through education. Similarly, it is reported in the literature that health education increases digital literacy skills and enables individuals to make more informed health decisions (Yang, Luo & Chiang, 2017; Britt et al., 2017). In this context, it is recommended that programs promoting healthy living in universities should be structured to include not only knowledge transfer but also digital literacy.

The study has some limitations. The study was limited to students studying in only one vocational college. This may limit the generalizability of the findings. In future research, it is recommended to conduct studies with students studying in different departments and with larger sample groups in universities with various demographic characteristics.

REFERENCES

1) Aktaş, N., & Özdoğan, Y. (2016). Food and nutrition literacy. Harran Journal of Agriculture and Food Sciences, 20(2), 146-153.

2) Aydın, R., Genç, A., Dere, G., & Kayar, O. Y. (2024). Examination of e-healthy nutrition literacy levels of Faculty of Sports Sciences students]. International Journal of Current Education Research, 10(2), 237-249.

3) Batmaz, H. (2018). Development of nutrition knowledge level scale for adults and validity and reliability study [Master's thesis, Marmara University].

4) Britt, R. K., Collins, W. B., Wilson, K., Linnemeier, G., & Englebert, A. M. (2017). E-Health literacy and health behaviors affecting modern college students: A pilot study of issues identified by the American College Health Association. Journal of Medical Internet Research, 19(12), e392.

5) Cammock, R., Tonumaipe'a, D., Conn, C., Sa'uLilo, L., Tautolo, E. S., & Nayar, S. (2021). From individual behaviour strategies to sustainable food systems: Countering the obesity and non-communicable diseases epidemic in New Zealand. Health Policy, 125(2), 229-238.

6) Duong TV, Pham KM, Do BN, Kim GB, Dam HT, Le VTT, et al. Digital healthy diet literacy and self-perceived eating behavior change during COVID-19 pandemic among undergraduate nursing and medical students among undergraduate nursing and medical students: a rapid online survey. International Journal of Environmental Research and Public Health, 2020, 17(19), 7185

7) Franklin, J., Holman, C., Tam, R., Gifford, J., Prvan, T., Stuart-Smith, W., et al. (2020). Validation of the e-NutLit, an electronic tool to assess nutrition literacy. Journal of Nutrition Education and Behavior, 52(6), 607-614.

8) Gao, T., Duan, Y., Qi, Q., et al. (2023). Nutrition literacy differs based on demographics among university students in Bengbu, China. Frontiers in Public Health, 11, 1113211.

9) Kaçar, E. Y., & Türker, P. (2024). Examining the relationship between eating awareness and e-health nutrition literacy levels of healthcare professionals and nutrition-related parameters [Examining the relationship between eating awareness and e-health nutrition literacy levels of healthcare professionals and nutrition-related parameters]. Journal of Başkent University Faculty of Health Sciences, 9(2), 206-222.

10) McNamara, J., Kunicki, Z. J., Olfert, M. D., Byrd-Bredbenner, C., & Greene, G. (2020). Revision and psychometric validation of a survey tool to measure critical nutrition literacy in young adults. Journal of Nutrition Education and Behavior, 52(7), 726-731.

11) Onbaşı, Ö. (2022). e-Sağlıklı beslenme okuryazarlığı (e-) ölçünün Türkçe'ye uyarlanması ve yetişkin bireylerde Covid-19 pandemic pre and during e-SBO levels in adult individuals and determination of the relationship between parameters related to nutrition [Doctoral dissertation, Başkent University].

12) Silk, K. J., Sherry, J., Winn, B., Keesecker, N., Horodynski, M. A., & Sayir, A. (2008). Increasing nutrition literacy: Testing the effectiveness of print, website, and game modalities. Journal of Nutrition Education and Behavior, 40(1), 3-10.

13) Taylor, M. K., Sullivan, D. K., Ellerbeck, E. F., Gajewski, B. J., & Gibbs, H. D. (2019). Nutrition literacy predicts adherence to healthy/unhealthy diet patterns in adults with a nutrition-related chronic condition. Public Health Nutrition, 22(12), 2157-2169.

14) Van Duong, T., Chiu, C. H., Lin, C. Y., et al. (2021). E-healthy diet literacy scale and its relationship with behaviors and health outcomes in Taiwan. Health Promotion International, 36(1), 20-33.

15) Van Duong, T., Lin, C. Y., Sorensen, K., Pelikan, J. M., & Huang, Y. H. (2021). Digital health literacy and health-related behaviors among university students during the COVID-19 pandemic: A cross-sectional study. Healthcare, 9(4), 376.

16) Vettori, V., Lorini, C., Milani, C., & Bonaccorsi, G. (2019). Towards the implementation of a conceptual framework of food and nutrition literacy: Providing healthy eating for the population. International Journal of Environmental Research and Public Health, 16(24), 5041.

17) Yang, S. C., Luo, Y. F., & Chiang, C. H. (2017). The associations among individual factors, eHealth literacy, and health-promoting lifestyles among college students. Journal of Medical Internet Research, 19(1), e15.

18) Yeşildemir, Ö. (2023). Evaluation of the relationship between sustainable and healthy eating behaviors with e-healthy diet literacy and nutrition knowledge level in adults [Evaluation of the relationship between sustainable and healthy eating behaviors with e-healthy diet literacy and nutrition knowledge level in adults]. Journal of Celal Bayar University Graduate School of Health Sciences, 10(3), 250-260.

TECHNOLOGICAL PREPAREDNESS FOR DISASTERS: AN INNOVATIVE APPROACH TO THE RISK OF DEW DISASTERS

Gamze AYDIN

Istanbul Esenyurt University, Vocational School of Health Services, First and Emergency Aid Program, Istanbul, Turkey

ORCID ID: https://orcid.org/0009-0009-7748-3884

ABSTRACT

Introduction and Purpose: Avalanche is a fast-developing natural phenomenon that occurs when the snow cover on sloping terrain slips due to gravity and causes loss of life and property. Effective response is difficult. Technological developments are critical in disaster management. The measures taken can prevent avalanches from turning into disasters. This study introduces the patent pending 'Avalanche Survival Equipment' and presents its technical and social contributions.

Materials and Methods: User needs, living conditions and risk perceptions were analyzed in the prototype design of the device. The thermofiber fabric prevents hypothermia by maintaining body temperature; the helmet-structured hood protects the mouth and nose from contact with snow, reducing the risk of asphyxia. Oxygen cylinders in the backpack prevent hypoxia by providing the necessary air in the event of an avalanche. An integrated GPS module pinpoints location and speeds up search and rescue, while a pulse sensor monitors vital signs. Shock absorbing structures protect the skeletal system and the equipment is resistant to extreme weather conditions. Equipped with a voice guidance module with breathing training and calming sounds for psychological support to the disaster victim.

Results: In the preliminary evaluations, the device's portability, ease of use and suitability for local conditions were found to be positive. Its reusable structure was evaluated as environment and user friendly. The device contributes to individual preparedness and resilience against disasters.

Discussion and Conclusion: Solutions developed through interdisciplinary efforts, such as the Avalanche Survival Equipment, increase local and global social resilience against avalanche disasters. The integration and widespread use of the device with public institutions will increase disaster preparedness capacity and reduce loss of life.

Keywords: Disaster; Technology; Avalanche; Preparedness; Response

GİRİŞ

Afetler, oluştuğu bölgeye göre toplumun tamamını veya belirli bir kesmini etkileyen, hayatı durduran ve tehlikeye uğratan, can ve mal kayıplarına neden olan olaylardır (Coppola, 2011). Afetler oluşmasına göre, ani ve yavaş gelişen afetler olarak iki grupta incelemek mümkündür. Ani gelişen afetlerden birisi çığ afetidir. Çığ, eğimli arazilerdeki kar örtüsünün yer çekimiyle kaymasıyla oluşan ve anında müdahalesi zor bir doğal afettir (McClung & Schaerer, 2006). Son yıllarda artan iklim değişiklikleri, doğaya müdahale, çığ riskinin artışına neden olmuştur (Beniston et al., 2018). Yaşanan bu durum afetlere hazırlıklı olmamız gerektiğini tekrar vurgulamıştır (Paton & Johnston, 2006). Gelişen teknolojiler ile birlikte afetlere hazırlık olarak teknolojik cihazların kullanılması gündeme gelmektedir. Çığ afeti, aniden ve hızla gelişen bir

afettir. Olay anında müdahale zordur. Bu nedenle bireysel önlemlerimizi afet öncesinde almamız gereklidir (Alexander, 2013).

Çığ altında kalan afetzedelerin büyük bir sorunlarından bazıları, uzun süreli kar altında kalmasıyla birey hipotermi, oksijensiz kalarak hipoksi, solunum yolları tıkanarak asfiksi ve çığ anında darbelere maruz kalarak fiziksel travma ile hayati risklerle karşı karşıya kalmaktadır. Çığ altında kalan birey hem fiziksel hem de psikolojik travmalar yaşaması mümkündür. Tüm bu bileşenler, çığ altındaki bireyin hayatta kalma süresini uzatmayı ve kurtarılana kadar güvenliğini sağlamayı hedeflemektedir.

Buluş, çığ felaketlerinde yaşanılan can kayıplarının önüne geçilmesi için tasarlanmış olup, çığ olayının buluş ile afete dönüşmesinin engellenmesi amaçlanmıştır. Buluşumuz, giyilebilen bir teknoloji olarak planlanan 'Çığ Altı Yaşam Ekipmanı' olarak adlandırılmıştır. Dağcılık sporu ile ilgilenen veya çığ riski bulunan bölgelerde görev alan bireylerin rahatlıkla çalışmalarına olanak sağlamaktadır.

Buluşun amacı, bireyleri olası çığ risklerine karşı korumak, yaşamlarını sürdürmelerine destek sağlamak, gerekli ısı dengesi ve yeterli oksijen miktarını sağlamak, nabız ve konum bilgileri ile arama kurtarma süreçlerinde müdahalenin hızını arttırmak ile birlikte ülkemizde yaşanabilecek çığ olayları öncesi önlem almak ve dünya teknolojilerine katkı sağlamaktır. Oluşabilecek riskleri en aza indirilmesi planlanarak, çığ altı yaşam ekipmanı oluşturulmuştur. Afet öncesinde hazırlıklı olarak afet anı ve sonrasının ise zararsız atlatılması için hazırlanan bir afet teknolojisidir.

KAVRAMSAL ÇERÇEVE

Afet yönetimini dört ana başlıkta incelemek mümkündür. Afet Yönetimi, risk azaltma, hazırlık, müdahale ve iyileştirme süreçlerini kapsamaktadır. Bu süreç çok yönlü ve disiplinlerarası çalışmaları içermektedir (Coppola, 2011). Teknolojik cihazlar, afet yönetiminin tüm aşamalarında olmalıdır. Ani gelişen doğa olaylarında bireyin hayatta kalmasını sağlayan çalışmalar önemli bir şekilde yürütülmelidir (Pantelopoulos & Bourbakis, 2010).

Afetlere hazırlık ve teknolojik dayanıklılık bu çalışmanın temelini oluşturmaktadır. Afetlerden önce bireylerin bilinçli ve hazırlıklı olmaları, toplumsal dayanıklılığın yapı taşını oluşturmaktadır. Çığ afeti, beklenmedik ve aniden ortaya çıkmasıyla kısa sürede yıkıcı etkiye sahiptir. Bu süreç gerçekleşmeden önce hazırlık yapılması çok önemlidir (Paton & Johnston, 2006).

Çığ Altı Yaşam Ekipmanı, bu çerçevede ele alındığında yalnızca teknik bir ürün değil; aynı zamanda sosyal bir inovasyon örneğidir. Giyilebilir teknolojiler, kriz anında etkili bir yöntemdir. Ekipman çok yönlü olarak, hayati fonksiyonlarının devamı için gerekli olan tüm detaylar düşünülmüştür. Ekipmanın tekrar tekrar kullanılabilir olması çevresel sürdürülebilirlik de önem arz etmektedir.

Hem ekonomik hem de ekolojik açıdan sürdürülebilirlik kriterlerini karşılamaktadır. Afetlerde kullanılan teknolojilerine çevresel ve sürdürülebilirliği açısından çok önemlidir (Kelman, 2007).

Bu tür ürünlerin kamu kurum ve kuruluşlarla, sivil toplum kuruluşlar ile entegrasyonu ile afet Yönetimi sadece teknik değil aynı zamanda yönetimsel bir süreçtir. Bu kapsamda geliştirilen her ürün, aynı zamanda toplumsal farkındalık oluşturmaktadır.

METODOLOJİ

Bu araştırma, çığ altında kalan bireyin yaşamsal fonksiyonlarının devam etmesi ve çığ sonrası arama-kurtarma çalışmalarının hızlı ve etkili bir şekilde yürütülmesi için geliştirilmiştir. Nitel

araştırmalarla desteklenen çalışma, ürünün hem teknik hem de insani yönlerden bütüncül bir çalışmadır.

Veri Toplama Süreci

Veri toplama sürecinde, geçmişte yaşanmış çığ afetlerine ilişkin araştırmaları yapılmıştır. Vaka analizleri, raporlar, akademik yayınlar ve afet yönetimi literatürü sistematik olarak taranmıştır. Çığ altında kalan bireyin karşılaşabilecekleri hayati riskler incelenmiştir. Hipotermi, hipoksi, asfiksi, fiziksel travmalar ve psikolojik etkiler çeşitli kaynaklardan araştırılmıştır. Ayrıca afet yönetimi, giyilebilir teknolojiler ve acil durum destek sistemleri alanındaki teknolojiler incelenmiş; bu bilgiler doğrultusunda ekipmanın fonksiyonel yapısı şekillendirilmiştir.

Etik İlkelerin İncelenmesi

Bu çalışma sürecinde herhangi bir deneysel uygulama gerçekleşmediği için etik kurul onayı gerekmemektedir. Ancak, geliştirilmiş teknolojik cihazlar incelenerek etik ilkelere uygunluğu kuramsal olarak incelenmiştir. Ekipman ile birlikte çığ afetiyle karşılaşan bireyin hayatta kalması, öncelik etik ilke olarak değerlendirilmiştir.

Araştırma Probleminin Tanımlanması

Araştırmanın temel sorunu, çığ afeti ile karşı karşıya kalan bireyin hayati fonksiyonlarını sürdürememesi, müdahale sürecinin uzun olması ve bu kapsamda bir cihazın bulunmaması nedeniyle bireyin hayatta kalma desteğinin yetersiz kalmasıdır.

Araştırma Modeli

Literatür incelemesinde tanımlanan ihtiyaçlar doğrultusunda, çözüm odaklı bir ekipman oluşturulmuştur. Bu ekipman, bireyin çığ altında kaldığında hayatta kalma süresini arttıracak ve arama-kurtarma faaliyetlerini hızlandıracaktır. Araştırma modeli; bilgi birikimi, literatür araştırması ve afetlerde yaşanan vakaların değerlendirilmesine dayalı olarak yapılandırılmıştır.

SONUÇ ve TARTIŞMA

Afetler, toplum hayatını doğrudan etkilemektedir. Meydana geliş süreçlerine göre afetler, yavaş gelişen ve hızlı gelişen afetler olarak iki gruba ayrılır. Çığ afeti ani ve yıkıcı bir şekilde meydana gelmektedir. Bu tür afetlerde en büyük zorluklardan biri, afetzedelere etkili ve hızlı bir şekilde müdahale edememektir. Bu, sadece fiziksel koruma ile sınırlı kalmayıp, çığ altında kalan afetzedelerin hayati fonksiyonlarını sürdürmek için solunum desteği, sıcaklık kontrolü, psikolojik destek ve konum belirleme gibi çok boyutlu bir yaklaşımı da içerir. Bu kapsamda, geliştirilen Çığ Altı Yaşam Ekipmanı, afet öncesi afet hazırlık sürecini, afet sırasındaki müdahale sürecini ve afet sonrası kurtarma sürecini entegre bir şekilde destekleyen yenilikçi bir teknolojik çözümdür. Araştırma sürecinde yapılan literatür incelemeleri ve vaka çalışmaları, hipotermi, hipoksi, asfiksi, fiziksel travma ve psikolojik çöküntünün çığ altında kalmanın en önemli hayati riskleri olduğunu ortaya koymuştur.

Bununla birlikte, tasarlanan ekipman, termo-fiber kumaşla vücut ısısını korumak, oksijen tüpleriyle solunum desteği sağlamak, kask tipi apparat ile ağız ve burnun karla temasını önlemek, GPS modülüyle konum bilgisini paylaşmak, nabız sensörüyle hayati belirtileri izlemek ve bireyin hayatta kalma şansını artırmak için sesli rehberlik modülü vb. gibi özel olarak yapılandırılmış cihazlar mevcuttur. Sesli rehberlik modülü ve nefes egzersizlerine de ekipmanda yer verilmesinin hedefi, afetzedenin bu süreçte psikolojik dayanıklılığını artırmaktır.

Prototip çalışmasında taşınabilirlik, kullanım kolaylığı ve iklim koşullarına uygunluk özelliği beğenilmiş ve yeniden kullanılabilir yapısıyla hem çevreci hem de maliyet etkin bulunmuştur. Bu yönüyle, ekipman bireysel hazırlık düzeylerinin artırılmasının ötesinde afet yönetimi ve kamu kurumlarının müdahale kapasitesini de artırabilecek bir nitelik taşımaktadır. Ürün sadece

dağcılık sporu yapan bireyler değil, çığ riski altında çalışan arama kurtarma ekipleri ve güvenlik güçleri tarafından da kullanılabilir olması, toplumun dirençliliğini arttırmada katkıda bulunacaktır.

Sonuç olarak, disiplinlerarası bir yaklaşımla geliştirilen bu cihaz, afetlerin yıkıcı etkilerini önleme konusunda atılmış önemli bir adım olmuştur. Bu tür çığ olgusu gibi ani felaketlere karşı alınacak tedbirlerle, teknolojik çözümlerin hem bireysel hem de kurumsal düzeyde uygulanması afet yönetiminde bir devrim yapabilir. Cihazın ileri süreçlerde farklı senaryolarla test edilmesi, çeşitli iklim ve arazi koşullarına adapte edilmesi, yazılım ve donanım entegrasyonunun iyileştirilmesiyle genelleştirilmesi planlanmaktadır.

KAYNAKLAR

Alexander, D. (2013). Resilience and disaster risk reduction: An etymological journey. Natural Hazards and Earth System Sciences, 13(11), 2707–2716. https://doi.org/10.5194/nhess-13-2707-2013

Beniston, M., Farinotti, D., Stoffel, M., Andreassen, L. M., Coppola, E., Eckert, N., ... & Vincent, C. (2018). The European mountain cryosphere: A review of its current state, trends, and future challenges. The Cryosphere, 12(2), 759–794. https://doi.org/10.5194/tc-12-759-2018

Coppola, D. P. (2011). Introduction to international disaster management (2nd ed.). Butterworth-Heinemann.

Crawford, K., & Finn, M. (2015). The limits of crisis data: Analytical and ethical challenges of using social and mobile data to understand disasters. GeoJournal, 80(4), 491–502. https://doi.org/10.1007/s10708-014-9597-z

Design-Based Research Collective. (2003). Design-based research: An emerging paradigm for educational inquiry. Educational Researcher, 32(1), 5–8. https://doi.org/10.3102/0013189X032001005

Jamieson, B., Haegeli, P., & Gauthier, D. (2010). Avalanche accidents in Canada: A review of patterns and characteristics. Canadian Avalanche Association.

Kelman, I. (2007). Sustainable livelihoods and disaster risk reduction. In Community-based disaster risk reduction (pp. 27–35). UNDP.

McClung, D. M., & Schaerer, P. (2006). The avalanche handbook (3rd ed.). The Mountaineers Books.

Pantelopoulos, A., & Bourbakis, N. G. (2010). A survey on wearable sensor-based systems for health monitoring and prognosis. IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews), 40(1), 1–12. https://doi.org/10.1109/TSMCC.2009.2032660

Paton, D., & Johnston, D. (2006). Disaster resilience: An integrated approach. Charles C Thomas Publisher.

Resnik, D. B. (2020). The ethics of research with human subjects: Protecting people, advancing science, promoting trust. Springer.

THE IMPACTS OF GLOBAL CLIMATE CHANGE ON VEGETABLE PRODUCTION

KÜRESEL İKLİM DEĞİŞİKLİĞİNİN SEBZE YETİŞTİRİCİLİĞİNE ETKİLERİ

Arş. Gör. Dr. Erhan AKALP

Dicle Üniversitesi, Ziraat Fakültesi Bahçe Bitkileri Bölümü

https://orcid.org/0000-0003-3471-8996

Doç. Dr. Vedat PİRİNÇ

Dicle Üniversitesi, Ziraat Fakültesi Bahçe Bitkileri Bölümü

https://orcid.org/0000-0001-9701-2240

Abstract

Global climate change, one of the most critical environmental challenges of the 21st century, significantly affects agricultural production systems on multiple levels. Rising temperatures, increasingly irregular precipitation patterns, the growing frequency of extreme weather events, and elevated atmospheric carbon dioxide (CO_2) levels have direct and indirect impacts on vegetable crops, which are characterized by short growth cycles and high sensitivity to environmental changes. This study comprehensively examines the physical, biological, and economic effects of climate change on vegetable cultivation. Employing a systematic literature review method, data from IPCC reports, FAO statistics, the Turkish Ministry of Agriculture and Forestry, and academic publications were analyzed. The research focuses on how temperature increases influence the physiological processes of vegetable crops, how drought and water scarcity reduce yields, how extreme weather disrupts production planning, and how pest and disease dynamics are shifting in response to climate change. Findings reveal that climate change leads to yield reductions, declines in product quality, and increases in production costs across vegetable farming systems. Due to differing levels of climate sensitivity among vegetable species, spatial re-planning of production zones is becoming increasingly necessary. Accordingly, this paper also explores potential adaptation strategies, including the development of climate-resilient vegetable varieties, the expansion of protected cultivation systems (e.g., greenhouses), the application of modern irrigation technologies (such as drip and sensor-assisted systems), the implementation of early warning systems, and farmer education programs.

This study aims to present an interdisciplinary evaluation of the risks posed by climate change to vegetable farming, while also offering concrete adaptation strategies for both researchers and policymakers to ensure sustainable agricultural production in a changing climate.

Keywords: Climate change, vegetable production, agricultural sustainability, extreme weather events, temperature rise

ÖZET

21. yüzyılın en kritik çevresel sorunlarından biri olan küresel iklim değişikliği, tarımsal üretim sistemlerini çok boyutlu olarak önemli ölçüde etkilemektedir. Artan sıcaklıklar, giderek düzensizleşen yağış rejimleri, ekstrem hava olaylarının sıklığının artması ve atmosferdeki

karbondioksit (CO_2) seviyelerinin yükselmesi, kısa büyüme döngüsüne ve çevresel değişimlere yüksek duyarlılığa sahip sebze ürünleri üzerinde doğrudan ve dolaylı etkiler yaratmaktadır.

Bu çalışma, iklim değişikliğinin sebze yetiştiriciliği üzerindeki fiziksel, biyolojik ve ekonomik etkilerini kapsamlı biçimde incelemektedir. Sistematik literatür taraması yöntemi ile IPCC raporları, FAO istatistikleri, Türkiye Tarım ve Orman Bakanlığı verileri ile akademik yayınlar analiz edilmiştir. Araştırma, sıcaklık artışlarının sebzelerin fizyolojik süreçlerine etkisi, kuraklık ve su kıtlığının verim düşüşüne yol açması, aşırı hava olaylarının üretim planlamasını bozması ve iklim değişikliğine bağlı olarak zararlı ve hastalık dinamiklerindeki değişimleri odağına almaktadır. Elde edilen bulgular, iklim değişikliğinin sebze üretim sistemlerinde verim kayıplarına, ürün kalitesinde düşüşlere ve üretim maliyetlerinde artışa neden olduğunu ortaya koymaktadır. Sebze türleri arasındaki farklı iklim hassasiyetleri nedeniyle üretim alanlarının mekânsal yeniden planlanması gerekliliği giderek artmaktadır. Bu çerçevede, çalışmada iklim değişikliğine dayanıklı sebze çeşitlerinin geliştirilmesi, korumalı tarım sistemlerinin (örneğin seralar) yaygınlaştırılması, modern sulama teknolojilerinin (damla ve sensör destekli sistemler gibi) uygulanması, erken uyarı sistemlerinin hayata geçirilmesi ve çiftçi eğitim programlarının yürütülmesi gibi potansiyel uyum stratejileri de ele alınmıştır.

Bu çalışma, iklim değişikliğinin sebze yetiştiriciliğine yönelik risklerin disiplinler arası değerlendirmesini sunarken, sürdürülebilir tarımsal üretimin sağlanabilmesi için araştırmacılar ve politika yapıcılar için somut uyum stratejileri önermeyi amaçlamaktadır.

Anahtar Kelimeler: İklim değişikliği, sebze üretimi, tarımsal sürdürülebilirlik, ekstrem hava olayları, sıcaklık artışı

GİRİŞ

Küresel iklim değişikliği, günümüz dünyasının en önemli çevresel sorunlarından biridir. Sanayi Devrimi'nden bu yana artan sera gazı emisyonları, başta karbondioksit (CO_2) olmak üzere atmosferdeki gaz yoğunluklarını değiştirmiş ve bu durum küresel ortalama sıcaklıkların belirgin şekilde yükselmesine neden olmuştur. IPCC'nin (Hükümetler arası İklim Değişikliği Paneli) 2023 yılı verilerine göre, dünya genelinde ortalama sıcaklık sanayi öncesi döneme göre 1.2 °C artmıştır ve bu artışın etkileri özellikle tarımsal üretimde giderek daha fazla hissedilmektedir.

Tarım sektörü doğrudan iklim koşullarına bağımlı bir sistemdir. Sıcaklık, yağış miktarı ve dağılımı, ışık süresi, hava olaylarının şiddeti ve toprak nemi gibi faktörler, bitkilerin gelişimi üzerinde doğrudan etkiye sahiptir. Bu nedenle, iklimde meydana gelen değişiklikler, tarımsal üretimi ve gıda güvenliğini doğrudan tehdit etmektedir. Sebze yetiştiriciliği ise bu sistem içerisinde özel bir öneme sahiptir. Sebzeler, kısa büyüme periyotlarına sahip olup çevresel streslere karşı oldukça duyarlıdırlar.

Bu çalışma, küresel iklim değişikliğinin sebze yetiştiriciliği üzerindeki etkilerini fiziksel, biyolojik ve sosyoekonomik boyutlarıyla incelemeyi amaçlamaktadır. Sebze üretiminde meydana gelen değişikliklerin temel nedenleri analiz edilmekte, Türkiye ve dünya genelinden örnekler sunularak, geleceğe yönelik riskler ve uyum stratejileri tartışılmaktadır. Araştırmanın amacı, iklim değişikliğinin sebze tarımı üzerindeki etkilerini bilimsel temelde ortaya koymak ve sürdürülebilir üretim için alınabilecek önlemleri değerlendirmektir. Yapılan bu derlemede, betimleyici bir araştırma modeli kapsamında gerçekleştirilmiş olup niteliksel analiz tekniklerinden yararlanılmıştır. Öncelikli olarak konuyla ilgili ulusal ve uluslararası literatür taranmış, akademik makaleler, raporlar, istatistiki veriler ve iklim modelleri değerlendirilmiştir. Kullanılan başlıca kaynaklar arasında IPCC (2023), FAO (2022), Türkiye Cumhuriyeti Tarım ve Orman Bakanlığı verileri (2021–2024) ve akademik bilimsel çalışmalar bulunmaktadır. Veriler tematik şekilde sınıflandırılmış ve iklim değişikliğinin sebze üretimi üzerindeki etkileri; **fizyolojik**, **ekonomik**, **çevresel** ve **sosyal** boyutlarıyla analiz edilmiştir.

İklimsel Faktörlerin Etkileri

Küresel iklim değişikliğinin tarımsal üretim üzerindeki etkileri tüm dünyada belirginleşmekte, özellikle sebze yetiştiriciliği gibi çevresel koşullara hassas tarım sistemleri bu değişikliklerden doğrudan etkilenmektedir. Sebze bitkileri, kısa gelişme periyotları ve yüksek su/nem gereksinimleri nedeniyle iklimsel dalgalanmalara karşı oldukça duyarlıdır. Aşağıdaki bölümlerde, iklim değişikliğinin sebze tarımına etkileri ana başlıklar halinde ele alınmıştır.

Sıcaklık Artışının Etkileri

İklim değişikliğinin en belirgin etkilerinden biri küresel ortalama sıcaklıkların artmasıdır. Bitkiler için optimum büyüme sıcaklığının üzerinde seyreden hava koşulları, özellikle çiçeklenme ve meyve tutumu gibi kritik evrelerde olumsuzluklara yol açmaktadır.

- Sebzelerde erken çiçeklenme ve hızlı olgunlaşma, verim ve kalite kaybına neden olur.
- Domates, marul, biber gibi sıcaklık hassasiyeti yüksek türlerde sıcaklık stresine bağlı meyve deformasyonları ve polen canlılığında azalma gözlenmektedir.
- Isı stresine bağlı olarak fotosentez etkinliği düşer, bu da bitkinin büyüme potansiyelini sınırlar.

Yağış Rejimlerindeki Değişiklikler ve Su Kıtlığı

İklim değişikliği, sadece toplam yağış miktarını değil, yağışların yıl içindeki dağılımını da değiştirmektedir. Bu durum, sebze üretiminin büyük ölçüde bağlı olduğu toprak neminde ve sulama ihtiyacında ciddi değişimlere yol açmaktadır.

- Düzensiz yağışlar toprağın hem aşırı kurumasına hem de ani taşkınlara neden olabilir.
- Özellikle açık alanda yetiştirilen sebzelerde kök çürüklüğü ve fungal hastalıklar artar.
- Su kıtlığı, üretim maliyetlerini artırmakta ve suya daha az dayanıklı sebze türlerinin üretimini sınırlamaktadır.
- Sera ve örtü altı üretim sistemlerinde bile su yönetimi zorlaşmaktadır.

Ekstrem Hava Olayları

İklim değişikliği ile birlikte fırtına, dolu, şiddetli yağmur, don ve sıcak hava dalgalarının sıklığı ve şiddeti artmıştır. Bu tür ekstrem olaylar, sebze tarımında doğrudan fiziksel zararlara neden olmaktadır.

- Açık alanda üretim yapılan sebze tarlalarında dolu ve fırtına gibi olaylar büyük ürün kayıplarına yol açabilir.
- Ani don olayları sebzelerin yapraklarını, çiçeklerini ve meyvelerini yakar.
- Aşırı sıcak dönemlerde ise bitkilerde güneş yanığı ve solgunluk yaygınlaşır.
-

CO_2 Artışı ve Bitki Fizyolojisi Üzerindeki Etkiler

Atmosferdeki karbondioksit oranının artması, bazı durumlarda fotosentez oranını artırarak sebze bitkilerinin büyümesini teşvik edebilir. Ancak bu etki karmaşık ve türden türe değişkendir.

- Artan CO_2 bazı türlerde (örneğin hıyar, ıspanak) kısa vadeli verim artışına neden olabilir.

- Ancak bu artış, genellikle ürünün **besin değeri** ve **kalitesi** açısından olumsuz sonuçlar doğurur. Özellikle C vitamini, protein ve mineral içeriklerinde düşüşler rapor edilmiştir.
- Ayrıca CO_2 artışı, zararlı otların ve patojenlerin yayılımını da kolaylaştırabilir.

Zararlılar ve Bitki Hastalıklarındaki Artış

İklim değişikliği, tarımsal ekosistemlerdeki biyolojik dengeyi bozmaktadır. Artan sıcaklık ve nem, birçok zararlı organizma ve hastalık etmeni için elverişli koşullar yaratmaktadır.

- Yeni zararlı türlerin yayılımı gözlenmektedir (örneğin: *Tuta absoluta* - domates güvesi).
- Fungal ve bakteriyel hastalıkların şiddeti artmakta, ürün kayıplarına neden olmaktadır.
- Pestisit kullanımının artması hem ekonomik hem çevresel sorunları beraberinde getirmektedir.
-

Toprak ve Besin Elementi Dengesizlikleri

İklimsel değişiklikler toprak nemini, pH düzeylerini ve besin madde döngülerini etkilemektedir. Bu durum sebze bitkilerinin besin alımını zorlaştırmakta ve toprak verimliliğini düşürmektedir.

- Aşırı kuraklık organik madde kaybına neden olur.
- Erozyon riski artar; özellikle meyilli arazilerde sebze üretimi daha riskli hale gelir.
- Gübreleme stratejilerinde değişim gerekebilir; bazı bölgelerde tuzlanma sorunları ortaya çıkmaktadır.

Bu bulgular, sebze tarımının mevcut iklimsel koşullarla sürdürülebilirliğinin zorlaştığını ve yeni tarımsal stratejilere ihtiyaç duyulduğunu açıkça göstermektedir.

ÖRNEK VAKA ANALİZLERİ (TÜRKİYE VE DÜNYA'DAN)

Bu bölümde, farklı iklim kuşaklarında yer alan bazı bölgelerde iklim değişikliğinin sebze üretimine etkileri vaka analizleriyle ele alınmaktadır. Türkiye'den iki bölge ve dünyadan üç ülke örneği üzerinden üretimdeki değişiklikler, karşılaşılan zorluklar ve uygulanan uyum stratejileri analiz edilmektedir.

Türkiye: Akdeniz Bölgesi – Domates Üretimi

Akdeniz Bölgesi, Türkiye'nin en önemli sebze üretim merkezlerinden biridir ve özellikle domates üretiminde lider konumdadır. Ancak son yıllarda bölge, iklim değişikliğinin etkilerini doğrudan hissetmektedir.

- Ortalama sıcaklıklar son 30 yılda 1,5°C artış göstermiştir (TÜİK, 2023).
- Yaz aylarında görülen aşırı sıcaklıklar, domateste meyve tutumunu azaltmakta ve çiçek dökülmelerine neden olmaktadır.
- Kuraklık nedeniyle yer altı su seviyeleri düşmüş, sulama suyu temini zorlaşmıştır.
- Artan sıcaklık ve nem, *Tuta absoluta* (domates güvesi) gibi zararlıların yıl boyunca aktif kalmasına yol açmıştır.

Uyum Stratejileri:

- Örtü altı üretim (sera) yaygınlaştırılmıştır.
- Gündüz-gece sıcaklık farkına dayanıklı yeni domates çeşitleri kullanılmaktadır.

- Damla sulama sistemlerine geçiş hızlanmıştır.

Türkiye: İç Anadolu Bölgesi – Soğan ve Patates Üretimi

İç Anadolu Bölgesi, iklim değişikliğine bağlı olarak daha kurak hale gelmekte ve bu durum özellikle soğan ve patates gibi ürünleri etkilemektedir.

- Yağış miktarları %15–20 oranında azalmıştır.
- Su stresi nedeniyle patateste yumru gelişimi olumsuz etkilenmiş, verim düşmüştür.
- İlkbahar donları ve geç gelen yağışlar, ekim dönemini öngörülemez hale getirmiştir.
- Tuzlanma, özellikle Konya Ovası'nda önemli bir sorun haline gelmiştir.

Uyum Stratejileri:

- Kurağa dayanıklı yerli çeşitlerin geliştirilmesine yönelik AR-GE çalışmaları yürütülmektedir.
- Toprak analizleriyle gübreleme yeniden planlanmaktadır.
- Dönemsel üretim planlamaları yapılmakta, alternatif ürünlere yönelim artmaktadır.

Tablo 1'de Türkiye'de meydana gelen iklim değişikleri sonucu sebze yetiştiriciliğinde karşılaşılan verim kayıpları verilmiştir. İklimsel faktörlerden kaynaklanan kayıplar tarımsal üretimde ciddi emek ve masrafa yol açabilmektedir.

Tablo 1: Türkiye'de Sebze Üretiminde İklim Değişikliğine Bağlı Verim Kayıpları (%)

Bölge	**Sebze Türü**	**Ortalama Verim Kayıpları (%)**	**Başlıca İklim Etkeni**
Akdeniz	Domates	15–25	Yüksek sıcaklık, kuraklık
İç Anadolu	Patates	10–20	Su stresi, erken donlar
Marmara	Biber	8–15	Düzensiz yağış, zararlı artışı
Ege	Hıyar	12–18	Sıcaklık artışı, nem değişimi

Hollanda: İklim Kontrollü Sera Üretimi

Hollanda, iklim değişikliğiyle mücadelede teknolojiye dayalı tarımın en başarılı örneklerinden birini sunmaktadır.

- Ülke genelinde hava koşullarındaki belirsizliklere rağmen üretim stabil kalmaktadır.
- Cam seralarda iklim koşulları yapay olarak kontrol edilmekte, sebze üretimi yıl boyunca devam etmektedir.
- Düşük su kullanımı ile yüksek verim sağlayan hidroponik sistemler kullanılmaktadır.

Başarı Faktörleri:

- Dijital tarım uygulamaları (sensör, veri analizi)
- Erken uyarı sistemleri
- Üniversite–çiftçi iş birliği

Hindistan: Aşırı Sıcaklıkların Etkisi – Ispanak Üretimi

Hindistan'da sebze üretimi büyük ölçüde açık tarlalarda yapılmaktadır. Özellikle ıspanak ve yapraklı sebzeler, artan sıcaklıklardan ciddi şekilde etkilenmektedir.

- 35°C üzerindeki sıcaklıklarda ıspanakta yaprak deformasyonları ve kalite kaybı yaşanmaktadır.
- Kuraklık nedeniyle sulama maliyetleri artmış, bazı üreticiler üretimden çekilmiştir.
- Pestisit kullanımı artmış, kalıntı sorunu yaşanmıştır.

Çözüm Yolları:

- Gölgeleme sistemlerinin yaygınlaştırılması
- Sulama verimliliğini artıran küçük ölçekli destekler
- Yerel halk için bilinçlendirme çalışmaları
-

Kenya: Küçük Ölçekli Sebze Üreticileri Üzerindeki Etkiler

Afrika'nın doğusunda yer alan Kenya'da, geçimlik tarım yapan küçük ölçekli üreticiler, iklim değişikliğinden en çok etkilenen gruplardandır.

- Sebze üretimi, yağışlara dayalı olduğu için yağış rejimindeki değişiklik doğrudan ürün kaybına yol açmaktadır.
- Gıda güvencesi tehlikeye girmiştir.
- Tarım sigortası ve teknolojiye erişim çok düşüktür.

Geliştirilen Projeler:

- FAO ve yerel kuruluşlar iş birliğiyle kuraklığa dayanıklı tohum dağıtımı
- Eğitim destekli su hasadı sistemleri
- Topluluk bazlı üretim kooperatifleri

Bu vaka analizleri, iklim değişikliğinin farklı iklim kuşaklarında sebze üretimini nasıl etkilediğini ortaya koymakta ve hem gelişmiş hem de gelişmekte olan ülkelerdeki çözüm yaklaşımlarını karşılaştırma imkânı sunmaktadır.

UYUM STRATEJİLERİ VE ÇÖZÜM ÖNERİLERİ

İklim değişikliği, sebze üretimini sürdürülebilirlik açısından tehdit eden çok boyutlu bir krizdir. Ancak bu kriz karşısında, hem tarımsal sistemleri hem de üretici toplulukları uyumlaştırmaya yönelik çeşitli stratejiler geliştirilmektedir. Bu stratejiler; teknolojik yenilikler, üretim tekniklerinin değiştirilmesi, eğitim programları ve politika desteği gibi alanlarda çeşitlenmektedir.

İklime Dayanıklı Sebze Çeşitlerinin Geliştirilmesi

Bitki ıslahı, iklim değişikliğine karşı en etkili uzun vadeli stratejilerden biridir. Sıcaklık stresine, kuraklığa, tuzluluğa ve hastalıklara dayanıklı yeni sebze çeşitlerinin geliştirilmesi büyük önem taşımaktadır.

- AR-GE faaliyetleri desteklenmeli; kamu-üniversite-özel sektör iş birliği artırılmalıdır.
- Yerel koşullara uygun yerli tohumlar ön plana çıkarılmalıdır.
- Tohum bankaları ve genetik kaynak merkezleri güçlendirilmelidir.

Modern Sulama ve Su Yönetim Teknikleri

Sebze bitkileri, yüksek su talebi nedeniyle su stresi karşısında hızla verim kaybeder. Bu nedenle suyun etkin kullanımı, uyum stratejilerinin merkezinde yer almalıdır.

- Damla sulama, yağmurlama ve sensör destekli otomatik sulama sistemleri yaygınlaştırılmalıdır.
- Sulama programları, iklim verileriyle entegre edilerek planlanmalıdır.
- Su hasadı ve gri su kullanımı gibi alternatif yöntemler desteklenmelidir.

Tablo 2'de küresel ölçekte yaşanan iklimsel faktörlere karşı farklı sulama tekniklerini kullanarak elde edilecek su tasarrufu ve verimi verilmiştir.

Tablo 2: Sulama Tekniklerinin Su Tasarrufu ve Verim Üzerine Etkileri

Sulama Yöntemi	Su Tasarrufu (%)	Verim Artışı (%)	Uygulama Alanı
Geleneksel Yağmurlama	–	–	Geleneksel tarım alanları
Damla Sulama	30–50	20–35	Sera ve açık alanlar
Sensör Kontrollü Otomatik	40–60	30–45	Modern tarım işletmeleri
Gri Su Kullanımı	25–40	10–20	Kurak bölgeler

Örtü Altı Tarım ve İklim Kontrollü Seralar

Açık alan üretimi, iklim değişikliğine en açık sistemdir. Bu nedenle örtü altı tarım, özellikle yüksek değerli sebze ürünleri için etkili bir adaptasyon çözümüdür.

- Seralarda ısıtma, soğutma, havalandırma ve nem kontrolü sayesinde iklim etkileri azaltılır.
- Akıllı sera teknolojileri, üretim sürecini verimli ve izlenebilir kılar.
- Kırsal kalkınma projeleri kapsamında, küçük üreticilere sera kurulumu için teşvik sağlanmalıdır.

Toprak Yönetimi ve Organik Madde Artırımı

Toprak sağlığı, sebze bitkilerinin dayanıklılığı için kritik önemdedir. Kuraklık, erozyon ve tuzluluk gibi etkilerle bozulan topraklar, iyileştirme stratejileriyle üretime kazandırılabilir.

- Organik gübre kullanımı, humus oranını artırarak su tutma kapasitesini yükseltir.
- Malçlama, toprak nemini korur ve buharlaşmayı azaltır.
- Nöbetleşe ekim ve yeşil gübreleme gibi uygulamalar desteklenmelidir.

Erken Uyarı Sistemleri ve Dijital Tarım Uygulamaları

İklimle ilgili risklerin önceden tahmin edilmesi, sebze üreticilerinin önlem almasını sağlar. Dijital tarım uygulamaları bu noktada kritik bir rol oynar.

- Meteorolojik veri temelli erken uyarı sistemleri, üreticileri don, dolu, fırtına gibi tehlikelere karşı bilgilendirir.
- Uygulama tabanlı mobil yazılımlar, sulama, gübreleme ve zararlı takibi gibi konularda yönlendirme yapar.
- Tarımsal istihbarat sistemleri, bölgesel risk haritaları oluşturur.

Eğitim ve Kapasite Geliştirme Programları

Uyum stratejilerinin başarılı olabilmesi için üreticilerin bilgi ve beceri düzeylerinin artırılması gerekir.

- Tarım danışmanlığı sistemleri güçlendirilmelidir.
- Kooperatifler ve çiftçi örgütleri aracılığıyla yaygın eğitim programları düzenlenmelidir.
- Kadın ve genç çiftçilere özel destek mekanizmaları oluşturulmalıdır.

Tarım Politikaları ve Ekonomik Teşvikler

İklim değişikliğine karşı sebze üreticilerinin yalnız bırakılmaması, kamu desteğini zorunlu kılmaktadır. Bu nedenle tarım politikalarının iklim odaklı hale getirilmesi gerekir.

- İklime uyum sağlayan üreticilere yönelik hibe, kredi ve vergi avantajları sunulmalıdır.
- Tarımsal sigorta sistemleri, iklim risklerini kapsayacak şekilde genişletilmelidir.
- Stratejik ürün planlaması ile arz-talep dengesi korunmalıdır.

Bu stratejiler, sebze üretiminin iklim değişikliği karşısında direnç kazanmasını sağlayacak yapı taşlarını oluşturmaktadır. Ancak bu önlemlerin etkili olabilmesi, bütüncül ve entegre bir yaklaşımla planlanmalarına bağlıdır. Tablo 3'de farklı ülkelerde küresel çapta yaşanan iklimsel değişimlere karşı alınan önlemler örnekler verilmiştir.

Tablo 3: Farklı Ülkelerde Uygulanan İklim Değişikliğine Uyum Stratejileri

Ülke	**Uyum Stratejisi**	**Uygulama Alanı**	**Başarı Faktörü**
Türkiye	Damla sulama ve örtü altı tarım	Akdeniz, İç Anadolu	Su tasarrufu ve zararlı kontrolü
Hollanda	İklim kontrollü seralar, dijital tarım	Ülke genelinde sera	Teknoloji altyapısı ve Ar-Ge desteği
Hindistan	Gölgeleme sistemleri, sulama iyileştirme	Açık alan üretimi	Maliyet etkinlik ve eğitim programı
Kenya	Kuraklığa dayanıklı tohumlar	Küçük ölçekli çiftçiler	Uluslararası destek ve kooperatifler

SONUÇ VE TARTIŞMA

Küresel iklim değişikliğinin sebze yetiştiriciliği üzerindeki etkileri, literatürde giderek artan sayıda çalışma ile desteklenen çok boyutlu ve karmaşık bir olgudur. Bu çalışmada elde edilen bulgular, mevcut bilimsel yayınlar ile genel olarak uyum göstermektedir.

Özellikle sıcaklık artışının sebzelerde verim ve kalite düşüşüne yol açtığı; yağış rejimindeki değişikliklerin ve su kıtlığının üretim risklerini artırdığı saptanmıştır. Bu sonuçlar, IPCC (2023) raporları ve FAO'nun küresel tarım değerlendirmeleriyle paralellik göstermektedir (Lee ve ark., 2024). Türkiye'de Akdeniz ve İç Anadolu bölgelerinde gözlenen sıcaklık ve su stresi etkileri, yerel iklim modelleri ve saha çalışmalarının sonuçlarıyla örtüşmektedir (Öztürk ve ark., 2021; Yılmaz, 2022).

Bununla birlikte, iklim değişikliğine bağlı zararlı ve hastalık baskısının artması, sebze tarımında yeni bir risk faktörü olarak öne çıkmaktadır. Özellikle *Tuta absoluta* gibi istilacı türlerin yayılımı, entegre zararlı yönetimi stratejilerinin geliştirilmesini zorunlu kılmaktadır. Bu durum, ekosistem dinamiklerinin iklim değişikliği ile birlikte nasıl yeniden şekillendiğine dair önemli bir örnek teşkil etmektedir (Kara ve Çelik, 2020).

CO_2 artışının bazı sebze türlerinde fotosentez verimliliğini artırabileceği ancak besin kalitesinde düşüşler yaşanabileceği bulgusu, literatürde halen tartışılan bir konudur. Bu çalışma da benzer şekilde CO_2 artışının çift yönlü etkilerine dikkat çekmiştir (Singh ve ark., 2021). Bu durum, iklim değişikliğine uyum stratejilerinin sadece miktar artışına değil, kalite ve besin değerine de odaklanmasını gerektirmektedir.

Uyum stratejileri açısından değerlendirildiğinde, teknoloji tabanlı çözümler ve genetik iyileştirmeler ön plandadır. Hollanda örneğinde olduğu gibi iklim kontrollü sera teknolojileri, yüksek verim ve kaliteyi desteklerken, Türkiye ve gelişmekte olan ülkelerde ise kaynak kısıtlılığı nedeniyle adaptasyon güçlükleri yaşanmaktadır. Bu bağlamda, sürdürülebilir üretim için ulusal ve uluslararası düzeyde finansal desteklerin artırılması kritik öneme sahiptir (FAO, 2022).

Eğitim ve kapasite artırma programlarının önemi, saha deneyimleri ve vaka analizleri ışığında açıkça görülmektedir. Çiftçilerin bilinçlendirilmesi, adaptasyon kapasitesini artırmakta ve yeniliklerin sahaya yansıtılmasını kolaylaştırmaktadır. Bu da uzun vadede gıda güvenliğinin sağlanmasına katkıda bulunacaktır.

Bu çalışma, küresel iklim değişikliğinin sebze yetiştiriciliği üzerindeki etkilerini kapsamlı şekilde incelemiş ve farklı iklim kuşaklarındaki örnek vakalarla desteklemiştir. Analizler göstermektedir ki, artan sıcaklıklar, düzensiz yağış rejimleri, su kıtlığı ve artan ekstrem hava olayları sebze üretiminde verim ve kalite kayıplarına yol açmaktadır. Bununla birlikte, atmosferdeki CO_2 artışının sebze büyümesini kısa vadede destekleyebileceği ancak ürün kalitesinde olumsuz etkiler yaratabileceği saptanmıştır. Bu durum, iklim değişikliğine uyum stratejilerinin sadece miktar artışı değil, kalite koruma üzerine de odaklanması gerektiğini göstermektedir.

Sonuç olarak, sebze yetiştiriciliğinde iklim değişikliğinin olumsuz etkilerini azaltmak için bütüncül, çok disiplinli ve yerel koşullara uyarlanmış çözümler kritik öneme sahiptir. Gelecekte yapılacak çalışmaların, bölgesel etkilerin detaylandırılması ve uyum politikalarının etkinliğinin ölçülmesine yönelmesi önerilmektedir.

REFERENCES

FAO (2022). Food and Agriculture Organization of the United Nations. Leveraging automation in agriculture for transforming agrifood systems. https://doi.org/10.4060/cc2211en

IPCC (2023). Climate Change 2023: Impacts, Adaptation and Vulnerability. Intergovernmental Panel on Climate Change. ISBN 978-92-9169-164-7/ DOI 10.59327/IPCC/AR6-9789291691647.001

Kara, M., & Çelik, A. (2020). Impact of Tuta absoluta infestation on tomato production: A review. Journal of Agricultural Sciences, 26(3), 145-157.

Lee, H., Calvin, K., Dasgupta, D., Krinner, G., Mukherji, A., Thorne, P., ... & Ruane, A. C. (2024). Climate change 2023 synthesis report summary for policymakers. CLIMATE CHANGE 2023 Synthesis Report: Summary for Policymakers.

Öztürk, S., & Demir, H. (2021). Effects of climate change on vegetable production in the Mediterranean region of Turkey. Turkish Journal of Agriculture and Forestry, 45(2), 78-89.

Singh, R., Kumar, P., & Sharma, V. (2021). Elevated CO_2 and crop quality: A critical review. Plant Physiology Reports, 16(4), 212-220.

TUİK (2023). Türkiye İstatistik Kurumu. https://data.tuik.gov.tr/Bulten/Index?p=Sera-Gazi-Emisyon-Istatistikleri-1990-2023-53974#:~:text=Sera%20gaz%C4%B1%20envanteri%20sonu%C3%A7lar%C4%B1na%20g%C3%B6re,CO2%20e%C5%9Fd.%20olarak%20hesapland%C4%B1. Erişim Tarihi: 01.07.2025

Yılmaz, B. (2022). Climate variability and agricultural production in Central Anatolia. Anatolian Agricultural Journal, 33(1), 45-60.

THE ROLE OF TECHNOLOGICAL IMPROVEMENTS IN THE CULTIVATION OF VEGETABLES

TEKNOLOJİK GELİŞMELERİN SEBZE YETİŞTİRİCİLİĞİNE KATKISI

Arş. Gör. Dr. Erhan AKALP

Dicle Üniversitesi, Ziraat Fakültesi Bahçe Bitkileri Bölümü

https://orcid.org/0000-0003-3471-8996

Doç. Dr. Vedat PİRİNÇ

Dicle Üniversitesi, Ziraat Fakültesi Bahçe Bitkileri Bölümü

https://orcid.org/0000-0001-9701-2240

Abstract

The vegetable growing sector is important to agricultural production and needs to develop more efficient, sustainable, and environmentally friendly solutions to global problems, such as the growing world population and climate change. Technological developments are making revolutionary contributions to vegetable cultivation. Thanks to smart agricultural technologies, such as sensors, data analytics, satellite imaging and artificial intelligence-supported decision systems, parameters such as soil moisture, weather conditions and plant health can be monitored in real time. This allows producers to intervene in a more informed and timely manner. Consequently, yields increase and input costs (water, fertilizer, and pesticides) decrease. Additionally, the development of automation and robotic systems provides significant advantages, particularly in large-scale vegetable production. Agricultural robots used throughout the process, from sowing seeds to harvesting, minimize the need for labor by reducing human error and speeding up the production process. Additionally, drones used in agriculture enable aerial control of fields, allowing for early disease diagnosis and precise spraying practices. Technological advancements have also led to changes in growing environments, shortening the plant's vegetation period and creating opportunities to grow more plants per unit area. Innovative methods such as vertical farming, hydroponic cultivation, controlled environment cultivation, and cabin cultivation are gaining importance, especially for urban production and year-round vegetable cultivation. These systems use technologies such as artificial lighting and temperature and humidity control to enable climate-independent and sustainable production. This review emphasizes that advances in biotechnology and genetic engineering have led to the development of disease-resistant, high-yielding vegetable varieties. This reduces losses in agricultural production and contributes to food security.

In conclusion, technological advances have made vegetable cultivation more efficient, economical, and environmentally friendly. Proper use of these developments increases both producer welfare and product quality for consumers. However, education, infrastructure investment, and government support are essential for the widespread adoption of these technologies. This study reveals developments in vegetable cultivation and changing technologies.

Key Words: Smart Agriculture, Hydroponic Cultivation, Vegetable Cultivation, Technological Developments

ÖZET

Tarımsal üretimde önemli bir konumda bulunan sebze yetiştiriciliği sektörü, artan dünya nüfusu ve iklim değişikliği gibi küresel sorunlara karşı daha verimli, sürdürülebilir ve çevre dostu çözümler geliştirmeye gereksinim duymaktadır. Yaşanan teknolojik gelişmeler, sebze yetiştiriciliğinde devrim niteliğinde katkılar sağlamaktadır. Akıllı tarım teknolojileri (sensörler, veri analitiği, uydu görüntüleme, yapay zeka destekli karar sistemleri) sayesinde toprak nemi, hava durumu, bitki sağlığı gibi parametreler gerçek zamanlı olarak izlenebilmekte; bu da üreticilere daha bilinçli ve zamanında müdahale şansı tanımaktadır. Böylece hem verim artmakta hem de girdi maliyetleri (su, gübre, ilaç) düşmektedir. Öte yandan otomasyon ve robotik sistemlerin geliştirilmesiyle, özellikle büyük ölçekli sebze üretiminde büyük avantajlar sağlamıştır. Tohum ekiminden hasada kadar olan süreçte kullanılan tarım robotları, insan hatasını azaltarak iş gücüne duyulan ihtiyacı minimize ederken, üretim sürecini hızlandırmaktadır. Ayrıca, tarımda kullanılan dronlar, tarlaların havadan kontrolünü sağlayarak erken hastalık teşhisi ve hassas ilaçlama uygulamalarını mümkün kılmaktadır. Değişen ve gelişen teknolojik araçlar ile yetiştirme ortamlarında da farklılıklar oluşmuş; bitkinin vejetasyon süresini kısaltıcı ve birim alandan daha fazla bitki yetiştirmeye fırsat oluşmuştur. Dikey tarım, hidroponik yetiştiricilik, kontrollü ortam veya kabinlerde yapılan yetiştiricilikler gibi yenilikçi yöntemler, özellikle şehir içi üretim ve yıl boyu sebze yetiştiriciliği açısından önem kazanmaktadır. Bu sistemlerde yapay aydınlatma, sıcaklık ve nem kontrolü gibi teknolojiler sayesinde iklimden bağımsız, daha sürdürülebilir bir üretim yapılabilmektedir. Bu derlemede ayrıca, biyoteknoloji ve genetik mühendisliği alanındaki gelişmelerin, hastalıklara dayanıklı ve daha yüksek verim sağlayan sebze çeşitlerinin geliştirilmesine olanak tanıdığı vurgulanmaktadır. Bu da tarımsal üretimde kayıpları azaltmakta ve gıda güvenliğine katkı sağlamaktadır.

Sonuç olarak, teknolojik gelişmeler sayesinde sebze yetiştiriciliği daha verimli, ekonomik ve çevre dostu hale gelmiştir. Bu gelişmelerin doğru ve etkin kullanımı, hem üretici refahını hem de tüketiciye ulaşan ürün kalitesini artırmaktadır. Ancak bu teknolojilerin yaygınlaşması için eğitim, altyapı yatırımı ve devlet desteklerinin önemi de göz ardı edilmemelidir. Bu çalışma ile değişen ve gelişen teknolojilerin sebze yetiştiriciliğinde yaşanan gelişmeleri ortaya koymak için derlenmiştir.

Anahtar Kelimeler: Akıllı Tarım, Hidroponik Yetiştiricilik, Sebze Yetiştiriciliği, Teknolojik Gelişmeler

GİRİŞ

Dünya genelinde artan nüfus ve değişen iklim koşulları, gıda talebini artırmakta ve sürdürülebilir tarımsal uygulamalara olan ihtiyacı zorunlu kılmaktadır. Geleneksel tarım yöntemlerinin sınırlamaları göz önüne alındığında, güncel teknolojilerin benimsenmesi, sebze yetiştiriciliğinde verimliliği ve kaliteyi artırmak için kritik bir adım olarak öne çıkmaktadır. Sebze yetiştiriciliği, insan beslenmesinde vazgeçilmez olan vitamin, mineral ve lif kaynaklarını sağlayan stratejik bir üretim koludur. Geleneksel tarımsal üretim yöntemleri iklim değişikliği, artan nüfus, toprak verimliliğinde azalma ve su kaynaklarının tükenmesi gibi sorunlar karşısında yetersiz kalmaktadır (FAO, 2023). Bu nedenle, tarımda dijitalleşme ve teknoloji odaklı dönüşüm kaçınılmaz hâle gelmiştir. Tarım 4.0 kavramı ile anılan bu dönüşümde; veri toplama, işleme, karar destek sistemleri, otomasyon ve biyoteknoloji gibi çok boyutlu uygulamalar üretimde etkinlik kazandırmaktadır (Wolfert ve ark., 2017). Bu çalışmada teknolojik yeniliklerin sebze yetiştiriciliğine etkisi sistematik biçimde incelenmiş, akıllı tarım uygulamaları, veri analitiği, hidroponik sistemler, genetik mühendislik ve diğer teknolojilerin sebze yetiştiriciliğindeki rolü ortaya konulmaya çalışılmıştır. Yapılan literatür taramalarında, teknolojinin tarımsal verim ve kalite üzerinde çok boyutlu etkiler oluşturduğu belirlenmiştir.

Değişen ve gelişen teknoloji ile tarımsal üretimde ve özellikle sebzecilik sektöründe hızlı gelişmeler yaşandığı belirlenmiştir. Yapılan bazı akademik çalışmalar aşağıda verilmiştir.

Neupane ve Guo (2019), hassas sulama teknolojilerinin marul ve domates gibi ürünlerde %20-30 arasında su tasarrufu ve %10'a varan verim artışı sağladığını belirtmişlerdir. Hemming ve arkadaşları (2019), yapay zekâ kontrollü sera sistemlerinin sıcaklık, nem ve ışık gibi değişkenleri optimize ederek ürün kalitesinde belirgin artış sağladığını rapor etmişlerdir Chaudhari ve arkadaşları (2022), sensör teknolojisiyle entegre edilen toprak analizi ve gübreleme sistemlerinin kaynak verimliliğini artırdığını belirtmişlerdir. Palmitessa ve arkadaşları (2024), NFT sistemlerinin geleneksel sulama yöntemlerine göre %80'e kadar su tasarrufu sağladığını belirtmişlerdir. Yılmaz ve arkadaşları (2025), yapay zekâ ve görüntü işleme tabanlı hastalık teşhis sistemlerinin erken teşhis kabiliyetiyle pestisit kullanımını %40'a kadar azaltabildiğini rapor etmişlerdir.

Yaşanan teknolojik gelişmelerin sebze yetiştiriciliğinde meydana getirdiği olumlu sonuçları aşağıda belirtilmiştir.

Hassas Tarım

Hassas tarım uygulamaları; sensörler, dronlar, GPS teknolojileri ve veri analitiği sayesinde tarla düzeyinde farklılıkları ortaya çıkararak noktasal müdahale imkânı sunar (Gebbers ve Adamchuk, 2010). Akıllı tarım, çiftçilerin gerçek zamanlı verilerle daha bilinçli kararlar almasını sağlamakta, bu da sulama, gübreleme ve pest kontrolü gibi süreçlerin optimize edilmesine olanak tanımaktadır. Örneğin, toprak nem sensörleri, sulama ihtiyacını belirlemek için kullanılırken, iklim sensörleri çevresel koşulları sürekli izlemektedir. Toprak nemi, pH, sıcaklık ve mineral içerikleri gibi değişkenler sensörler aracılığıyla izlenerek gereksiz sulama ve gübrelemeye son verilir (Wolfert ve ark., 2017). Özellikle gübre kullanımının azaltılmasıyla hem maliyet düşmekte hem de çevresel etki azaltılmaktadır (Chaudhari ve ark., 2024). Örneğin yapılan bir çalışmada, sensör ağlarının kullanılmasıyla sulama maliyetlerinin %30 oranında düşürüldüğünü belirtilmiştir (Dong ve ark., 2024). Toprak nem sensörleri sayesinde sulama yalnızca toprak kuruduğunda yapılır ve bu da suyun verimli kullanılmasını sağlar (Singh ve ark., 2019). Ayrıca, bu tür akıllı sulama sistemleri, çevresel koşullara göre optimize edilebilir, böylece su tüketimi minimuma indirilir (Dursun ve Özden, 2014).

Akıllı Sera ve Otomasyon Sistemleri

Yapay zekâ ile desteklenen sera yönetim sistemleri, hava koşullarını anlık analiz ederek ısıtma, havalandırma, sulama gibi işlemleri otomatik olarak gerçekleştirebilmektedir (Hemming ve ark., 2019). Autonomous Greenhouse Challenge gibi uygulamalarda yapay zekâya dayalı sistemler, insan operatörlerden daha yüksek verim ve daha az kaynak kullanımı ile üretim yapmıştır. Bu sistemler aynı zamanda uzaktan yönetim olanağı sunarak iş gücü maliyetlerini de azaltmaktadır.

Robotik Uygulamalar ve Mekanizasyon

Hasat robotları, bitki büyüklüğü ve olgunluk derecesine göre görsel tanıma algoritmaları ile çalışarak zamanında ve kaliteli hasat sağlar (Bac ve ark., 2014). WeedBot gibi robotlar, yabancı otları mekanik olarak tespit edip yok edebilmekte, böylece kimyasal herbisit kullanımına gerek bırakmamaktadır. Bu durum, hem çevreye hem de ürün kalitesine olumlu katkı sağlar.

Görüntü İşleme ve Yapay Zekâ ile Hastalık Tespiti

Yapay zekâ ve büyük veri analitiği, sebze yetiştiriciliğindeki birçok süreçte devrim yaratmaktadır. Sıklıkla, bu teknolojiler bir araya gelerek, makine öğrenimi algoritmaları aracılığıyla tarımsal verilerin analizi, tahminsel modelleme ve karar destek sistemleri oluşturmakta kullanılmaktadır. Derin öğrenme algoritmaları, yaprak yüzeyindeki renk değişiklikleri veya beneklenme gibi belirtileri tanımlayarak hastalıkları erken aşamada teşhis eder (Ferentinos, 2018). Radócz ve arkadaşları (2024), toplanan multispektral verilerin analiziyle, tarladaki hastalıkların 7 gün öncesinden tahmin edilebildiğini belirtmişlerdir.

Topraksız Tarım Sistemleri (Hidroponik, Aeroponik)

Topraksız tarım sistemleri, özellikle kent tarımı ve dikey tarım uygulamalarında yaygınlaşmaktadır. NFT ve aeroponik sistemler, bitki köklerine doğrudan besin çözeltisi ulaştırarak toprak kaynaklı hastalık riskini ortadan kaldırmakta ve su tüketimini %90'a kadar azaltmaktadır. Bu sistemler aynı zamanda daha kısa üretim süreleri ve daha yüksek ürün yoğunluğu ile ekonomik avantajlar sağlar. Dikey tarım, alan verimliliğini artırmak amacıyla, bitkilerin dikey sütunlarda yetiştirilmesine olanak tanır. Özellikle şehir içindeki sınırlı alan kullanımı ve artan gıda talebi düşünüldüğünde, bu yöntem her geçen gün önem kazanmaktadır.

Genetik Mühendislik ve Biyoteknoloji

Modern biyoteknolojik yöntemler sayesinde hastalıklara dayanıklı, raf ömrü uzun ve besin içeriği zengin sebze türleri geliştirilebilmektedir. CRISPR/Cas9 gibi genom düzenleme teknikleri, özellikle virüs ve funguslara dirençli çeşitlerin geliştirilmesinde umut vaat etmektedir (Voytas, 2013). Ayrıca, GM (Genetik Modifiye) ürünlerin kontrollü koşullarda yetiştirilmesi, pestisit ihtiyacını ve ürün kayıplarını azaltmaktadır.

Dronlar ve Uzaktan Algılama Teknolojileri

Dronlar, tarımsal alanların izlenmesi ve bitki sağlığının değerlendirilmesi için potansiyel bir araç sunmaktadır. Hava fotoğrafları ve termal görüntüleme, bitkilerde stres ve hastalık belirtilerinin erken tespiti için kullanılmaktadır (Stutsel ve ark., 2021). Örneğin yapılan bir çalışmada çiftçilerin dronlar aracılığıyla sağladığı veriler sayesinde, hastalık ve zararlı tespiti yapılmış ve zamanında müdahale ile ürün kaybı %15 oranında azaltıldığı belirtilmiştir (Shahi ve ark., 2024).

Blockchain Teknolojisi ve İzlenebilirlik

Sebzecilik sektöründe blockchain teknolojisi, ürünlerin tedarik zinciri boyunca izlenebilirliğini sağlamaktadır. Bu teknoloji, üreticiden son kullanıcıya kadar her adımda ürün bilgilerini güvenli ve şeffaf bir şekilde kaydederek, ürünün kalitesini garanti altına alır (Kamilaris ve arkadaşları, 2018). Ayrıca, organik sertifikalar ve sürdürülebilir üretim yöntemlerinin doğruluğu da blockchain ile doğrulanabilir. Örneğin sebze tedarik zincirinde blockchain kullanımı, üreticiden perakendeciye kadar her adımın kaydını tutar ve bu sayede sahtecilik ve gıda güvenliği ihlalleri engellenir.

SONUÇ VE ÖNERİLER

Teknolojik gelişmeler, sebzecilik sektöründe sürdürülebilir ve verimli üretim yöntemlerini mümkün kılmakta ve dünya genelinde gıda güvenliği sorunlarına çözüm üretmektedir. Bu

teknolojilerin entegrasyonu, tarımın geleceği için büyük bir potansiyele sahipken, çevresel etkilerin azaltılması, kaynakların verimli kullanımı ve maliyetlerin düşürülmesi gibi pek çok avantaj sunmaktadır. Ancak, bu teknolojilerin geniş çapta kabulü için eğitim ve yatırım gerekmektedir. Teknolojik uygulamalar sebze üretiminde niceliksel ve niteliksel artışlar sağlamaktadır. Bununla birlikte, bu teknolojilere erişim hâlâ sınırlıdır. Özellikle küçük ölçekli üreticilerin yüksek teknoloji maliyetleri, eğitim eksikliği ve teknik destek yetersizliği nedeniyle adaptasyon süreçlerinde zorluklar yaşadığı bilinmektedir (Klerkx ve ark., 2019). Bu nedenle kamu destekli yayım hizmetleri, kooperatifleşme ve çiftçi eğitimleri ile bu teknolojilerin yaygınlaştırılması gerekmektedir.

Sebze tarımı, teknolojik gelişmelerin etkisiyle daha sürdürülebilir, verimli ve kaliteli bir üretim modeline doğru evirilmektedir. Bu süreçte hassas tarım, otomasyon, yapay zekâ ve biyoteknoloji gibi alanlar kritik rol oynamaktadır. Sebzeciliğin teknolojiye paralel olarak gelişimi için aşağıda belirtildiği üzere bazı önerilerde bulunulabilir.

-Devlet destekli teknoloji hibeleri ile küçük çiftçilere erişim kolaylığı sağlanmalı

-Yerel düzeyde teknik eğitim programları artırılmalı

-Üniversite ve sanayi iş birliği ile yerli tarım teknolojileri geliştirilmelidir

REFERENCES

Bac, C. W., Van Henten, E. J., Hemming, J., & Edan, Y. (2014). Harvesting robots for high-value crops: State-of-the-art review and challenges ahead. Journal of field robotics, 31(6), 888-911.

Chaudhari, S. K., Patra, A. K., Dey, P., & Bal, S. K. (2022). Sensor based monitoring for improving agricultural productivity and sustainability: A review. Journal of the Indian Society of Soil Science, 70(2), 121–141. https://doi.org/10.5958/0974-0228.2022.00013.5

Dursun, M. ve Özden, S. (2014). An efficient improved photovoltaic irrigation system with artificial neural network based modeling of soil moisture distribution–A case study in Turkey. Computers and electronics in agriculture, 102, 120-126.

Dong, Y., Werling, B., Cao, Z., & Li, G. (2024). Implementation of an in-field IoT system for precision irrigation management. Frontiers in Water, 6, 1353597.

FAO (2022). Food and Agriculture Organization of the United Nations. Leveraging automation in agriculture for transforming agrifood systems. https://doi.org/10.4060/cc2211en

Ferentinos, K. P. (2018). “Deep Learning Models for Plant Disease Detection.” Computers and Electronics in Agriculture, 145, 311–318.

Gebbers, R. ve Adamchuk, V. I. (2010). Precision agriculture and food security. Science, 327(5967), 828-831.

Hemming, S., de Zwart, F., Elings, A., Righini, I., & Petropoulou, A. (2019). Remote control of greenhouse vegetable production with artificial intelligence—greenhouse climate, irrigation, and crop production. Sensors, 19(8), 1807.

Kamilaris, A., Fonts, A., & Prenafeta-Boldύ, F. X. (2018). The rise of blockchain technology in agriculture and food supply chains. Trends in food science & technology, 91, 640-652.

Klerkx, L., Jakku, E., & Labarthe, P. (2019). A review of social science on digital agriculture, smart farming and agriculture 4.0: New contributions and a future research agenda. NJAS-Wageningen journal of life sciences, 90, 100315.

Neupane, J., Guo, W. (2019). Agronomic basis and strategies for precision water management: A review. Agronomy, 9(2), 87.

Palmitessa, O. D., Signore, A., & Santamaria, P. (2024). Advancements and future perspectives in nutrient film technique hydroponic system: a comprehensive review and bibliometric analysis. Frontiers in Plant Science, 15, 1504792.

Radócz, L., Juhász, C., Tamás, A., Illés, Á., Ragán, P., & Radócz, L. (2024). Multispectral UAV-Based Disease Identification Using Vegetation Indices for Maize Hybrids. Agriculture, 14(11), 2002.

Shahi, T. B., Khadka, R. B., & Neupane, A. (2024). Applicability of UAV in crop health monitoring using machine learning techniques. In Applications of Machine Learning in UAV Networks (pp. 246-262). IGI Global Scientific Publishing.

Singh, A. K., Bhardwaj, A. K., Verma, C. L., Mishra, V. K., Singh, A. K., Arora, S., ... & Ojha, R. P. (2019). Soil moisture sensing techniques for scheduling irrigation. J. Soil Salin. Water Qual, 11(1), 68-76.

Stutsel, B., Johansen, K., Malbéteau, Y. M., & McCabe, M. F. (2021). Detecting plant stress using thermal and optical imagery from an unoccupied aerial vehicle. Frontiers in plant science, 12, 734944.

Voytas, D. F. (2013). Plant genome engineering with sequence-specific nucleases. Annual review of plant biology, 64(1), 327-350.

Wolfert, S., Ge, L., Verdouw, C., & Bogaardt, M. J. (2017). Big data in smart farming–a review. Agricultural systems, 153, 69-80.

Yılmaz, E., Bocekci, S. C., Safak, C., & Yildiz, K. (2025). Advancements in smart agriculture: A systematic literature review on state-of-the-art plant disease detection with computer vision. IET Computer Vision, 19(1), e70004.

A DIGITAL EDUCATIONAL GAME FOR TEACHING OCCUPATIONAL HEALTH AND SAFETY FOR CHILDREN

Dr. Öğr. Üyesi İsa AVCI
Karabük Üniversitesi, Bilgisayar Mühendisliği, Mühendislik Fakültesi
ORCID: 0000-0001-7032-8018

Buse KÖSE
Karabük Üniversitesi, Bilgisayar Mühendisliği, Mühendislik Fakültesi
ORCID: 0009-0004-3448-7117

Şevval BOLAT
Karabük Üniversitesi, Bilgisayar Mühendisliği, Mühendislik Fakültesi
ORCID: 0009-0006-9554-8328

ABSTRACT

This study introduces a digital game prototype developed to reinforce occupational health and safety (OHS) awareness in children. The game has been designed in a two-dimensional format using the Unity engine, and it comprises ten development-level tasks. Each of these tasks reflects a real-life hazard, such as the selection of personal protective equipment (PPE), the safe collection of electrical cables, the disposal of broken glass, and the extinguishing of small fires. The purpose of these scenarios is to assist children in cultivating secure response behaviours in high-risk scenarios through experiential learning. During the design process, the prototype was subjected to rigorous testing in multiple sprint cycles by the development team and an a class occupational safety and health (OSH) expert. The observations yielded three key insights: firstly, that each risk could not be undertaken without the appropriate PPE being worn; secondly, that the complexity of the tasks increased in a manner commensurate with the age group of the children; and thirdly, that the fixed warning panel, which was informed by the errors made in the five-question pre-test, provided players with critical safety concepts in a timely manner. Despite the initial plan for an adaptive feedback module being postponed due to technical issues, this static panel successfully fulfilled its guidance function. The Unity's Particle System component has been demonstrated to maintain 60 frames per second (fps) stability even on entry-level hardware, thereby supporting the scalability of the game to computer labs in educational settings. Initial trials involving a small number of children yielded favourable responses, and observational data indicated that students exhibited a more thorough approach to risk assessment and adopted safer behaviours. Consequently, the prototype was found to be both an enjoyable and effective tool for instilling a culture of safety at an early age and laid the groundwork for more comprehensive, data-driven educational applications in the future.

Keywords: Occupational Health and Safety, Game-Based Learning, Children’s Safety Awareness, Personal Protective Equipment, Risk Assessment Skills.

INTRODUCTION

In today's world, the field of occupational health and safety (OHS) has evolved beyond its original remit of safeguarding adult workers. There is now an imperative to extend its purview to encompass more vulnerable groups, such as children, young people, and students. Educational institutions are environments where children experience their first social interactions and may encounter various hazards, making them places where OSH measures must be systematically implemented (Van Dijk et al., 2015). Following the enactment of Türkiye's Occupational Health and Safety Law No. 6331, educational institutions, encompassing both the public and private sectors, are obligated to undertake risk assessments and establish secure environments (Özbakır, 2024).

The World Health Organization (WHO) has underscored the long-term physical, psychological, and social ramifications of childhood accidents, and consequently, has advocated for the implementation of awareness training to prevent such incidents from an early age (Sellström, 2000). However, the cognitive limitations inherent in children's abstract thinking abilities can impede their comprehension of safety regulations. Consequently, innovative approaches such as age-appropriate pedagogical methods and game-based digital tools have become increasingly important in the field of occupational safety and health (OSH) education (Pertiwi et al., 2025).

Indeed, the utilisation of game-based learning environments has been demonstrated to enhance children's participation and facilitate the process of internalising safe behaviours (Adio-Moses, 2015). In accordance with this, the present project employed a scenario-based and interactive digital educational game to convey OSH rules to children. Within the game, students are guided by an OSH expert and encounter questions that, if answered incorrectly, are transformed into opportunities to experience risky situations and find solutions. The utilisation of protective equipment constitutes a pivotal component of this educational process, having been integrated into the flow of the game (Avcı, 2022; Avcı et al., 2022).

This approach has been demonstrated to be effective in raising individual awareness and contributing to the establishment of a culture of social safety from an early age. The utilisation of such innovative methodologies within educational settings has been demonstrated to enhance children's motivation to learn and to perpetuate safety behaviours (Widowati et al., 2019; Castro Mejía et al., 2023).

LITERATURE REVIEW

It is an established fact that injuries sustained during childhood constitute a significant cause of mortality and disability on a global scale. The World Health Organization's World Report on Child Injury Prevention emphasizes that hundreds of thousands of children lose their lives each year as a result of preventable accidents, with school and home environments identified as the main risk areas. This highlights the importance of initiating safety education at an early age (World Health Organization, 2008). Türkiye's Law No. 6331 on Occupational Health and Safety, which came into force, legally obliges all institutions, including schools, to conduct risk assessments and establish safe environments. The Ministry of National Education has issued comprehensive guidelines delineating the obligations of educational institutions, encompassing the provision of personal protective equipment and the formulation of emergency response plans (Inozu, 2019). However, traditional safety training methods, which rely on brochures and lectures, have been shown to fall short of meeting the information needs of children, particularly in terms of experiential learning, which is known to enhance retention of information (Avcı, 2021).

At this point, game-based learning (GBL) approaches assume particular significance. Prensky (2003) defines games as "natural learning machines", while Gee (2003) argues that well-

designed games support problem solving and knowledge transfer. In recent years, there has been an adaptation of this theoretical framework for application in the domain of safety education. To illustrate this point, consider a randomized controlled Safe City intervention that was conducted with 340 elementary school students in Hong Kong. It was reported that there was a significant increase in safety knowledge and behavior scores among the group that used the mobile game (Miyata, 2024; Wong et al., 2024). A VR-based program for pediatric inpatients in 2024 reported a 35% reduction in expected safety incidents, demonstrating the potential of virtual reality in child safety education (Hyeon & Oh, 2025). A comprehensive systematic review focusing on the adult population emphasizes that gamified OSH training increases motivation and knowledge retention, but that studies targeting children remain limited (Condori Colan & Barco Peralta, 2023; Avcı & Koca, 2023). A comprehensive systematic review focusing on the adult population highlights that gamified OSH training increases motivation and knowledge retention, but studies on children remain limited.

Digital environments specifically targeting the use of personal protective equipment (PPE) have also become a focus of research. A recent VR simulation has been shown to reduce the rate of incorrect sequencing among healthcare workers by half, by teaching them the correct steps for putting on and taking off PPE. In a similar vein, the puzzle game PE Lab Gear Up and hybrid RFID-based PPE games have demonstrated the efficacy of utilizing practical equipment selection skills in a recreational context (Zhou et al., 2025; Matthews et al., 2024; Merilampi et al., 2021). However, most of these studies have focused on adult or adolescent participants, and there is a paucity of research on the effectiveness of a local game prototype involving industrial risk scenarios for 9 to 11-year-olds.

The Purpose of Study

The objective of this study is to design the first domestic digital OSH game prototype containing industrial risk scenarios for the 9 - 11 age group and to validate its technical-pedagogical feasibility (playability, task-PPE matching, feedback flow) through expert feedback from the development team. The second objective is to establish a solid, testable foundation for subsequent experiments to be conducted with children.

Questions of Research

Q1: Functional integrity: Does the prototype truly prevent every hazard until the correct PPE is worn, and does it accurately reflect the errors made in the information test in the ‘Things to Note’ box?

Q2: Usability and pedagogical suitability: According to the developer and expert observations, are the task sequence, visual cues, and text language appropriate for the 9–11 age group?

Q3: Learning effect (planned field experiment): Does the game increase children's OSH knowledge scores and the rate of correct PPE selection in risky situations compared to traditional instruction?

Q4: Feedback design (planned field experiment): How does a pre-test-based static warning panel affect the time taken to complete in-game tasks and the frequency of safe behaviors?

Hypothesis: Students participating in the game intervention will show a significant increase in (a) pre-test/post-test OSH knowledge scores and (b) the rate of correct PPE selection in risky scenarios compared to the control group.

This framework elucidates the current prototype validation objectives while concurrently delineating quantifiable assumptions for subsequent child-participatory research.

METHODOLOGY AND MATERIAL

This section presents a comprehensive overview of the methods employed, from research design to game engine specifications, task flow to user testing. Figures 1-8 illustrate the pertinent interface and scenario screenshots.

Research Design

This study constitutes the formative phase of the design-based research cycle. At this stage, the prototype has only been tested by members of the development team and an occupational health and safety (OHS) expert; child participants have not yet been included. The objective of this study is twofold: firstly, to demonstrate that it is impossible to pass each hazard without wearing the appropriate personal protective equipment (PPE); and secondly, to enhance the interface-feedback timing prior to the classroom trial. The pilot study principles proposed by Julious (2005) and Leon et al. (2011) have been retained as a guide for future user research. However, it should be noted that the data presented in this section are qualitative notes based solely on developer observations. The game cycle, which comprises evaluation, guidance, and task execution, is outlined in Figure 1.

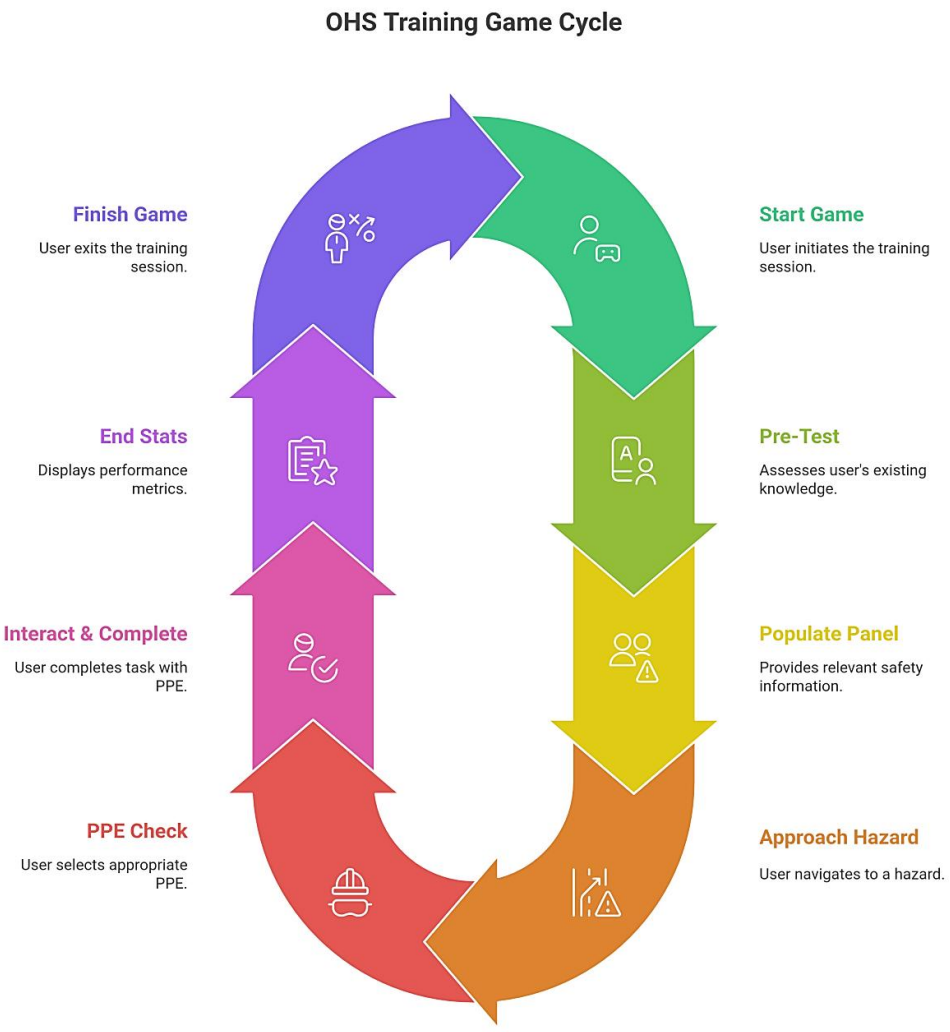


Figure 1. OHS Training Game Cycle - Proposed game flow and feedback scheme.

Development Environment and Infrastructure

The game prototype was developed using the Unity 2022.3 LTS engine and C# language. During the modelling phase, low-poly protective equipment (consisting of a helmet, goggles, and gloves) was created in Blender and positioned within the scene, in conjunction with laboratory objects procured from the Unity Asset Store (Unity Technologies, 2025). The development process was conducted on university laboratory computers equipped with an Intel i7-9700 processor, 16 GB RAM, and an NVIDIA GTX 1660 graphics card. The creation of fire and smoke effects was achieved by utilising Unity's Particle System component, a technique employed to enhance visual realism. Concurrently, the dynamic interplay of flames on ambient light was simulated through the implementation of light mapping techniques within the Universal Render Pipeline (URP). The frame rate was set to 60 fps to ensure both smoothness and an optimal experience for child users.

Training Content and Task Scenarios

The content was structured in collaboration with an A-class occupational health and safety expert and consisted of ten tasks, which were ranked according to increasing risk levels. Each task was paired with a specific hazard source (e.g., dangling electrical cable, broken glass bottle, chemical leak, small-scale fire) and designed to be completed only when the correct personal protective equipment (PPE) was provided. Moving-object hazards, frequently studied in intelligent-transport contexts (Avcı & Koca, 2024), informed the progressive difficulty curve embedded in our task sequence. The session commenced with a brief five-item pre-test for the participant (see Figure 2).

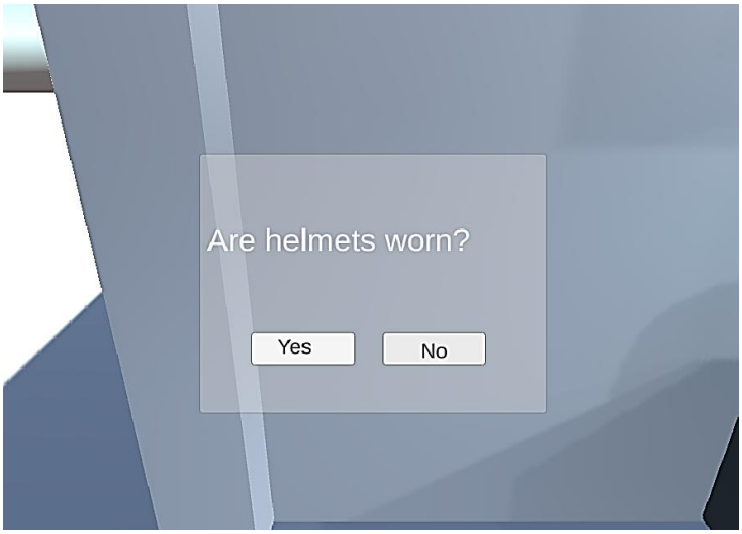


Figure 2. Security question directed at the player: ‘Are helmets worn?’

Each erroneous response in the preliminary test was automatically reflected in the 'Things to Consider' box located adjacent to the task board on the game screen, enabling the student to receive instantaneous feedback throughout the game on areas where they were deficient (see Figure 3).



Figure 3. General view of the task board and alert box

Table 1. Summary of Hazard Scenarios and Required PPE

Task	Hazard / Scenario (in-game object)	Mandatory PPE & Tool	Target Skill / Learning Outcome
1	Dangling live electrical cable	Insulated rubber gloves	Safe handling of exposed wires; power-off awareness
2	Shattered glass bottle on the floor	Safety goggles + cut-resistant gloves	Proper collection & disposal of sharp objects
3	Wet/slippery chemical spill	Non-slip laboratory shoes	Recognizing slip hazards; cautious gait
4	Fume-emitting chemical beaker	Face shield + nitrile gloves	Basic chemical-handling etiquette; eye–skin protection
5	Overloaded multi-socket outlet	Insulated gloves + circuit-breaker switch	Identifying electrical overload and isolating power
6	Blocked emergency exit (boxes)	Work gloves	Keeping egress routes clear; manual material handling
7	Unlabelled liquid container	Goggles + lab coat	Reading / applying GHS labels & hazard pictograms
8	Ladder reaching high shelf	Helmet + spotter prompt	Three-point contact rule; working-at-height safety
9	Small shelf fire	CO_2 fire-extinguisher (PASS steps)	Initial fire-fighting; selecting correct extinguisher
10	Audible gas-leak alarm	Respirator + gas-shutoff valve	Leak isolation; emergency ventilation & evacuation

Task Flow and User Interactions

The player navigates the laboratory scene by using the W, A, S, D keys to move and the 'E' key to interact. Initially, task items are displayed in a grey colour; upon collection of the requisite PPE, the line transitions to green, accompanied by a brief auditory signal (see Figure 4). In trials of the KKD-free approach, a red warning symbol is displayed in the centre (see Figure 5), serving to intuitively remind the player of the necessity of safe behaviour. As illustrated in the example of the electrical cable, it is imperative that gloves are worn when handling risky objects (see Figure 6).

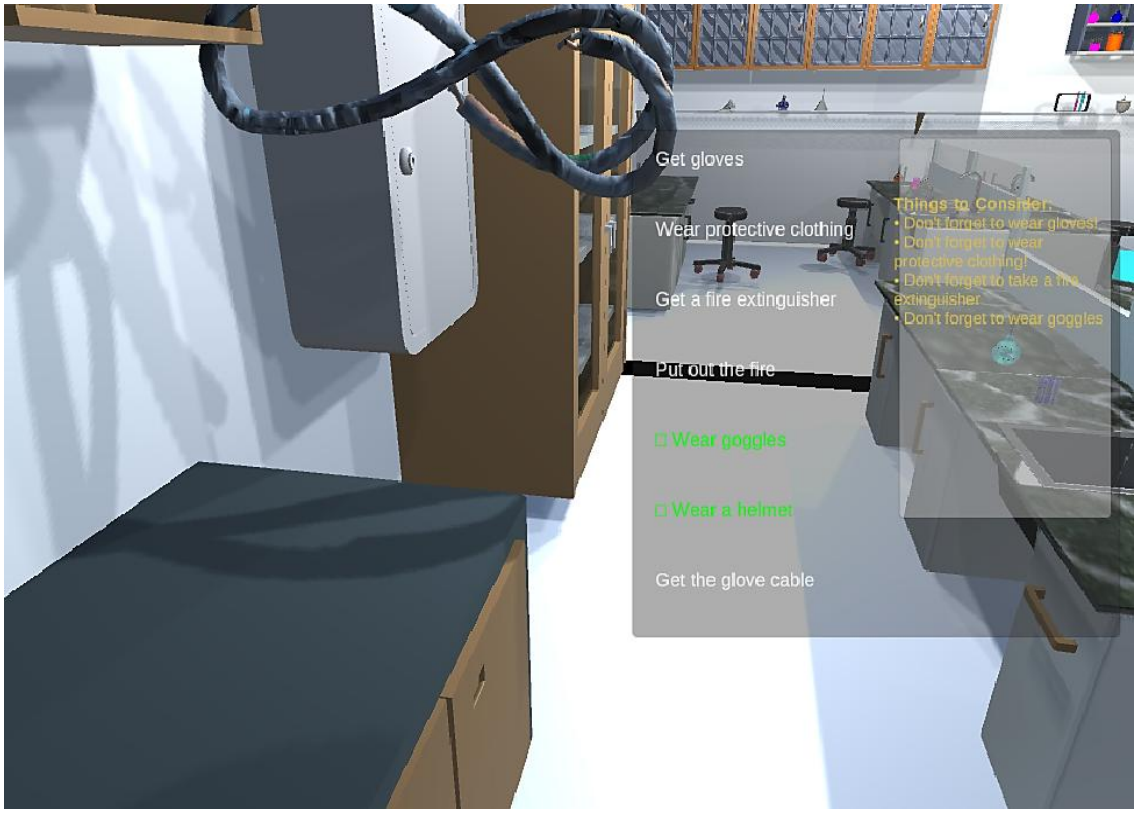


Figure 4. An image showing that some steps in the task list have been successfully completed



Figure 5. Screen unable to complete task due to lack of protective equipment

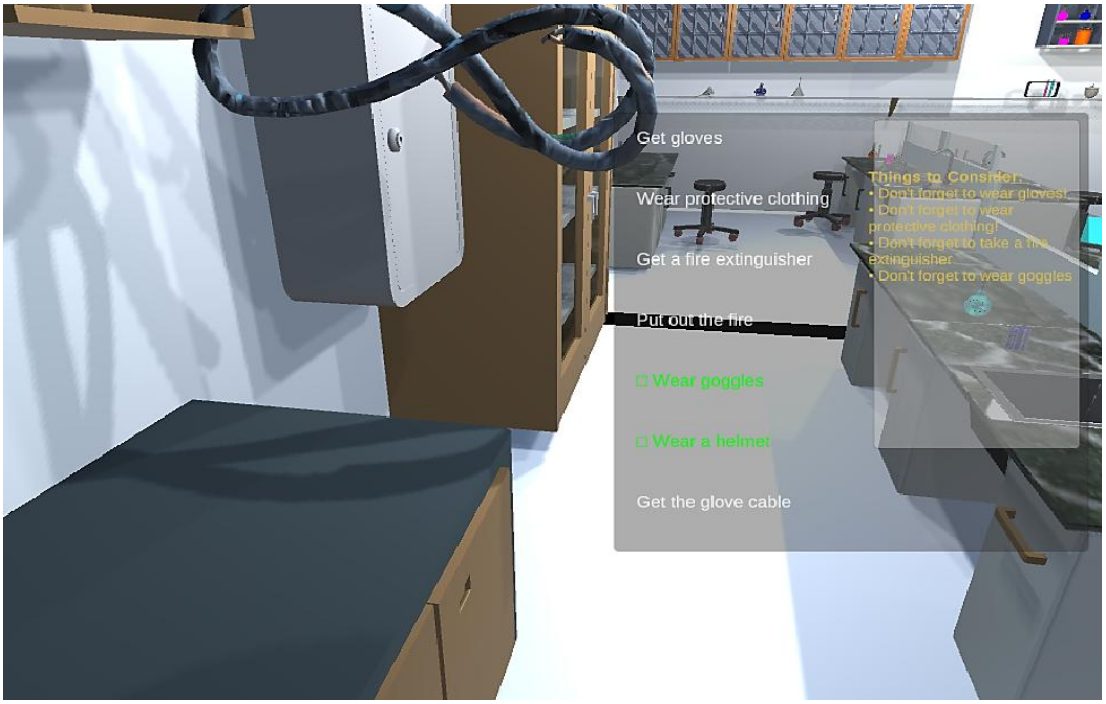


Figure 6. A scenario screen that allows the electrical cable to be removed after the glove function has been completed.

Fire Scenario and Intervention

A pivotal element of the design pertains to the small-scale fire scenario that occurs on the laboratory shelf. The student first completes the task of acquiring an understanding of the device by means of the 'Get the fire extinguisher' exercise. Thereafter, in the 'Extinguish the fire' step (see Figure 7), the student disperses the flame particles with the nozzle direction. In the event of a successful extinguishment, the task bar transitions to a green colour, and the active fire scene (see Figure 8) is substituted by a completion screen, indicating a fire intensity of zero (see Figure 9).



Figure 7. A screenshot from the fire scenario

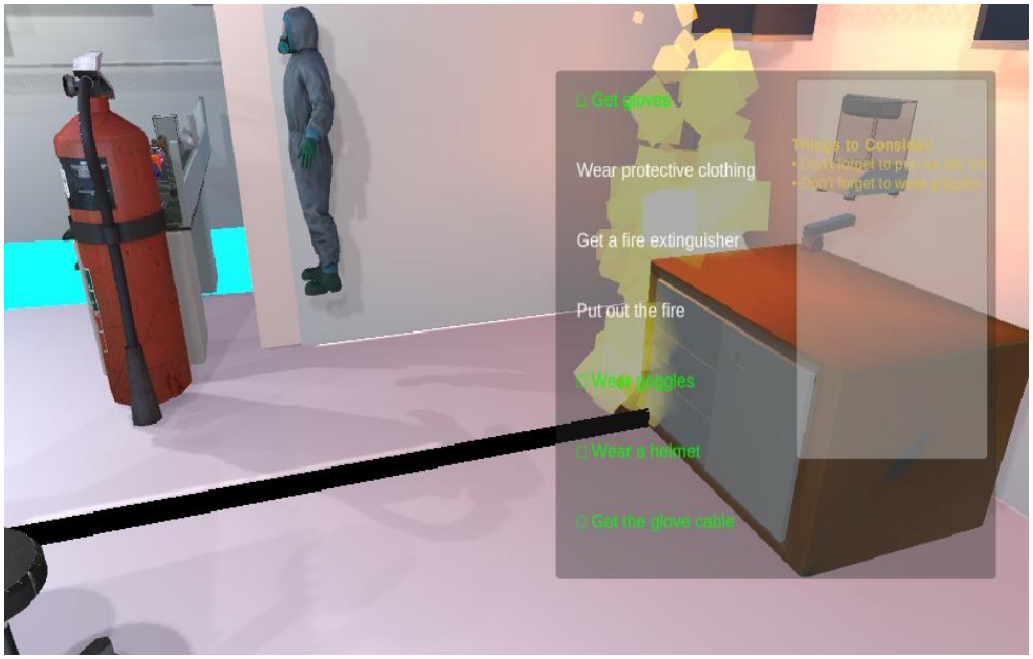


Figure 8. Screen showing the last mission and active fire



Figure 9. Screen showing that the amount of fire has decreased and the task has been completed

Although the initial plan was for reinforcement learning-based adaptive feedback, technical constraints during the pilot phase led to the implementation of a static text box based on pre-test results. The function of this box is to provide hints on topics with which the student is unfamiliar, thus ensuring that the cognitive load remains low. Previous studies have demonstrated the efficacy of text-based hints in providing goal-oriented feedback in the context of mobile security games (Wong et al., 2024; Kelleher, 2022).

The observations gathered during this formative stage confirmed the mechanical integrity and pedagogical applicability of the prototype. The game has thus attained a level of maturity that will provide a solid technical and didactic foundation for future field studies.

DISCUSSION AND CONCLUSION

It has been demonstrated by means of formative tests that the prototype successfully meets its basic objectives. The development team and A-class OHS expert have confirmed that progress is impeded until the correct PPE is worn for each hazard, and that the fixed warning box derived from the pre-test reflects errors in a timely and error-free manner. The task sequence, which aligns with a low-to-high risk logic, the text language, which has a simple structure suitable for the 9-11 age level, and the visual-auditory reinforcements, which do not increase cognitive load, have provided important pedagogical gains. In a manner analogous to the focused cue model proposed by Wong et al. (2024), the warning panel has been observed to direct the player's attention towards the target concept during critical moments. It is important to note that Unity's Particle System component could maintain a constant frame rate even on entry-level hardware, thus offering scalability potential for school laboratories. However, it should be noted that mechanical accuracy does not directly translate to learning gains; experimental studies using real student data are still necessary (Özarpa & Avcı, 2021). Furthermore, given that the risk scenarios in the game are centred on industrial environments, the generalisation capacity to traffic or home accidents remains constrained.

CONCLUSION

The study has revealed the design principles, technical infrastructure, and developer-centered formative test findings of the first local digital OSH game prototype for children. The set of ten task scenarios matches each risk factor with the relevant PPE use, while the fixed warning box generated from the five-question pre-test provides the player with personalized yet concise guidance. It has been demonstrated through internal trials that the game is both pedagogically suitable and characterized by smooth gameplay flow. This establishes a solid technical and didactic foundation for field research to be conducted in classroom settings.

The initial phase of the study will entail the execution of a classroom pilot, which is scheduled to encompass approximately thirty primary school students, ranging in age from 9 to 11 years. In this pilot study, a multifaceted approach will be employed to analyse the impact of the game on learning. This approach will integrate pre-test and post-test knowledge scores, in-game telemetry data, and structured observation rubrics, facilitating a comprehensive and statistically robust examination. Subsequently, the existing fixed warning panel will be converted into an adaptive feedback system based on reinforcement learning using the Unity ML-Agents infrastructure. Performance metrics such as the reduction of incorrect repetitions or the shortening of task completion time will be evaluated using an A/B design. In the third phase, knowledge retention will be measured through the administration of four-week delayed tests, and the transfer of learning will be investigated based on safe behaviours observed in a realistic laboratory model. Finally, the addition of colour-blind palettes, audio narration options, and customisable key assignments will be made in accordance with accessibility goals. The WebGL version will be developed to ensure its readiness for widespread use on low-specification school computers. It is anticipated that upon the conclusion of the present series of studies, the game will be regarded as a sustainable and measurable safety education instrument within the primary school curriculum.

REFERENCES

Adio-Moses, R. O. (2015). Health and safety of young people: looking beyond the 21st century. Faculty of Education, University of Ibadan.

Avcı, İ. (2021). Investigation of cyber-attack methods and measures in smart grids. Sakarya University Journal of Science, 25(4), 1049–1060.

Avcı, İ. (2022). Akıllı evlerde IoT teknolojileri ve siber güvenlik. Avrupa Bilim ve Teknoloji Dergisi, (34), 226-233.

Avcı, İ., Özarpa, C., Özdemir, M., Kınacı, B. F., & Kara, S. A. (2022). Akıllı ulaşım araçlarında siber güvenlik ve çok katmanlı güvenlik önlemi. Akıllı Ulaşım Sistemleri ve Uygulamaları Dergisi, 5(1), 22-35.

Avcı, İ., & Koca, M. (2023). Cybersecurity attack detection model using machine-learning techniques. Acta Polytechnica Hungarica, 20(7), 29–44.

Avcı, İ., & Koca, M. (2024). Intelligent transportation system technologies, challenges and security. Applied Sciences, 14(11), 4646.

Castro Mejía, P. J., Campos Coronel, C. S., Ancajima Gaona, L. E., Delgado Ventura, J. F., Flores Montero, D. H., & Huilca Alcántara, W. E. (2023). Health and safety proposal to reduce risks in the construction of a school. Sustainability, 15(21), 15189.

Condori Colan, C. A. N., & Barco Peralta, D. A. (2023). Gamification in occupational safety training: A systematic literature review.

Gee, J. P. (2003). What video games have to teach us about learning and literacy. Computers in Entertainment, 1(1), 20.

Hyeon, R., & Oh, W. O. (2025). Virtual reality education for preventing safety incidents in pediatric hospital settings: Quasi-experimental design pre-post testing. Journal of Pediatric Nursing, 80, 56-63.

Inozu, M. A. (2019). Official Gazette, Turkey Occupational Health and Safety Law No. 6331.

Julious, S. A. (2005). Sample size of 12 per group rule of thumb for a pilot study. Pharmaceutical Statistics, 4(4), 287-291.

Kelleher, I. (2022). How to Reduce the Cognitive Load on Students During Lessons. https://www.edutopia.org/article/how-reduce-cognitive-load-students-during-lessons/ Son erişim: 16.06.2025.

Leon, A. C., Davis, L. L., & Kraemer, H. C. (2011). The role and interpretation of pilot studies in clinical research. Journal of Psychiatric Research, 45(5), 626-629.

Matthews, H., Rafiq, R., Abedalreza, D., Yahya, F., & Jones, M. (2024). PPE Lab Gear Up: A Personal Protective Equipment Puzzle Game.

Merilampi, S., Leino, M., Jyräkoski, T., Mehmood, A., Huhtasalo, J., Poberznik, A., … & Virkki, J. (2021, August). Co-designing a hybrid game for training use of proper personal protective equipment in different clinical scenarios. In 2021 IEEE 9th International Conference on Serious Games and Applications for Health (SeGAH) (pp. 1-6). IEEE.

Miyata, S. (2024). Effectiveness of virtual reality training in teaching personal protective equipment skills. JAMA Network Open, 7, e2355358.

Özbakır, O. (2024). Risk perception and occupational health and safety: Evaluation in national and global context. Doğu Fen Bilimleri Dergisi, 6(2), 11-23. https://doi.org/10.57244/dfbd.1347259

Pertiwi, W. E., Denny, H. M., Setyaningsih, Y., & Laksono, D. A. (2025). Strengthening occupational health and safety (OHS) in schools to minimize risks for students, teachers, and visitors: Policy recommendation. Journal of Indonesian Health Policy and Administration, 10(2), 40-47.

Prensky, M. (2003). Digital game-based learning. Computers in Entertainment, 1(1), 21.

Sellström, E. (2000). Studies in safety promotion for preschool children. Karolinska Institutet.

Unity Technologies. (2025, 16 June). Particle Systems (Unity Documentation). https://docs.unity3d.com/2022.3/Documentation/Manual/ParticleSystems.html Son erişim 16.06.2025.

Van Dijk, F. J., Bubas, M., & Smits, P. B. (2015). Evaluation studies on education in occupational safety and health: Inspiration for developing economies. Annals of Global Health, 81(4), 548-560.

Widowati, E., Husodo, A. H., Istiono, W., & Lazuardi, M. L. (2019, November). The utilization of mHealth for assessing child safety education is a necessity. In 5th International Conference on Physical Education, Sport, and Health (ACPES 19) (pp. 268-272). Atlantis Press.

World Health Organization. (2008). World report on child injury prevention. WHO Press. https://www.who.int/publications/i/item/9789241563574 Son erişim: 15.05.2025.

Wong, R. S., Tung, K. T., Ho, F. K., Wong, W. H., Chow, C. B., Chan, K. L., … & Ip, P. (2024). Effect of a mobile game–based intervention to enhance child safety: Randomized controlled trial. Journal of Medical Internet Research, 26, e51908.

Zhou, L., Liu, H., Fan, M., Liu, J., Yu, X., Zhao, X., & Zhang, S. (2025). Personal protection equipment training as a virtual reality game in immersive environments: Development study and pilot randomized controlled trial. JMIR Serious Games, 13(1), e69021.

ANALYSIS OF THE INTERACTION OF MONETARY AND MACROPRUDENTIAL POLICIES: EMPIRICAL EVIDENCE FROM ALBANIA

Gent Sejko

University of Tirana, Faculty of Economy, Department of Economics; Bank of Albania

Dr. Altin Tanku

Bank of Albania, Research Department

Meri Papavangjeli

Bank of Albania, Research Department; Charles University

Prof. Dr. Tonin Kola

University of Tirana, Faculty of Economy, Department of Economics

ABSTRACT

This paper investigates the interdependence between monetary policy and macroprudential regulation within the specific framework of a small, open, and highly euroized emerging economy, taking Albania as a case study. The central premise is that the two policy spheres are not independent but instead exert reciprocal influences on one another. Drawing on data covering the period 2000–2022, the analysis provides an empirical assessment of how these policies shape each other's objectives and outcomes. To facilitate this investigation, a novel quantitative indicator is developed to capture macroprudential policy actions in Albania.

The empirical strategy relies on the estimation of a small structural vector autoregression (SVAR) model with cointegrated I(1) policy and non-policy variables. Proper identification is achieved by applying the SVECM-to-SVAR methodology advanced by Oularis, Pagan, and Restrepo (2018). The results demonstrate clear evidence of interaction between the two policy domains. In particular, the findings indicate that the Bank of Albania systematically aligns the tightening of macroprudential measures with an accommodative stance in monetary policy.

The recognition of such policy interplay has significant implications for the design and conduct of central bank policies. Specifically, it underscores the importance of coordination between monetary and macroprudential instruments in mitigating risks to both price stability and financial stability.

Keywords: monetary policy, macroprudential measures, interaction, macroeconomic effects

JEL: E3, E44, G01, G21

INTRODUCTION

In the evolving sphere of economic governance, monetary policy and macroprudential regulation constitute two fundamental instruments for safeguarding both price stability and financial stability. While these policies pursue distinct objectives, their interaction can either reinforce one another's effectiveness or generate unintended trade-offs. This study undertakes

an empirical investigation of how these two policy domains have interacted and been coordinated in Albania, focusing on the period 2000–2022. In particular, it examines whether the strategies pursued by the Bank of Albania in the realm of monetary and macroprudential policy have served to complement or obstruct the attainment of each other's primary goals. To address this question, the paper develops a novel quantitative indicator that systematically captures macroprudential policy actions in Albania and applies a framework that integrates vector autoregressive (VAR) models with vector error correction mechanisms (VECM) to jointly estimate policy interactions.

The empirical analysis relies on the underlying data-generating process, specifically the information embedded in cointegration relationships, to identify a Structural Vector Autoregressive (SVAR) model. This identification strategy enables a detailed exploration of the dynamic interlinkages between monetary and macroprudential policy stances. The study makes two original contributions: first, the construction of a macroprudential indicator that operationalizes policy actions into a measurable variable; and second, the application of an SVAR–SVECM approach that enhances the precision of empirical inference. Together, these innovations provide valuable insights and tools for both policymakers and academic researchers.

The findings confirm the central hypothesis that the Bank of Albania coordinates monetary and macroprudential instruments in a complementary manner. Evidence suggests that episodes of macroprudential tightening are often accompanied by an accommodative monetary stance. Moreover, while monetary policy decisions are largely independent of macroprudential actions, the latter strengthen the scope for monetary policy to respond effectively to macroeconomic developments. Of particular note is the period from 2006 until the onset of the COVID-19 pandemic, during which the Bank of Albania consistently harmonized the two policy domains: expansionary monetary measures were often aligned with either direct macroprudential easing or with postponements in the implementation of agreed regulatory measures. The empirical evidence thus supports the proposition that these policies can be coordinated without producing adverse spillovers.

The research is structured in a progressive manner, beginning with a review of the conceptual foundations and existing literature, followed by an in-depth discussion of Albania's monetary framework, including the objectives and instruments underpinning monetary and macroprudential policymaking. Building on this context, the study conducts a rigorous econometric assessment of the policies' interaction and their implications for price and financial stability. It concludes by distilling the principal results and formulating recommendations with direct relevance for the policy decisions of the Bank of Albania.

POLICY FRAMEWORK IN ALBANIA

Macroprudential policy provides the central bank with a set of instruments to address risks that may arise from the conduct of monetary policy. By targeting systemic vulnerabilities, these tools mitigate the financial imbalances often associated with periods of monetary easing. Instruments such as loan-to-value (LTV), loan-to-income (LTI), and debt-service-to-income (DSTI) ratios have proved especially effective in restraining rapid credit growth. Empirical studies reinforce this complementarity: Altavilla, Laeven, and Peydró (2020) show that the impact of accommodative monetary policy on bank lending and risk-taking is magnified when macroprudential settings are also loose, particularly in banks with weaker capitalization. Likewise, Aiyar, Calomiris, and Wieladek (2014) find that a simultaneous tightening of monetary policy and capital requirements reduces the availability of bank credit. The reverse relationship has also been documented. For instance, Mendicino et al. (2020) and Cozzi et al. (2020) demonstrate that higher capital requirements may contract credit and lower GDP in the short term, while Van der Ghote (2021) and Tressel and Zhang (2016) argue that

macroprudential tightening during monetary easing can dampen systemic risk and curb excessive house price and credit growth.

This perspective is particularly relevant for Albania, where the institutional framework of the Bank of Albania (BoA) reflects the dual pursuit of price and financial stability. The Bank's primary mandate is to maintain price stability, defined by a medium-term inflation target of 3 percent based on the Consumer Price Index. Since 2008, financial stability has also been recognized as a core objective, leading to the systematic use of macroprudential tools to mitigate systemic risks.

The monetary policy framework follows the logic of a small, open economy with a flexible exchange rate. The key policy rate is the main instrument, supported by open market operations—including one-week repurchase and reverse repurchase agreements—designed to regulate liquidity and influence short-term interest rates.

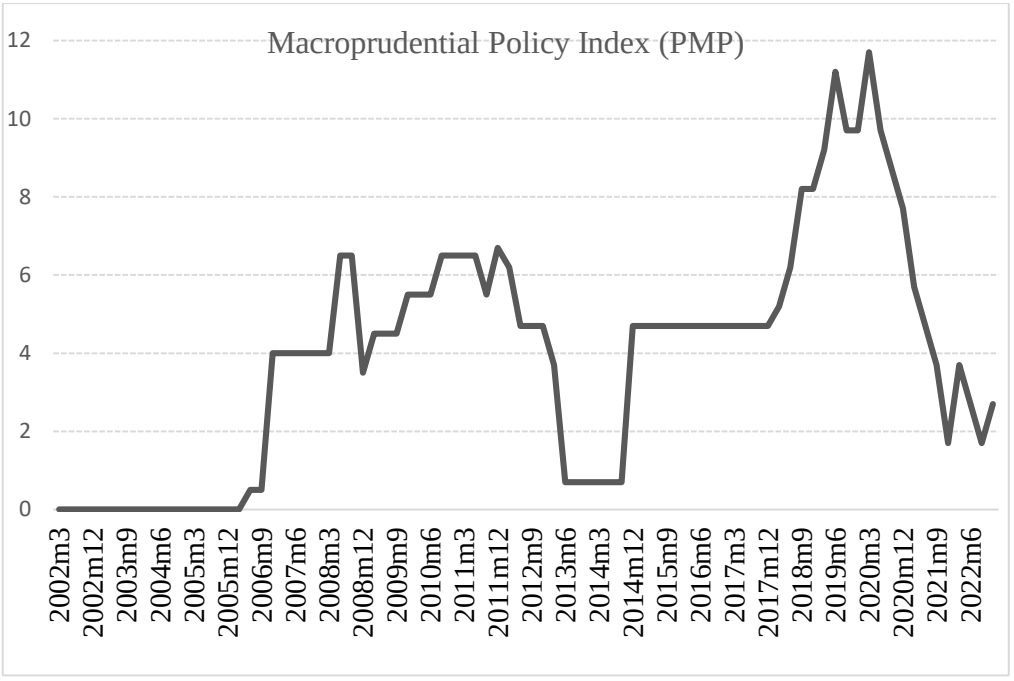
In response to the global financial crisis and the European debt crisis, the BoA pursued a strongly accommodative stance, cutting the policy rate from 6.25 to 0.5 percent and providing liquidity to sustain banking activity. However, the impact of this easing was dampened by weak demand, appreciation of the domestic currency, rising debt burdens, and a surge in non-performing loans, all of which limited the transmission of monetary policy and kept inflation below target.

To reinforce monetary policy and support credit intermediation, the BoA introduced macroprudential measures that eased regulatory constraints and bolstered resilience. Between 2008 and 2014, risk weights on certain categories of credit growth were reduced to encourage lending. Government securities were accepted as collateral to ease liquidity pressures, and dividend distributions were temporarily suspended—initially in 2008–2009 and later during the COVID-19 crisis—to strengthen bank capitalization. These measures highlight how macroprudential policy was aligned with monetary easing to cushion the economy during periods of stress.

To evaluate such measures systematically, this study constructs a composite macroprudential policy index for Albania covering 2006–2022, based on the methodology of Alam et al. (2019). Each Supervisory Council decision is coded as +1 for tightening, −1 for easing, and 0 for neutral, with intermediate values of ±0.5 applied when measures affected only part of the system. The index captures both the introduction and withdrawal of measures, reflecting the dynamic character of macroprudential policy.

The index includes a wide range of instruments, such as LTV and DSTI limits, capital adequacy requirements, countercyclical buffers, and measures on liquidity and foreign exchange exposure. For example, the activation of a countercyclical capital buffer is classified as a tightening action (+1), while its postponement, as during the pandemic, is classified as easing (−1). Aggregating these decisions produces a single series that summarizes the macroprudential stance over time and provides a key input for the empirical analysis. Data for the index are drawn from official BoA sources, including Supervisory Council decisions and annual reports.

Figure 1. Performance of the macroprudential policy (MPP) index.



Source: Bank of Albania and authors's calculations.

METHODOLOGY

This study investigates the interaction between monetary and macroprudential policies in Albania through a structural vector autoregressive (SVAR) model. Following the approach of Blanchard and Quah (1989), the aim is to estimate the impulse responses of endogenous variables to structural shocks by imposing identification restrictions derived from cointegration relationships and the error-correction mechanism.

A standard VAR captures the dynamic interactions among variables, where each variable is explained by its own lags and the lags of all others. Formally, a VAR(p) can be expressed as:

$$z_t = A_1 z_{t-1} + A_2 z_{t-2} + \ldots + A_p z_{t-p} + \mu + \varepsilon_t \qquad (1)$$

where z_t is a vector of size (nx1) with n endogenous variables A_1,…, A_p are matrices of size (nxn) of parameters to be estimated (nxn), μ is a vector (nx1) of constants and ε_t represents a vector (nx1) of the "white noise" error terms.

Impulse responses trace the effect of shocks on the system. To identify structural shocks, the error term must be orthogonalized $\varepsilon_t = Bu_t$, where u_t represents the uncorrelated (orthogonalized) errors and matrix B represents the matrix of constraints that enable orthogonalization.

This leads to the SVAR representation:

$$Az_t = A_L + Bu_t \qquad (2)$$

When cointegration is present, the appropriate specification is a vector error correction model (VECM):

$$\Delta\zeta_t = \alpha\beta'\zeta_{t-1} + \Phi_1\Delta\zeta_{i-1} + e_t \qquad (3)$$

where β contains cointegration vectors and α captures adjustment coefficients.

This framework enables the identification of both long-term equilibrium relationships and short-run dynamics.

Neext, we provide a comprehensive description of the data used in the empirical analysis.The empirical analysis relies on quarterly data spanning the period 2002–2022. The variables were chosen to capture the main objectives and instruments of both monetary and macroprudential policies, in line with the existing literature and consistent with the framework discussed by Sejko (2021). Monetary policy is represented by the key interest rate, specifically the one-week REPO, which serves as the primary instrument through which the central bank influences borrowing costs, liquidity conditions, and the overall stance of monetary policy. Inflation, measured as the annual change in the Consumer Price Index, reflects the Bank of Albania's price stability objective and is included as a core policy target.

The macroprudential dimension is incorporated through a composite index of macroprudential measures, constructed following the methodology of Alam et al. (2019). The index is derived from decisions of the Supervisory Council of the Bank of Albania, where each measure is coded as +1 when policy is tightened, −1 when it is eased, and 0 when it remains neutral; in certain cases where a measure applied only partially to the banking system, an intermediate value of ±0.5 was used. To complement this indicator, the Banking Soundness Index (BSI), compiled quarterly by the Bank of Albania, is introduced as a proxy for financial stability. This index accounts for factors such as capitalization, asset quality, profitability, and liquidity, providing a comprehensive assessment of banking sector resilience.

Finally, two broader macroeconomic variables are included. Gross Domestic Product (GDP) is employed as a measure of economic activity and to assess the effectiveness of both policies in supporting overall macroeconomic stability. The lek/euro exchange rate is also incorporated due to Albania's high degree of euroization, which makes the exchange rate a critical variable for both monetary transmission and financial stability, influencing inflation dynamics, competitiveness, debt servicing capacity, and the exposure of the banking system to external shocks.

Next, the results of the analysis performed using the SVAR model combined with SVEC, are presented. First, we study possible long-run relationships between the variables described above, since they all turned out to be integrated of the first order I(1). This is made possible through the Johansen cointegration tests: the trace test and the maximum eigenvalue test, the results of which are presented in Table 2 below. Both tests suggest the existence of two stable long-term equilibrium relationships between them.

Table 2 Johansen cointegration test.

Sample: 2003Q3 2022Q4 Included observations: 78 Series: LOG(GDP) LOG(ALL_EUR) LOG(CPI) REPO BSI PMP Lags interval: 1 to 2 Selected (0.05 level*) Number of Cointegrating Relations by Model					
Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept No Trend	Intercept No Trend	Intercept No Trend	Intercept Trend	Intercept Trend
Trace	1	2	2	2	1
Max-Eig	2	2	2	2	2
*Critical values based on MacKinnon-Haug-Michelis (1999)					

Source: Author's computations.

This shows that the process that generated the data in the database is directed or conditioned by the existence of two long-term relationships. This structure/dominant characteristic of the database contains important information that must be taken into account in formulating the model and its functional form. Consequently, in line with Ouliaris et al. (2018), accurate identification of the structure of the SVAR model will need to take this important information

into account. As we have seen above in the theoretical description of the methodology, it is necessary for these relationships to be defined in the structure (matrix of coefficients) of the long-term relationship. Consequently, this first requires the identification and evaluation of these cointegrating relationships. Next, the two cointegration relations are evaluated through the ARDL (Autoregressive distributed lag) procedure, the results of which are presented in Table 3 below. The statistics reported from the estimation of the ARDL model reconfirm the existence of two cointegration relationships, where the F statistic exceeds its critical value and the error correction term is negative and statistically significant.

Regarding the identification, our interpretation is that these two cointegrating relationships go to each of the two policies. First, the monetary policy relationship suggests that prices are cointegrated with economic activity and the monetary policy rate to which they respond. In this case, the basic assumption is that the cointegrating relationship is carried by the CPI. This assumption is more than reasonable considering not only the current monetary policy framework that is based on price stability (which means prices correct and stay around the target), but also referring to statistics, which show that prices in long-term periods remain stable around equilibrium in response to fluctuations in other indicators.

Second, the other cointegrating relationship goes to macroprudential policy, which shows that the exchange rate, macroprudential policy indicator and banking soundness indicator are related in the long run. In this case, the basic assumption is that the cointegrating relationship is carried by the bank soundness indicator. This assumption, as in the case of monetary policy, requires that exchange rate shocks and macroprudential policies interact to maintain a satisfactory level of banking soundness, forcing it to adjust to remain at a reasonable and desirable level.

Table 3 Estimation of the cointegrating relationship equation.

	Long-term coefficients					Statistical diagnostics		
	Constant	LGDP	REPO	LER	PMP	Statistic F-Bound		Error correction term
Cointegrationg relation 1	0.53	0.47	-0.01			5.15		-0.37
	(1.32)	(5.84)	(2.66)			I(0) në 5%	I(1) në 5%	(3.99)
						3.79	4.85	
Cointegrationg relation 2	0.20			0.26	0.01	6.27		-0.373
	(3.58)			1.45	1.32	4.87	5.85	(4.41)

Source: Author's computations.

Oularis, Pagan and Restrepo (2018) suggests that these two relationships can be evaluated consistently through the ARDL method introduced by Pesaren, Shin and Smith (2001). Consequently, for the above reasons, given the long-term structure identification methodology based on Olaris et al. (2018), it has been suggested that the shocks of the two cointegrating relations respectively "CPI" and "BSI" do not leave long-term stochastic trends in the other variables of the model. This is illustrated in matrix F in Figure 2 below.

In addition to these assumptions, it is also assumed that the productivity shock is exogenous to all other variables, a standard assumption in the economic literature. Taking all these assumptions together, we define 13 constraints. Since the standard number of constraints for correct model identification is 15, then it is necessary to place two additional constraints on the short-term matrix[1].

[1] Given that the number of constraints for correct identification is (k*(k-1))/2.

Figure 2. Imposing long-term and short-term restrictions in matrices F and S, respectively.

F	ε_{GDP}	ε_{REPO}	ε_{ec1}	ε_{ER}	ε_{MAPP}	ε_{ec2}
GDP	NA	0	0	0	0	0
REPO	NA	NA	0	NA	NA	0
$CPI_{(EC1)}$	NA	NA	NA	NA	NA	0
ER	NA	NA	0	NA	NA	0
MAPP	NA	NA	0	NA	NA	0
$BSI_{(EC2)}$	NA	NA	0	NA	NA	NA

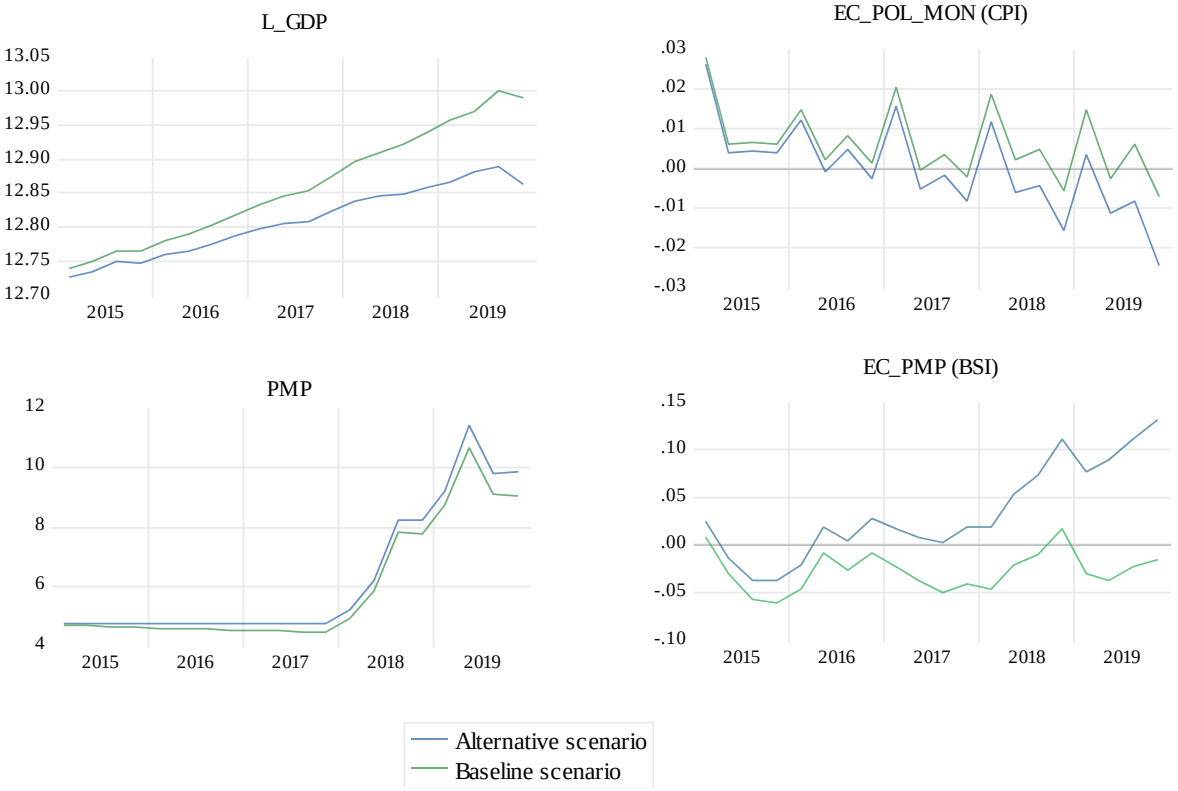
S	ε_{GDP}	ε_{REPO}	ε_{ec1}	ε_{ER}	ε_{MAPP}	ε_{ec2}
GDP	NA	0	NA	NA	NA	NA
REPO	NA	NA	NA	0	NA	NA
$CPI_{(EC1)}$	NA	NA	NA	NA	NA	NA
ER	NA	NA	NA	NA	NA	NA
MAPP	NA	NA	NA	NA	NA	NA
$BSI_{(EC2)}$	NA	NA	NA	NA	NA	NA

The identification strategy rests on two key restrictions. First, monetary policy is assumed not to exert an immediate impact on productivity, since its transmission occurs with time lags. Second, consistent with the operational framework of the Bank of Albania, exchange rate shocks are not addressed through adjustments in the policy rate but rather through interventions in the foreign exchange market. These assumptions are embedded in the model by assigning zeros in the restriction matrix S (Figure 2), which ensures the required fifteen constraints and enables the empirical estimation of the system. To better capture the specific conditions of the sample period, the model also incorporates a dummy variable that takes the value of 1 during major crisis episodes, namely, the global financial crisis, the Eurozone debt crisis, and the COVID-19 pandemic, and 0 otherwise. By introducing these restrictions and enriching the model with a crisis dummy, the SVAR specification more closely approximates the actual data-generating process. The empirical estimation is carried out in EViews, and, as in the VAR framework, the interpretation relies on the impulse responses of the key variables to identified policy shocks. In the structural setting, responses are presented relative to a baseline scenario, thereby providing additional insight by comparing the behaviour of each variable both with and without the shock.

The results focus first on the impact of a monetary policy shock on GDP, inflation, the exchange rate, the macroprudential policy indicator, and the Banking Soundness Index. The findings suggest that macroeconomic variables behave as theory predicts: a tightening of monetary policy leads to a contraction of GDP and accelerates price adjustment, while the exchange rate exhibits little difference across scenarios. These outcomes confirm that the model adequately captures the dynamics of the Albanian economy and is well suited for scenario analysis. Turning to the financial stability indicators, the macroprudential policy index shows only a negligible reaction to monetary shocks, whereas the Banking Soundness Index displays a more complex response. On one hand, higher interest rates increase debt burdens, discouraging borrowing and raising repayment difficulties. On the other hand, they improve banks' profitability by widening interest margins and strengthening capital adequacy, which enhances overall soundness. The net effect is positive: the banking sector appears more resilient when policy rates rise, reducing the need for macroprudential interventions.

Taken together, these results indicate that monetary policy shocks in Albania generate the expected effects on output and prices without undermining the effectiveness of macroprudential policy. This finding is significant from a policy perspective, as it supports the view that the Bank of Albania can pursue its primary mandate of price stability without jeopardizing its secondary goal of safeguarding financial stability.

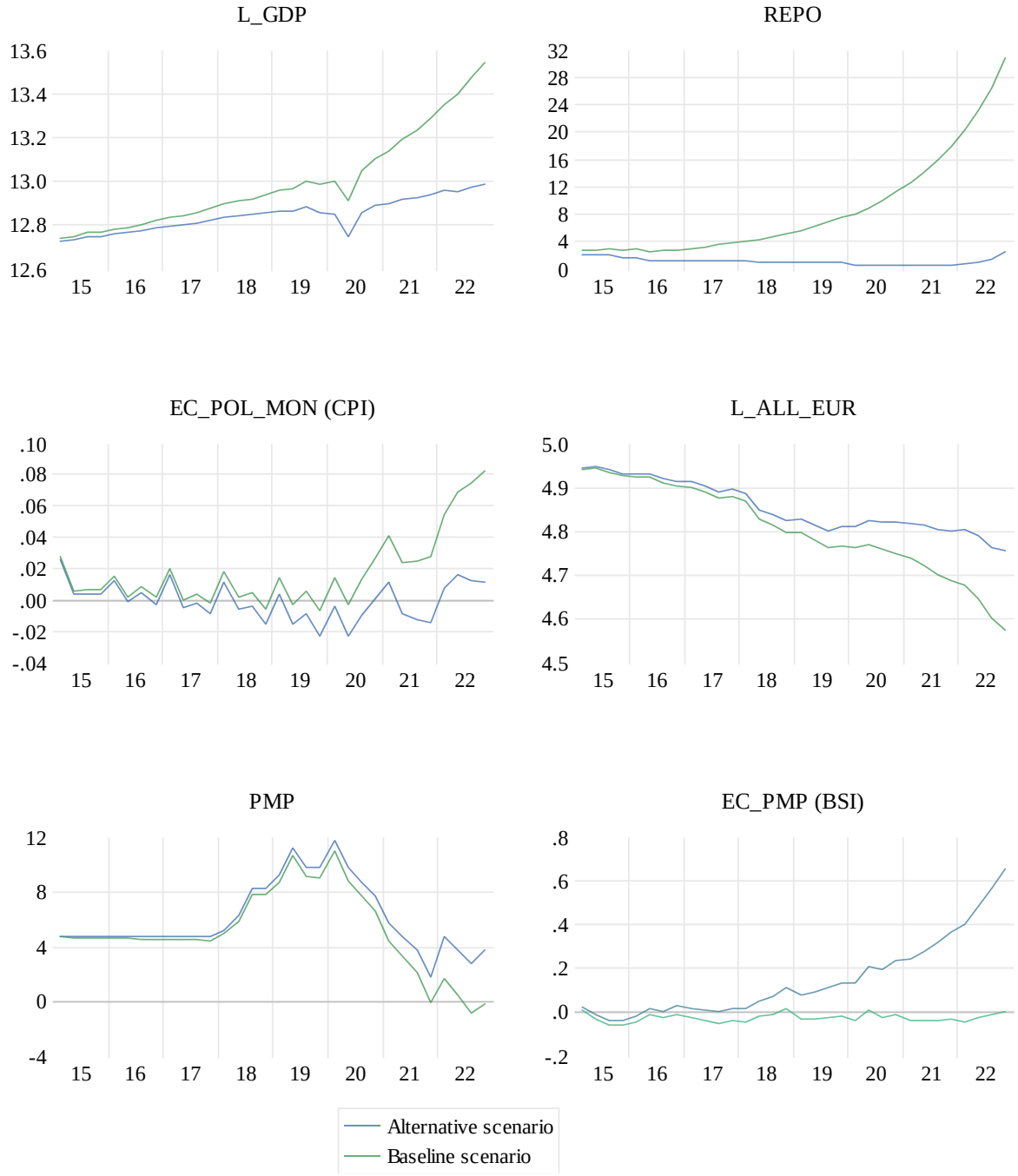
Figure 3. Results of a positive REPO shock scenario.



An equally important question is whether macroprudential measures exert an influence on monetary policy. The structural identification employed in the SVAR framework makes it possible to examine this relationship. Here, the analysis again focuses on the behaviour of key macroeconomic indicators and the monetary policy instrument, with the results summarized in Figure 4.

The findings indicate that a tightening of macroprudential policy restricts credit availability, leading to weaker economic activity and lower aggregate demand. Consistent with this mechanism, GDP and prices both decline, while the domestic currency shows a mild depreciation. These outcomes reinforce the view that the specification of the model is well-suited to the Albanian economy. At the same time, stricter macroprudential conditions strengthen the Banking Soundness Index, reflecting improved capitalization and resilience in the banking system. This suggests that the Bank of Albania's policy interventions have been effective in safeguarding financial stability.

Figure 4. Results of the macroprudential policy index shock scenario.



The interaction between the two policy domains is particularly revealing. The results show that when macroprudential policy is tightened—thereby improving the soundness indicator—monetary policy tends to ease, with a reduction in the policy interest rate. In other words, stricter macroprudential regulation can create space for a more accommodative monetary stance that supports economic activity. This finding has important implications for policymaking, as it confirms that the coordinated use of macroprudential instruments can allow the Bank of Albania to pursue its primary mandate of price stability while simultaneously preserving financial stability.

In essence, macroprudential policy acts as a safeguard that frees monetary policy from potential trade-offs with financial stability. This finding carries significant weight for policymaking, as it validates the Bank of Albania's central hypothesis on the coordinated use of the two frameworks and confirms the appropriateness of its past decisions. In situations where the policy rate approached its lower bound, or when the transmission of monetary impulses

weakened—as occurred during the European sovereign debt crisis, the 2019 earthquake, and the COVID-19 pandemic—the Bank of Albania resorted to easing macroprudential requirements to sustain economic activity. Such episodes illustrate the practical value of policy interaction, showing that coordination enhances effectiveness without undermining the hierarchy of objectives.

The results further suggest an asymmetric relationship between the two policies. While monetary policy does not exert direct influence on macroprudential measures, the latter provide the space for monetary policy to operate independently of banking soundness concerns. This preserves price stability as the Bank's primary mandate, while financial stability remains a complementary objective that supports, rather than constrains, the pursuit of the main goal. In this sense, the secondary objective is effectively placed in the service of the primary one, ensuring coherence in the overall policy strategy of the Bank of Albania.

CONCLUSION AND DISCUSSION

This research explores the interplay between monetary and macroprudential policies and how they respond to each other in the pursuit of their respective goals. While earlier studies—both in Albania and internationally—have examined these interactions, most have relied on single-equation approaches. Such frameworks are limited because they fail to capture the simultaneous dynamics and endogeneity among variables. To overcome this limitation, the present study employs a system-of-equations methodology, enabling a more comprehensive analysis where variables influence and respond to one another concurrently. Specifically, autoregressive vector models are applied to assess the behavior and interdependencies of macroeconomic and financial indicators.

A preliminary statistical assessment of the data series was carried out to properly identify the empirical structure of the model. The evidence revealed two cointegrating relationships, providing a strong basis for model specification. In line with Oularis, Pagan, and Restrepo (2018), this study incorporates the information embedded in the data-generating process into the identification scheme, thereby minimizing the author's discretionary choices in model constraints. This approach enhances the robustness and credibility of the results, constituting an important methodological contribution to the literature.

The empirical results underscore the significant influence of monetary policy on macroeconomic activity. Increases in the base interest rate are found to contract GDP and exert a swift downward adjustment on prices, confirming the effectiveness of monetary policy transmission. In contrast, macroprudential indicators appear largely unaffected by changes in monetary policy, highlighting the independence of the two policy domains. This separation underlines the importance of preserving policy autonomy to safeguard effectiveness.

The findings also demonstrate the central role of macroprudential measures in shaping credit conditions, economic activity, and banking stability. While restrictive measures tend to curb credit expansion and reduce output and inflation, they simultaneously strengthen the banking soundness index. This dual outcome suggests that the Bank of Albania's macroprudential stance has effectively balanced the objectives of financial and price stability.

Given these complementarities, coordinated policymaking becomes crucial. Effective alignment between monetary and macroprudential instruments ensures the attainment of stability objectives while limiting the risk of conflicting measures. Policymakers should retain the flexibility to adjust macroprudential tools according to shifts in banking sector resilience and emerging risks, guided by continuous monitoring of soundness indicators.

Furthermore, the Albanian context, characterized by high euroization, requires particular attention to external shocks. Decisions of the European Central Bank and exchange rate

dynamics exert considerable influence on domestic outcomes, and their effects must be incorporated into the design of national policy responses.

While the results are valuable for both theory and practice, they are drawn from the setting of a small open economy with a flexible exchange rate regime, liberalized capital flows, and independent monetary authority. It remains an open question whether similar conclusions would hold in economies with different institutional arrangements, such as currency board systems or regimes where financial stability takes precedence over price stability. Future studies could address these issues by conducting comparative analyses across alternative monetary frameworks. Such research would not only deepen the understanding of policy interactions but also provide practical guidance for central banks operating under diverse economic and institutional conditions.

REFERENCES

Adrian, T and H S Shin (2012): "Procyclical leverage and value-at-risk", Federal Reserve Bank of New York Staff Report, 338, Federal Reserve Bank, New York.

Aiyar, S, W Charles, C Calomiris and W Tomasz (2014): "Identifying channels of credit substitution when bank capital requirements are varied", Bank of England Working Paper, no 485, January.

Allen, F and G Douglas (2000): "Bubbles and crises", Economic Journal, vol 110, no 460, pp 236–55.

Altavilla, C., Laeven, L., & Peydró, J. L. (2020). Monetary and Macroprudential Policy Complementarities: evidence from European credit registers. ECB Working Paper No. 2504. https://www.ecb.europa.eu/pub/pdf/scpwps/ecb.wp2504~2ea8ce96ed.en.pdf.

Bean, C, P Matthias, P Adrian, and T Taylor (2010): "Monetary policy after the fall", Federal Reserve Bank of Kansas City in Macroeconomic Challenges: The Decade Ahead: Proceedings of the Federal Reserve Bank of Kansas City Economic Symposium, Jackson Hole.

Bernanke, Ben, M Gertler, and S Gilchrist, (1996): "The financial accelerator and the flight to quality", Review of Economics and Statistics, vol 78, no 1.

Bhattacharya, S (1982): "Aspects of monetary and banking theory and moral hazard", Journal of Finance, vol 37, pp 371−384.

Borio, C and H Zhu (2008): "Capital regulation, risk-taking and monetary policy: a missing link in the transmission mechanism?", BIS Working Paper, no 268, December.

Bruno, V, and H S Shin (2012): "Capital flows and the risk-taking channel of monetary policy", 11th BIS Annual Conference, Bank for International Settlements, Basel.

Ciccarelli, M, A Maddaloni, and J-L Peydró (2010): "Trusting the bankers, a new look at the credit channel of monetary policy", ECB Working Paper Series, no 1228, European Central Bank, Frankfurt.

Cozzi, G, M Darracq Pariès, P Karadi, J Körner, C Kok, F Mazelis, K Nikolov, E Rancoita, A Van der Ghote and J Weber (2020), "Macroprudential policy measures: macroeconomic impact and interaction with monetary policy", ECB, Working Paper Series No 2376.

Darracq Paries, M., Kok, C. & Rancoita E. (2019). Macroprudential policy in a monetary union with cross-border banking. ECB Working Paper No. 2260. https://www.ecb.europa.eu/pub/pdf/scpwps/ecb.wp2260~30decf9827.en.pdf.

Dell'Ariccia, G, L Laeven, and R Marquez (2015): "Bank leverage and monetary policy's risk-taking channel: evidence from the United States", International Monetary Fund, mimeo.

Del Negro, M and C Otrok (2007): “99 Luftballons: monetary policy and the house price boom across U.S. states”, Journal of Monetary Economics, vol 54, pp 1962–985.

Dimova, D., Kongsamut, P., & Vandenbussche, J. (2016). Macroprudential Policies in Southeastern Europe (IMF Working Paper No. 2016/029). International Monetary Fund. https://www.imf.org/en/Publications/WP/Issues/2016/12/31/Macroprudential-Policies-in-Southeastern-Europe-43709

Hahm, J H, F Mishkin, H S Shin, and K Shin (2012): “Macroprudential policies in open emerging economies,” NBER Working Paper Series 17780, Cambridge, Massachusetts: National Bureau of Economic Research.

Goodhart, C, D Tsomocos and A Vardoulakis (2009): "Foreclosures, monetary policy and financial stability,” conference proceedings of the 10th International Academic Conference on Economic and Social Development, Moscow.

Illing, G (2007): “Financial stability and monetary policy — a framework”, CESifo Working Paper, no 1971.

IMF (2023), “Macroprudential Policy and Bank Systemic Risk: Does Inflation Targeting Matter?” IMF Working Paper No. WP/2023/119

International Monetary Fund, 2013a, The interaction of monetary and macroprudential policies, International Monetary Fund, Washington.

_____ 2013b, The interaction of monetary and macroprudential policies—background paper, International Monetary Fund, Washington.

_____ 2013c, Key aspects of macroprudential policies, International Monetary Fund, Washington.

Jiménez, G, S Ongena, J L Peydró and J Saurina (2012): “Credit supply and monetary policy: identifying the bank-balance sheet channel with loan applications”, American Economic Review, vol 102 (5), pp 2301−2326.

Jiménez, G, S Ongena, J-L Peydró and J Saurina, (2014): “Hazardous times for monetary policy: what do twenty-three million bank loans say about the effects of monetary policy on credit risk-taking?” Econometrica, vol 82 (2), pp 463–505.

Karadi, P., & Nakov, A. (2020). Effectiveness and addictiveness of quantitative easing. Journal of Monetary Economics, Volume 117, January 2021, Pages 1096-1117.

Laeven, L, A Maddaloni and C Mendicino, (February, 2022), “Monetary Policy, Macroprudential Policy and Financial Stability”, ECB Working Paper No. 2022/2647, Available at SSRN: https://ssrn.com/abstract=4043288 or http://dx.doi.org/10.2139/ssrn.4043288

Mendicino, C., Nikolov, K., Rubio Ramirez, J., Suarez, J. & Supera, D. (2020a). “Twin Defaults and Bank Capital Requirements”. CEPR Discussion Paper 14330. ECB Working Paper No. 2414. https://www.ecb.europa.eu/pub/pdf/scpwps/ecb.wp2414~7e78d5098c.en.pdf

Mendicino, C., Nikolov, K., Suarez, J., & Supera, D. (2020b). Bank Capital in the Short and in the Long Run. Journal of Monetary Economics, 115, 64-79.

Merrouche, O, and E Nier (2010): “What caused the global financial crisis? – Evidence on the drivers of financial imbalances 1999–2007”, IMF Working Paper, no 10/265, International Monetary Fund, Washington.

Ouliaris, S., Pagan, A. R., & Restrepo, J. (2018). Quantitative Macroeconomic Modeling with Structural Vector Autoregressions: An EViews Implementation.

Papavangjeli, M., Bode A. dhe Vorpsi B. (2017), "Ndikimi i politikës monetare te marzhi neto i interesave: Evidencë për Shqipërinë", Revista Ekonomike 6M-I, 2017.

Papavangjeli, M., Bode, A., & Vorpsi, B. (2024, Forthcoming). Monetary Policy and Bank Profitability: Unveiling Nonlinearities in an Era of Low Interest Rates and Flattening Yield Curves. Bank of Albania Working Paper Series.

Rey, H (2013): "Dilemma not trilemma: the global financial cycle and monetary policy independence", paper presented at the Federal Reserve Bank of Kansas City Jackson Hole Symposium, August.

Sejko, G., Dushku, E., 2018, "Rritja ekonomike në Shqipëri: Evidenca të reja, në studime mbi sistemin bankar dhe zhvillimin ekonomik", ed. Sejko, G., Banka e Shqipërisë, Tiranë, 2018, ISBN 978-9928-262-11-0

Tressel, T, and Y Zhang (2016): "Effectiveness and channels of macroprudential instruments", IMF Working Paper, no 16/4, International Monetary Fund, Washington.

Van der Ghote, A. (2021). Replication data for: Interactions and Coordination between Monetary and Macroprudential Policies. American Economic Association [publisher], Inter-university Consortium for Political and Social Research [distributor]. https://doi.org/10.3886/E118645V1.

Vika, Ilir, dhe Suljoti, Erjona. (2018) "Një rishikim mbi kanalin e kredisë bankare në mekanizmin e transmisionit në Shqipëri", në botimin me titull "Studime mbi sistemin bankar dhe zhvillimin ekonomik" Sejko, Gent. (2018), Banka e Shqipërisë.

COMPREHENSIVE BENCHMARKS FOR AMYLOID PRONENESS PREDICTION

Zohra YAGOUB

Département d'Informatique Université des Sciences et de la Technologie d'Oran Mohamed Boudiaf

Hafida BOUZIANE

Département d'Informatique Université des Sciences et de la Technologie d'Oran Mohamed Boudiaf

ABSTRACT

Amyloid prediction is regarded as one of the most significant recent advances in various sciences due to its relation to the effective diagnosis of several diseases, including Alzheimer's disease, diabetes mellitus, prion diseases, and familial amyloidosis, as well as its role in designing new protein-based therapeutics. To identify amyloidogenic sequences, computational methods offer a powerful, cost-effective, and rapid alternative to laborious experimental approaches. However, the reliability, robustness, and ultimately, the accuracy of these in silico prediction models are closely related to the quality of the datasets and the strategies used for training, validation, and evaluation. This work systematically explores the essential benchmarks necessary for achieving accurate amyloid proneness prediction using machine learning and deep learning based tools. We delve into the critical criteria that define high-quality datasets, the methodological considerations, and the rigorous evaluation standards required to ensure the performance of predictive tools contributing to their utility and impact on the field.

Keywords: Amyloid prediction, generalization, benchmark datasets, experimental validation, robustness.

INTRODUCTION

Amyloid protein aggregation is a transition of proteins from soluble to fibrillar states where they lose their native functional structures and form insoluble deposits, leading to a variety of human diseases, including Alzheimer's, Parkinson's, Huntington's, and Type 2 Diabetes (Knowles et al., 2014). Therefore, amyloid prediction has become of interest to many scientists and has emerged in several disciplines. A critical step for accurate prediction is the understanding of the amyloid formation process, where proteins misfold and aggregate into insoluble fibrils called amyloid fibers that share a common cross-β spine architecture (Eisenberg and Jucker, 2012).

Beyond their role in pathology, it is increasingly recognized that some proteins also form functional amyloid structures, playing diverse and essential roles in biological processes across various organisms (Chiti and Dobson, 2006). Regardless of their functional outcome, understanding the fundamental characteristics of amyloid and the mechanisms of their formation is crucial for both therapeutic intervention and the development of robust bioinformatics predictive tools.

Considering the integration of sequence, structure, and other factors that lead to amyloid formation, computational approaches have emerged as useful tools for predicting

amyloidogenicity. These methods range from sequence-based algorithms that predict aggregation propensity for peptides and proteins, structure-based tools that identify aggregation-prone regions, machine learning (ML), and deep learning (DL) based approaches. Recently, several amyloid proneness studies have explored the application of various ML and DL algorithms. For example, AmyloGram, Cross-beta-RF, RFAmyloid, and ReRF-Pred predictors are trained using random forest classifiers (Burdukiewicz et al., 2017; Gonay et al., 2025; Niu et al., 2018; Teng et al., 2021). Bouziane and Chouarfia (2020) and Zhou et al. (2019) developed their methods using support vector machines for predicting amyloidogenic regions in proteins and peptides. APPNN and PredAmyl-MLP tools are created by employing artificial neural networks (Família et al., 2015; Li et al., 2020). Some developers combined several models and averaged them to get a single final predictor like AMYPred-FRL, ANuPP, and EcAmyloid (Charoenkwan et al., 2022; Prabakaran et al., 2021; Yang et al., 2023a). The adaptive boosting algorithm is trained using the multi-view features to obtain the Amy_Fuse predictor (Yang et al., 2023b). Eshari et al. (2023) introduced a protein aggregation propensity predictor by employing a logistic regression model that incorporates both sequence and feature information.

In the last two years, deep learning models have been integrated into amyloid prediction studies. In the AggreProt tool (Planas-Iglesias et al., 2024), an ensemble of recurrent deep neural networks is used, highlighting its effectiveness in predicting and engineering aggregation-prone regions within a protein sequence. Sun et al. (2024) developed a graph convolutional neural network model for predicting protein aggregation using the AlphaFold dataset with the Protein Data Bank database.

Zhuowen Li proposed an attention-based bidirectional long short-term memory model for in silico identification of amyloid proteins (Li, 2025). Significant progress has been made in this field, such as using large language models. For example, AggNet is developed through a deep learning framework based on the protein language model ESM2 (He et al., 2025). Notably, once these computational methods are completed and evaluated, they demonstrate their performance and generalization ability when comprehensive benchmarks are established.

METHODOLOGY

This systematic review was completed by collecting information from peer-reviewed scientific literature focusing on amyloid formation, amyloid prediction algorithms, and the construction of datasets for protein aggregation studies. Searches were performed on major scientific databases, including Elsevier, PubMed, and Google Scholar. The search considered terms including "amyloid prediction", "amyloidogenic sequence databases," "protein aggregation", and "bioinformatics tools". Literature discussing the construction of datasets, validation, and limitations of amyloid predictors was considered.

This section defines the essential criteria that contribute to an accurate amyloid prediction, aiming to guide researchers in their future work in this field. We categorize these benchmarks according to three core areas: Data collection, Training, and Evaluation.

DATA COLLECTION

A benchmarking dataset in amyloid prediction should be a robust resource that reflects the diverse biological reality of amyloid formation, allowing for the rigorous evaluation and comparison of predictive algorithms. Therefore, it should combine these essential characteristics:

- **Experimental Verification:** The primary requirement in constructing an amyloid

prediction dataset is that every amyloid and non-amyloid entry in it must be supported by robust experimental evidence. This includes, but is not limited to, the following techniques:

- **X-ray Fiber Diffraction:** These techniques provide direct structural evidence of the cross-β architectures. The characteristic reflections at approximately 4.7 Å and 10.2 Å are definitive indicators of amyloid fiber detection (Eisenberg and Jucker, 2012).
- **Solid-State Nuclear Magnetic Resonance (ssNMR):** ssNMR provides detailed structural information on amyloid fibrils at the atomic level, confirming the precise arrangement of β-strands and the overall cross-β topology (Tycko, 2011).
- **Congo Red Birefringence:** This method is used to confirm the presence of amyloid in tissue. It exhibits a characteristic apple-green birefringence under polarized light during in vitro investigations to detect amyloid deposits (Nilsson, 2004; Yakupova et al., 2019).
- **Thioflavin T staining (ThT):** ThT is a fluorescent dye used to study the structural properties and kinetics of amyloid fibril formation (Freire et al., 2014; Nielsen et al., 2001).
- **Transmission Electron Microscopy (TEM) and Atomic Force Microscopy (AFM):** These high-resolution techniques allow for direct demonstration of fibrillar morphologies that indicate the presence of protein aggregates with characteristic amyloid fibril structures (Nilsson, 2004; Ruggeri et al., 2019).

● **Biological Relevance and Diversity:** In addition to experimental rigor, a benchmarking dataset should include biological relevance and diversity. Computational predictors aim to identify amyloidogenic regions (ARs) in proteins that are relevant to human diseases or exhibit functional amyloid roles in various organisms. Therefore, the dataset should mainly contain:

- **Naturally Occurring Amyloids:** The most valuable entries are ARs derived from proteins known to form amyloid fibrils *in vivo* or *in vitro* under biologically relevant conditions. This includes sequences from proteins implicated in neurodegenerative diseases (e.g., Amyloid-β, Tau, α-synuclein, Huntingtin), systemic amyloidoses (e.g., transthyretin, immunoglobulin light chains), and functional amyloids (e.g., from bacteria, fungi, or human proteins with specific roles like Pmel17 or amyloid-forming hormones) (Fowler et al., 2006; Gazit, 2002).
- **Cross-Species Representation:** Including sequences from a variety of organisms (e.g., human, yeast, bacteria, viruses) ensures that the developed models are not overly biased towards a specific species (Beerten et al., 2015).
- **Consideration of Experimental Conditions:** Experimental conditions (e.g., pH, ionic strength, temperature) can significantly influence amyloid formation kinetics and thermodynamics (Chiti and Dobson, 2006). Excluding data proven to have been formed under extreme conditions can lead to accurate prediction.

● **Balanced Classes:** Given the imbalance of the published amyloid-related datasets, which influence the prediction performance of a predictor with low accuracy for the minority class but high accuracy for the majority class, strategies such as oversampling the minority class should be adopted to deal with this problem.

● **Non-Redundancy:** When collecting data from various sources, the benchmarking dataset may contain many redundant samples. This affects the experimental results of the amyloid predictor, which does not reflect the true predictive performance on novel sequences. To avoid overfitting and reduce homologous bias, tools like CD-HIT should be used to remove any sequence redundancy in the original positive and negative datasets.

TRAINING AND OPTIMIZATION

To establish a robust amyloid predictor, significant challenges must be overcome during the training phase:

- **Features Interpretability:** One of the main objectives of research on protein aggregation is to unveil the properties that underpin amyloid formation. Therefore, in order to improve scientific knowledge of amyloidogenicity, the features selected for training should be interpretable and align with current understanding of amyloid structure and aggregation mechanisms.

- **Addressing Overfitting and Parameter Optimization:** Rigorous validation procedures are crucial during model training, such as K-fold cross-validation and jackknife cross-validation tests, to address overfitting problems, ensure the reliability of the developed model, and optimize its hyperparameters.

EVALUATION

While evaluating the performance of the developed tools, critical benchmarks should be applied:

- **Comprehensive Performance Evaluation:** To examine and compare the performance of amyloid prediction models, various metrics should be used, including sensitivity, specificity, precision, F1-score, Matthew's correlation coefficient, and the Area Under the Receiver Operating Characteristic Curve. Other measures that align with amyloid-prone regions prediction are important to fully reflect the reliability, robustness, and generalization of the model prediction results.

- **Independent Validation Sets:** A cornerstone of robust amyloid predictor evaluation is the use of an independent test set. This portion of the data is held back and not used during any stage of model development to provide an unbiased assessment of the model's generalization performance on unseen data.

- **Generalization Across Different Levels of Protein Complexity**: Robust amyloid predictors should generalize across various levels of protein sequence, involving both short peptides and full-length proteins. Many amyloid prediction models are trained on short, experimentally validated amyloidogenic peptides (e.g., 5–15 residues). However, these models must be able to predict aggregation-prone regions within the context of full-length proteins accurately. If the method is designed to predict the amyloid proteins, it must not only classify a protein as amyloidogenic but also identify the aggregation-prone regions responsible for the formation of the amyloid.

APPLICATIONS OF THE DETAILED BENCHMARKS IN LITERATURE

This table systematically reviews examples of selected amyloid prediction studies, highlighting how they apply key benchmarks across data collection, model training and evaluation, and generalization assessment.

	Benchmarks	Application in amyloid prediction
DATA COLLECTION	**Experimental Verification**	-The Cross-Beta DB is a database created by Gonay et al. (2025) from the Protein Data Bank (PDB) and AmyPro database. Its entries are composed of cross-β amyloids and examined based on experimental studies, including X-ray fiber diffraction, electron diffraction via the transmission electron microscope, ss-NMR spectroscopy, Congo-red birefringence, electron microscopy, Fourier Transform Infrared Spectroscopy, and Circular Dichroism spectroscopy.
	Biological Relevance and Diversity	*-The commonly used database in recent amyloid protein predictors - AmyPro (Varadi et al., 2018) is a collection of amyloid fibre-forming proteins classified into pathogenic proteins, functional amyloids, and functional prions.* -The pH and temperature were selection criteria to create the Cross-Beta DB (Gonay et al., 2025).
	Classes Balance	-The OPTICS-SMOTE (Ordering Points To Identify the Clustering Structure - synthetic minority over-sampling technique) is proposed in (Yang et al., 2023b) to solve the imbalanced data problem.
	Non-Redundancy	-The redundant sequences in the dataset constructed in ECAmyloid (Yang et al., 2023a) are eliminated using the CD-HIT program with a cutoff threshold of 80%.
TRAINING AND OPTIMIZATION	**Features Interpretability**	-The method developed by Bouziane and Chouarfia (2020) specifically integrates key protein sequence features implicated in amyloidogenesis, including predicted secondary structure and solvent accessibility. -The propensity scores of dipeptides are extracted in iAMY-SCM (Charoenkwan et al., 2021), providing an understanding and knowledge of the biological process of amyloid proteins
	Addressing Overfitting and Parameter Optimization	-The 10-fold cross-validation procedure is explored in AMYPred-FRL (Charoenkwan et al., 2022) to perform parameter optimization of some protein sequence descriptors.
EVALUATION	**Performance Evaluation**	-The prediction of aggregation-prone regions in amyloidogenic proteins in ANuPP (Prabakaran et al., 2021) is compared based on the Segment Overlap measure (Zemla et al., 1999).
	Independent Validation Sets	-The ReRF-Pred (Teng et al., 2021) predictor is compared with state-of-the-art methods on two independent datasets: Pep-251 and Reg33.
	Generalization Across Different Levels of Protein Complexity	-AggreProt server (Planas-Iglesias et al., 2024) provides a per-residue numerical aggregation propensity value and an overall protein aggregation propensity profile.

Table 1: Application of Key Benchmarks in Selected Amyloid Predictor Literature

CONCLUSION

In conclusion, this review has highlighted the advantages of integrating key benchmarks into amyloid prediction. This integration has the potential to significantly increase the predictive tools' performance, generalization, and reliability across three core areas, commencing with data collection, by defining essential characteristics that should be present in a high-quality dataset. Beyond data, the training and evaluation phases demand robust feature engineering and a comprehensive performance evaluation using metrics beyond simple accuracy, while rigorous cross-validation is essential for optimizing hyperparameters and preventing overfitting. Ultimately, the hallmark of a truly accurate and impactful amyloid predictor lies in its generalization ability, its capacity to perform reliably on entirely independent validation sets, and to accurately identify aggregation-prone regions not only within short peptides but also within the complex context of full-length proteins. By considering these rigorous benchmarks, the scientific community can foster the development of highly accurate and reliable amyloid prediction tools, thereby significantly advancing our understanding of protein misfolding diseases and facilitating the design of novel protein-based therapeutics.

REFERENCES

Beerten, J., Van Durme, J., Gallardo, R., Capriotti, E., Serpell, L., Rousseau, F., Schymkowitz, J., 2015. WALTZ-DB: a benchmark database of amyloidogenic hexapeptides. Bioinformatics 31, 1698–1700. https://doi.org/10.1093/bioinformatics/btv027

Bouziane, H., Chouarfia, A., 2020. Sequence- and structure-based prediction of amyloidogenic regions in proteins. Soft Comput. 24, 3285–3308. https://doi.org/10.1007/s00500-019-04087-z

Burdukiewicz, M., Sobczyk, P., Rödiger, S., Duda-Madej, A., Mackiewicz, P., Kotulska, M., 2017. Amyloidogenic motifs revealed by n-gram analysis. Sci. Rep. 7, 12961. https://doi.org/10.1038/s41598-017-13210-9

Charoenkwan, P., Ahmed, S., Nantasenamat, C., Quinn, J.M.W., Moni, M.A., Lio', P., Shoombuatong, W., 2022. AMYPred-FRL is a novel approach for accurate prediction of amyloid proteins by using feature representation learning. Sci. Rep. 12, 7697. https://doi.org/10.1038/s41598-022-11897-z

Charoenkwan, P., Kanthawong, S., Nantasenamat, C., Hasan, Md.M., Shoombuatong, W., 2021. iAMY-SCM: Improved prediction and analysis of amyloid proteins using a scoring card method with propensity scores of dipeptides. Genomics 113, 689–698. https://doi.org/10.1016/j.ygeno.2020.09.065

Chiti, F., Dobson, C.M., 2006. Protein Misfolding, Functional Amyloid, and Human Disease. Annu. Rev. Biochem. 75, 333–366. https://doi.org/10.1146/annurev.biochem.75.101304.123901

Eisenberg, D., Jucker, M., 2012. The Amyloid State of Proteins in Human Diseases. Cell 148, 1188–1203. https://doi.org/10.1016/j.cell.2012.02.022

Eshari, F., Momeni, F., Nezhadi, A.F., Shemehsavar, S., Habibi-Rezaei, M., 2023. Prediction of protein aggregation propensity employing SqFt-based logistic regression model. Int. J. Biol. Macromol. 249, 126036. https://doi.org/10.1016/j.ijbiomac.2023.126036

Família, C., Dennison, S.R., Quintas, A., Phoenix, D.A., 2015. Prediction of Peptide and Protein Propensity for Amyloid Formation. PLOS ONE 10, e0134679. https://doi.org/10.1371/journal.pone.0134679

Fowler, D.M., Koulov, A.V., Alory-Jost, C., Marks, M.S., Balch, W.E., Kelly, J.W., 2006. Functional amyloid formation within mammalian tissue. PLoS Biol. 4, e6. https://doi.org/10.1371/journal.pbio.0040006

Freire, S., De Araujo, M.H., Al-Soufi, W., Novo, M., 2014. Photophysical study of Thioflavin T as fluorescence marker of amyloid fibrils. Dyes Pigments 110, 97–105. https://doi.org/10.1016/j.dyepig.2014.05.004

Gazit, E., 2002. A possible role for π-stacking in the self-assembly of amyloid fibrils. FASEB J. 16, 77–83. https://doi.org/10.1096/fj.01-0442hyp

Gonay, V., Dunne, M.P., Caceres-Delpiano, J., Kajava, A.V., 2025. Developing machine-learning-based amyloidogenicity predictors with Cross-Beta DB. Alzheimers Dement. 21. https://doi.org/10.1002/alz.14510

He, W., Xu, X., Li, H., Zhou, J., Gao, X., 2025. AggNet: Advancing protein aggregation analysis through deep learning and protein language model. Protein Sci. Publ. Protein Soc. 34, e70031. https://doi.org/10.1002/pro.70031

Knowles, T.P.J., Vendruscolo, M., Dobson, C.M., 2014. The amyloid state and its association with protein misfolding diseases. Nat. Rev. Mol. Cell Biol. 15, 384–396. https://doi.org/10.1038/nrm3810

Li, Y., Zhang, Z., Teng, Z., Liu, X., 2020. PredAmyl-MLP: Prediction of Amyloid Proteins Using Multilayer Perceptron. Comput. Math. Methods Med. 2020, 1–12. https://doi.org/10.1155/2020/8845133

Li, Z., 2025. Predicting amyloid proteins using attention-based long short-term memory. PeerJ Comput. Sci. 11, e2660. https://doi.org/10.7717/peerj-cs.2660

Nielsen, L., Frokjaer, S., Brange, J., Uversky, V.N., Fink, A.L., 2001. Probing the Mechanism of Insulin Fibril Formation with Insulin Mutants. Biochemistry 40, 8397–8409. https://doi.org/10.1021/bi0105983

Nilsson, M., 2004. Techniques to study amyloid fibril formation in vitro. Methods 34, 151–160. https://doi.org/10.1016/j.ymeth.2004.03.012

Niu, M., Li, Y., Wang, C., Han, K., 2018. RFAmyloid: A Web Server for Predicting Amyloid Proteins. Int. J. Mol. Sci. 19, 2071. https://doi.org/10.3390/ijms19072071

Planas-Iglesias, J., Borko, S., Swiatkowski, J., Elias, M., Havlasek, M., Salamon, O., Grakova, E., Kunka, A., Martinovic, T., Damborsky, J., Martinovic, J., Bednar, D., 2024. AggreProt: a web server for predicting and engineering aggregation prone regions in proteins. Nucleic Acids Res. 52, W159–W169. https://doi.org/10.1093/nar/gkae420

Prabakaran, R., Rawat, P., Kumar, S., Michael Gromiha, M., 2021. ANuPP: A Versatile Tool to Predict Aggregation Nucleating Regions in Peptides and Proteins. J. Mol. Biol. 433, 166707. https://doi.org/10.1016/j.jmb.2020.11.006

Ruggeri, F.S., Šneideris, T., Vendruscolo, M., Knowles, T.P.J., 2019. Atomic force microscopy for single molecule characterisation of protein aggregation. Arch. Biochem. Biophys. 664, 134–148. https://doi.org/10.1016/j.abb.2019.02.001

Sun, J., Song, J., Kim, J., Kang, S., Park, E., Seo, S., Min, K., 2024. Enhancing protein aggregation prediction: a unified analysis leveraging graph convolutional networks and active learning. RSC Adv. 14, 31439–31450. https://doi.org/10.1039/D4RA06285J

Teng, Z., Zhang, Z., Tian, Z., Li, Y., Wang, G., 2021. ReRF-Pred: predicting amyloidogenic regions of proteins based on their pseudo amino acid composition and tripeptide composition. BMC Bioinformatics 22, 545. https://doi.org/10.1186/s12859-021-04446-4

Tycko, R., 2011. Solid-State NMR Studies of Amyloid Fibril Structure. Annu. Rev. Phys. Chem. 62, 279–299. https://doi.org/10.1146/annurev-physchem-032210-103539

Varadi, M., De Baets, G., Vranken, W.F., Tompa, P., Pancsa, R., 2018. AmyPro: a database of proteins with validated amyloidogenic regions. Nucleic Acids Res. 46, D387–D392. https://doi.org/10.1093/nar/gkx950

Yakupova, E.I., Bobyleva, L.G., Vikhlyantsev, I.M., Bobylev, A.G., 2019. Congo Red and amyloids: history and relationship. Biosci. Rep. 39. https://doi.org/10.1042/bsr20181415

Yang, R., Liu, J., Zhang, L., 2023a. ECAmyloid: An amyloid predictor based on ensemble learning and comprehensive sequence-derived features. Comput. Biol. Chem. 104, 107853. https://doi.org/10.1016/j.compbiolchem.2023.107853

Yang, R., Liu, J., Zhang, Q., Zhang, L., 2023b. Multi-view feature fusion and density-based minority over-sampling technique for amyloid protein prediction under imbalanced data. Appl. Soft Comput. 150, 111100. https://doi.org/10.1016/j.asoc.2023.111100

Zemla, A., Venclovas, ?Eslovas, Fidelis, K., Rost, B., 1999. A modified definition of Sov, a segment-based measure for protein secondary structure prediction assessment. Proteins Struct. Funct. Genet. 34, 220–223. https://doi.org/10.1002/(SICI)1097-0134(19990201)34:2<220::AID-PROT7>3.0.CO;2-K

Zhou, C., Liu, S., Zhang, S., 2019. Identification of amyloidogenic peptides via optimized integrated features space based on physicochemical properties and PSSM. Anal. Biochem. 583, 113362. https://doi.org/10.1016/j.ab.2019.113362

DEEP LEARNING-DRIVEN FAULT DETECTION IN SOLAR PANELS: A YOLOV5M IMPLEMENTATION APPROACH

Gulnabat GOCHOVA

Gazi University Faculty of Engineering, Department of Electrical - Electronic Engineering, Ankara, Turkiye

ORCID ID: https://orcid.org/0009-0003-2298-8822

Kubilay AYTURAN

Gazi University Faculty of Engineering, Department of Electrical - Electronic Engineering, Ankara, Turkiye

ORCID ID: https://orcid.org/0000-0001-9406-4694

Fırat HARDALAÇ

Gazi University Faculty of Engineering, Department of Electrical - Electronic Engineering, Ankara, Turkiye

ORCID ID: https://orcid.org/0000-0003-1358-0756

ABSTRACT

Solar panel efficiency is critically impacted by surface-level defects such as cracked cells, dirt accumulation, and structural damage, which necessitate rapid and accurate detection to maintain optimal energy output. Traditional manual inspection methods are labor-intensive, costly, and prone to human error, highlighting the need for automated solutions. This study presents a robust deep learning-based approach utilizing the YOLOv5m architecture to classify and localize three defect types (broken, dirty, and clean) in aerial imagery of solar farms. The collected dataset contains 6,686 high-resolution images annotated in YOLO format, split into training (64%), validation (18%), and test sets (18%). Through comparative analysis of four YOLOv5 variants (YOLOv5s, m, l, x), we demonstrate that YOLOv5m achieves the optimal balance between accuracy and computational efficiency, attaining 96.4% mAP@0.5 after 50 epochs of training on a Kaggle T4 GPU with a batch size of 16. The model's lightweight design (42MB) enables real-time deployment on edge devices, reducing inspection costs compared to manual methods. This work provides a scalable, drone-compatible solution for industrial solar farm maintenance, validated by class-specific detection accuracies of 99.3% for broken cells, 95.7% for dirty panels, and 94.0% for clean panels.

INTRODUCTION

Solar energy is one of the most promising renewable sources for sustainable development, offering clean, abundant, and increasingly cost-effective electricity generation [1]. However, the environmental and operational factors can reduce the performance and efficiency of photovoltaic (PV) systems over time. Common issues include surface contamination from dust and dirt, micro-cracks, and severe damage such as broken glass, leading to power losses [2]. For example, even minor soiling can cause a significant drop in output efficiency, while cracks can create hotspots that permanently damage PV modules [3][5].

Traditionally, solar panel inspections have been conducted manually, with the help of on-site technicians who visually inspect or use handheld devices to identify faults. This method is effective in small-scale installations; however, in large solar farms where regular monitoring is required, manual inspection is time-consuming, labor-intensive, costly, and highly susceptible to human error [4]. The limitations of manual inspections have driven research into automated and intelligent fault detection systems that can provide accurate, real-time assessments [6].

Deep learning-based computer vision systems, particularly object detection algorithms like YOLO (You Only Look Once), have shown remarkable potential in addressing this challenge by enabling rapid, accurate, and scalable inspection solutions [3][8][7]. Among YOLO models, the YOLOv5 family developed by Ultralytics [9] offers multiple variants—YOLOv5s, YOLOv5m, YOLOv5l, and YOLOv5x—each balancing accuracy, speed, and computational requirements differently [8]. Several studies have demonstrated that YOLOv5 outperforms traditional convolutional neural network (CNN)-based methods for solar panel defect detection in both precision and inference time [3][10][5].

This project uses YOLOv5m to detect and classify solar panel faults into three categories: clean, dirty, and broken. The YOLOv5m variant was selected after a comparative evaluation of all YOLOv5 models to find the best trade-off between detection accuracy and computational efficiency, making it an optimal choice for real-world deployment in large solar farms.

CONCEPTUAL FRAMEWORK

Problem Definition and Objective

The core challenge lies in automating the inspection of solar panels to detect faults such as broken surfaces and dirt coverage. Manual inspection not only consumes considerable time and human effort but also lacks consistency, especially in large solar farms where panel counts can reach tens of thousands [4]. Automated image-based inspection systems are needed to handle large volumes of data reliably and in real-time.

Our primary objective is to create a computer vision system capable of identifying the condition of solar panels using image classification and object detection methods. Specifically, the model classifies each panel into one of three categories: clean, dirty, or broken.

To accomplish this, the project sets out to:

- Develop a detection pipeline using the YOLOv5m model.
- Evaluate the model's performance using metrics such as precision, recall, and mAP.
- Compare YOLOv5m’s results against other YOLOv5 models (YOLOv5s, YOLOv5l, YOLOv5x).
- Recommend the best-fit model based on performance and practicality.

Before finalizing YOLOv5m as the preferred model, all four YOLOv5 variants were evaluated. YOLOv5s and YOLOv5m were trained for 20 epochs each, while YOLOv5l and YOLOv5x required a minimum of 25 epochs to reach stable performance levels [8]. The larger models (YOLOv5l, YOLOv5x) were more computationally expensive and time-consuming to train, while YOLOv5m provided a balance of speed and accuracy [3][5].

Model Selection

YOLO (You Only Look Once) is a popular real-time object detection architecture developed for fast and efficient object detection. The YOLOv5 series by Ultralytics consists of four primary versions [9]:

- YOLOv5s (small): Designed for speed and lower computational cost, but generally less accurate.
- YOLOv5m (medium): Balanced between speed and accuracy.
- YOLOv5l (large): Higher accuracy, but slower training and inference.
- YOLOv5x (extra-large): Highest accuracy among the four, but very computationally demanding.

To identify the most suitable model for solar panel fault detection, we conducted a comparative training experiment using all four YOLOv5 versions. Each model was trained under the same dataset conditions:

- YOLOv5s and YOLOv5m: Trained for 20 epochs
- YOLOv5l and YOLOv5x: Trained for 25 epochs due to their higher convergence thresholds

Despite being lighter, YOLOv5m exhibited strong results close to those of the larger models, while consuming significantly fewer computational resources [8] [5]. The training process for YOLOv5l and YOLOv5x took considerably longer and required higher GPU memory, making them impractical for resource-constrained environments.

Based on this analysis, YOLOv5m was selected for its excellent trade-off between performance and efficiency. It offered high precision and recall scores while maintaining a fast and smooth training experience. This made it the best fit for our objective of deploying a scalable and accurate solar panel inspection system. Table 1 displays the results of a comparison in numbers.

MODEL	mAP0.5	PRECISION	RECALL	TRAINING TIME
YOLOv5s	0.943	0.885	0.887	~0.3hrs
YOLOv5m	0.948	0.901	0.907	0.583hrs
YOLOv5l	0.939	0.827	0.876	~1.2hrs
YOLOv5x	0.957	0.886	0.888	1.545hrs

Table 1. Evaluation Metrics and Performance Results

METHODOLOGY

Dataset Preparation

After the desired model has been selected, we started the training of the YOLOv5m model with the meticulously collected dataset. For this task, a custom image dataset was used, formatted

specifically for the YOLO object detection framework [3]. The dataset was manually labeled and structured into three distinct categories:

- Broken: Solar panels with visible cracks or damage
- Dirty: Panels covered with dust or dirt
- Clean: Panels without visible defects

The complete dataset consisted of 6,686 images, divided as follows:

- Training set: 4,254 images
- Validation set: 1,216 images
- Test set: 1,216 images

Each image had a corresponding .txt file that contained object coordinates and class information in YOLO format. The images and labels were systematically organized under the train, val, and test folders, adhering to the YOLOv5 directory structure. This labeling process was crucial for training the model to detect each class with high accuracy.

Model Training and Evaluation Setup

Training was conducted using the Kaggle Notebook environment, which supports GPU acceleration. The Ultralytics YOLOv5 GitHub repository was used to access the model architecture and training scripts [9]. The training procedure involved the following configuration:

- **Pretrained Weights:** YOLOv5m
- **Image Size:** 640 × 640 pixels for a clear enough pictures to spot tiny cracks
- **Batch Size:** 16 for optimized speed and accuracy
- **Epochs:** Initially tested with 1 and 20 epochs to test the stability of the training; final training ran for 50 epochs to improve the metrics for better accuracy.
- **Validation:** Performed after each epoch to monitor model performance

Performance Metrics Used

In deep learning-based object detection, evaluating performance accurately is mandatory [3]. The metrics used include:

- **Precision:** Indicates how many of the predicted bounding boxes were correct (i.e., how precise the model is).
- **Recall:** Measures the model's ability to find all relevant objects.
- **mAP@0.5 (Mean Average Precision):** The average precision when Intersection over Union (IoU) is set at 0.5. This provides a clear idea of object detection accuracy.
- **mAP@0.5:0.95:** A more stringent and comprehensive metric that averages the precision across multiple IoU thresholds (from 0.5 to 0.95 with a step of 0.05).

In addition to numerical results, visual tools such as confusion matrices and performance curves were generated to interpret the model's behavior more intuitively.

Improvements on Yolov5m Model

Once the model that balances speed and accuracy were selected (YOLOv5m), the epoch number was increased to 50 in order to enhance the performance of the model. After training the YOLOv5m model for 50 epochs, a comparison table was built to observe the enhancement. Table 2 and Table 3 shows the improvements achieved on each evaluation metrics:

Metrics	20 epochs	50 epochs	Improvement
mAP0.5	0.948	0.964	+1.6%
mAP0.5-0.95	0.946	0.961	+1.5%
Precision	0.901	0.904	+0.3%
Recall	0.907	0.914	+0.7%

Table 2. Enhanced Performance of YOLOv5m after 50 epochs

Class	mAP (%)
Broken	99.3% (near-perfect)
Dirty	95.7% (robust)
Clean	94.0% (minor confusion with "dirty")

Table 3. The Results Obtained from a Confusion Matrix

These values above indicate that the model can accurately detect and differentiate between broken, dirty, and clean solar panels [3] [5]. The performance remained stable throughout training and showed consistent improvement across epochs. This high precision and recall combination confirms that the model has minimal false positives and misses very few actual faults, making it highly effective in practical applications.

Visual Evaluation Metrics

The following plots were generated to provide a visual understanding of model performance:

The Confusion Matrix of the Model is shown in Figure 1, the Precision-Recall Curve of the Model is shown in Figure 2, the F1 Score-Confidence Curve of the Model is shown in Figure 3, and the Recall-Confidence Curve of the Model is shown in Figure 4.

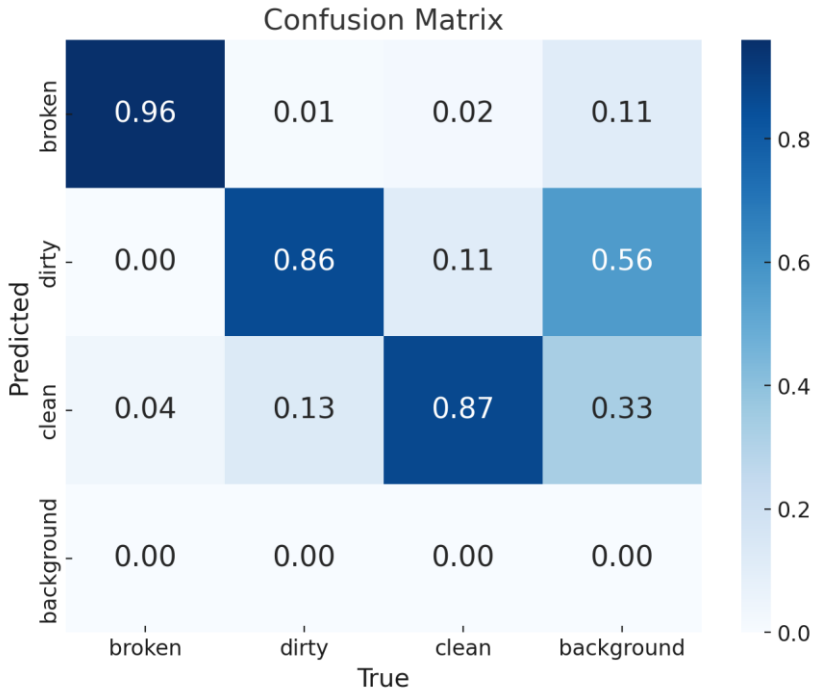


Figure 1. Confusion Matrix of the Model

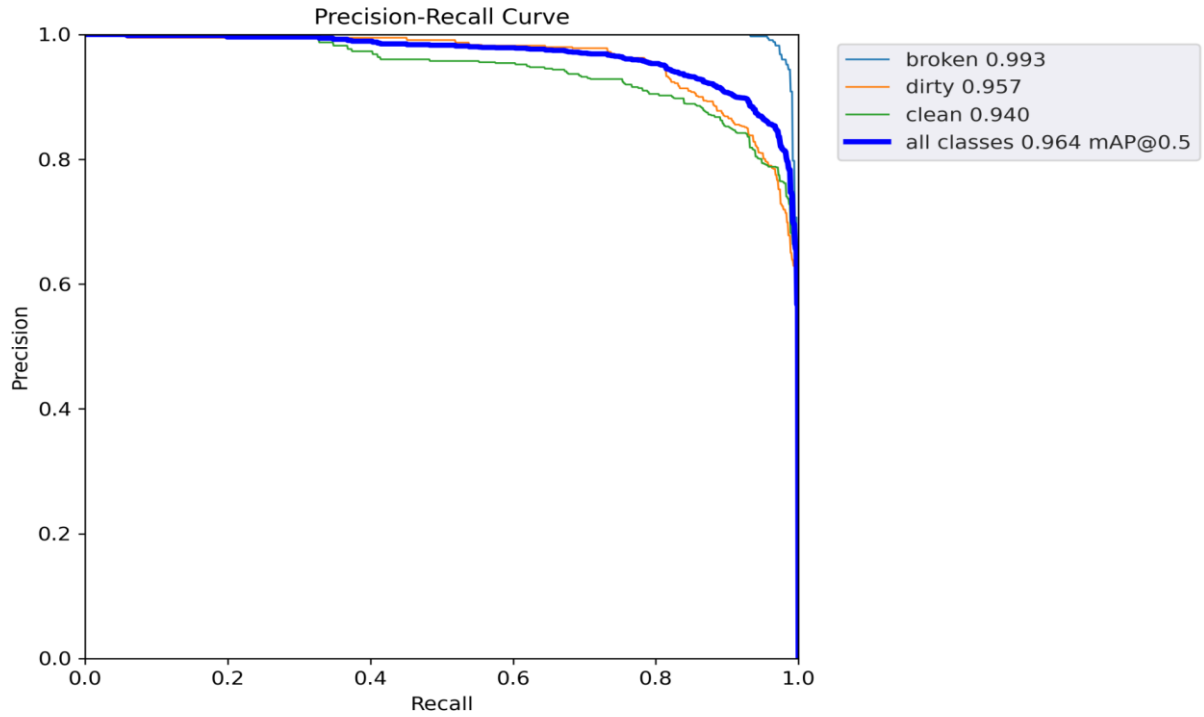


Figure 2. Precision-Recall Curve of the Model

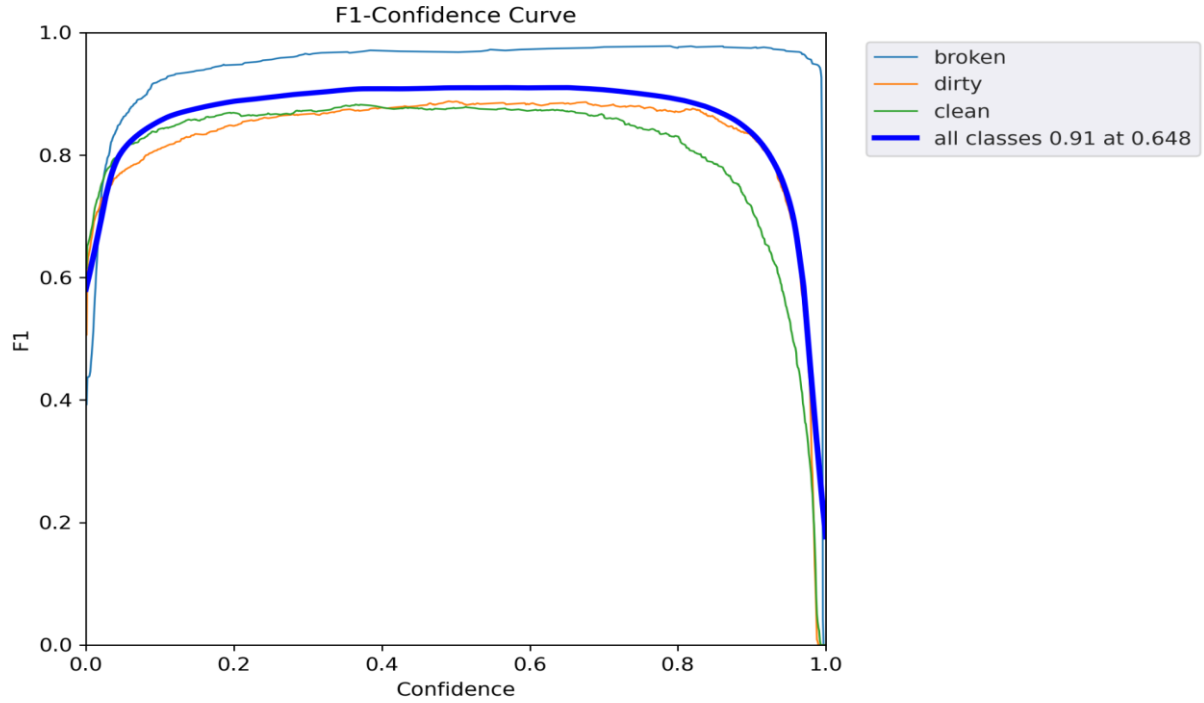


Figure 3. F1 Score vs Confidence Curve of the Model

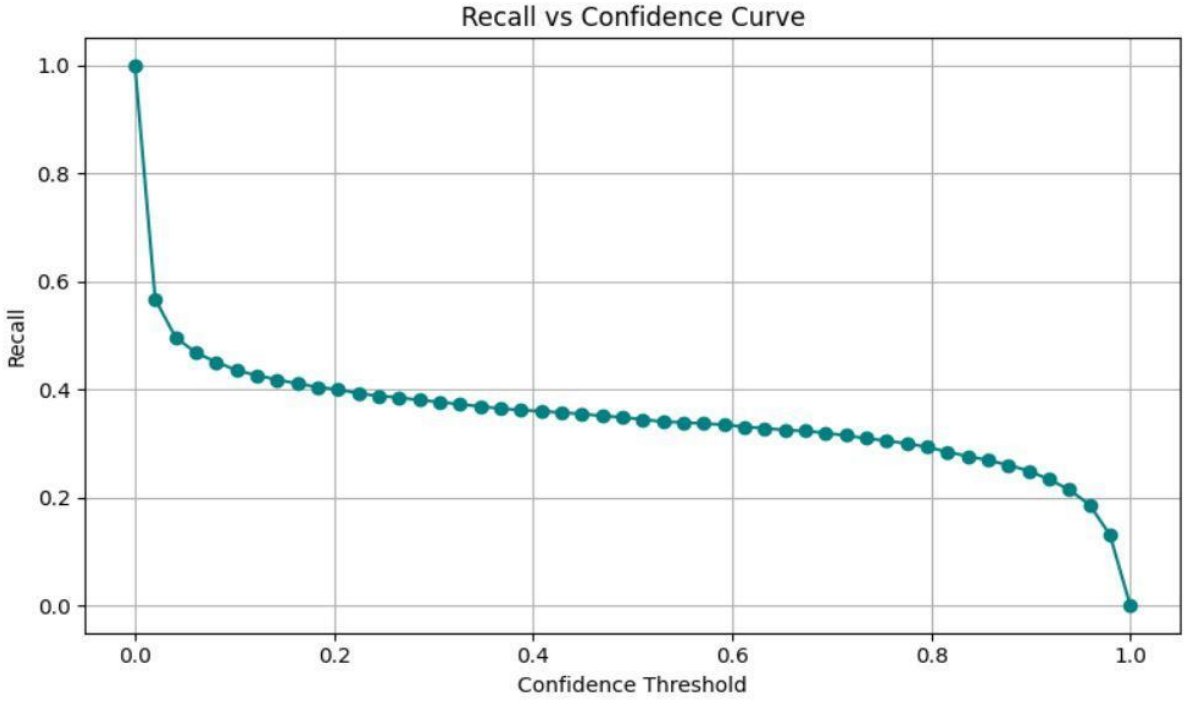


Figure 4. Recall vs Confidence Curve of the Model

The visual performance assessment of the model was conducted using four distinct plots, each highlighting different strengths of the system. Figure 1, the confusion matrix, clearly illustrates the model's capability to distinguish between classes. The "Broken" class achieved an almost perfect detection rate of 99.3%, while the "Dirty" and "Clean" classes were classified with 95.7% and 94.0% accuracy, respectively. These high values indicate that false positive and false negative rates are minimal, meaning that class-to-class misclassification is rare. The slight

confusion between “Clean” and “Dirty” is primarily due to visual similarities, a common challenge in image-based fault detection.

Figure 2, the Precision–Recall curve, shows that the Area Under the Curve (AUC) remains consistently high across all classes. This demonstrates that the model maintains robust precision and recall even at lower IoU thresholds. The balanced progression of the curve along both axes confirms that the model minimizes false detections while successfully identifying the majority of relevant objects. This behavior is particularly critical for industrial PV inspections where low error tolerance is essential.

In Figure 3, the F1 Score–Confidence curve illustrates the optimal trade-off between precision and recall across varying confidence thresholds. The curve reaches its maximum F1 score at approximately 0.6–0.7 confidence, indicating this range as the optimal threshold for practical deployment. The model can achieve high accuracy at this setting while maintaining sufficient coverage, ensuring effective real-time performance in field operations.

Finally, Figure 4, the Recall–Confidence curve, shows how recall varies with increasing confidence scores. The YOLOv5m model retains a high recall rate even at elevated confidence levels, confirming that it avoids overproducing predictions at low thresholds and minimizes missed detections at high thresholds. This property is significant for critical fault detection, where the risk of overlooking a defect must be kept to an absolute minimum.

These visual metrics confirm that the YOLOv5m model not only delivers high numerical accuracy but also exhibits stable and reliable decision-making behavior. Such performance characteristics make it a strong candidate for integration into industrial-scale, drone-based, or fixed-camera PV monitoring systems. It provides a real-time, cost-effective, and highly dependable solution for maintaining solar power infrastructure efficiency.

CONCLUSION AND DISCUSSION

This study demonstrates that YOLOv5m is the most effective choice for automated solar panel defect detection when balancing accuracy, speed, and computational efficiency [8] [5] [7]. Through the comparison training with all YOLOv5 variants (s, m, l, x) at their ideal minimum epoch counts, YOLOv5m delivered high precision (0.904), recall (0.914), and mAP@0.5 (0.964) while demanding significantly less training time in comparison to the larger models such as YOLOv5l and YOLOv5x. Even though YOLOv5s trained quickly, its accuracy was relatively lower, making it less suitable for reliable deployment.

After extending YOLOv5m’s training from 20 to 50 epochs, the enhanced performance confirmed its strength, with excellent mAP scores of 99.3% for broken panels, 95.7% for dirty panels, and 94.0% for clean panels. These results demonstrate the model’s strong generalization ability and low error rates in detecting surface defect types.

Compact size, competitive accuracy, and real-time inference capabilities prove that the YOLOv5m can be integrated seamlessly into drone-based or fixed-camera solar farm monitoring systems, considerably reducing inspection costs and time compared to manual methods. This locates YOLOv5m as a scalable and industry-ready solution for maintaining the efficiency and reliability of solar power infrastructure.

REFERENCES

[1] A. O. M. Maka and J. M. Alabid, “Solar energy technology and its roles in sustainable development,” Clean Energy, vol. 6, no. 3, pp. 476–483, 2022. https://academic.oup.com/ce/article/6/3/476/6606003

[2] Subarnan, G. M., Damodaran, M., & Madhu, K. (2022). *A Review on Investigation of PV Solar Panel Surface Defects and MPPT Techniques.* Recent Advances in Electrical & Electronic Engineering, 15(8). https://doi.org/10.2174/2352096515666220620093933

[3] Ayturan, K., Sarıkamış, B., Akşahin, M. F., & Kutbay, U. (2025). *SPHERE: Benchmarking YOLO vs. CNN on a Novel Dataset for High-Accuracy Solar Panel Defect Detection in Renewable Energy Systems.* Applied Sciences, 15(9), 4880. https://doi.org/10.3390/app15094880

[4] Garud Survey. (2025). *Solar Panel Inspection: How Drones Improve Efficiency and Cost-Effectiveness*. https://garudsurvey.com/solar-panel-inspection-how-drones-improve-efficiency-and-cost-effectiveness/

[5] Huang, J., Zeng, K., Zhang, Z., & Zhong, W. (2023). *Solar panel defect detection design based on YOLOv5.* Heliyon, 9(8), e18826. https://doi.org/10.1016/j.heliyon.2023.e18826

[6] Abdelsattar, M., Abdelmoety, A., Ismeil, M. A., & Emad-Eldeen, A. (2025). *Automated Defect Detection in Solar Cell Images Using Deep Learning Algorithms.* IEEE Access, 13, 4136–4157. https://ieeexplore.ieee.org/abstract/document/10820315

[7] Hussain, M. (2024). *YOLOv5, YOLOv8 and YOLOv10: The Go-To Detectors for Real-time Vision.* Preprint. https://arxiv.org/pdf/2407.02988

[8] Khanam, R., Asghar, T., & Hussain, M. (2025). *Comparative Performance Evaluation of YOLOv5, YOLOv8, and YOLOv11 for Solar Panel Defect Detection.* Solar, 5, 6. https://doi.org/10.3390/solar5010006

[9] Ultralytics, "YOLOv5 Documentation," 2023. [Online]. Available: https://docs.ultralytics.com

[10] Iqbal Basheer, M. Y., Ali, A. M., Abdul Hamid, N. H., & Yusoff, M. Z. M. (2024). *Solar Panel Defect Detection and Panel Localization Using YOLOv5.* InvENT 2024, Atlantis Press. Atlantis Press

MORPHOMETRIC AND TOPOGRAPHIC EVALUATION OF THE FORAMEN MANDIBULAE IN ARCHAEOLOGICAL MANDIBLES FROM THE ROMAN PERIOD

ROMA DÖNEMİNE AİT ARKEOLOJİK MANDİBULALARDA FORAMEN MANDİBULAE'NİN MORFOMETRİK VE TOPOGRAFİK DEĞERLENDİRMESİ

Dr. Hilal Kübra GÜÇLÜ EKİNCİ

Erciyes Üniversitesi Tıp Fakültesi, Anatomi ABD, Türkiye

ORCID Code: 0000-0001-7849-1768

ABSTRACT

Introduction and Purpose: The aim of this study is to determine the localization of the foramen mandibulae (FM) in the mandibles of archaeological individuals from the Roman Empire period and to perform morphometric measurements for clinical evaluation.

Materials and Methods: The study was carried out on 15 dry human mandibles obtained from tombs dated to the Roman Empire period (AD 218–244), located in the Köşkdağı area of Kayseri province (Melikgazi, Central Anatolia, Turkey). Distances between FM and anatomical reference points including the caput mandibulae, the anterior and posterior borders of the ramus mandibulae, the inferior border of the corpus mandibulae, the incisura mandibulae, and the angulus mandibulae were measured using a digital caliper. A total of six different anatomical reference points were used for morphometric evaluation.

Results: The mean distances between the foramen mandibulae and the anatomical landmarks caput mandibulae, posterior border of the ramus mandibulae, anterior border of the ramus mandibulae, inferior border of the corpus mandibulae, the deepest point of the incisura mandibulae, and the most prominent point of the angulus mandibulae—were measured as follows: on the right side: 40.61 ± 2.87 mm; 13.92 ± 1.89 mm; 12.67 ± 2.06 mm; 29.07 ± 4.01 mm; 22.97 ± 3.07 mm; 23.09 ± 4.11 mm, and on the left side: 40.58 ± 2.79 mm; 14.01 ± 1.68 mm; 12.53 ± 1.99 mm; 28.69 ± 3.88 mm; 23.04 ± 2.89 mm; 22.79 ± 3.61 mm. Although there were differences between the right and left sides, no statistically significant difference was found.

Discussion and Conclusion Knowing the anatomical localization of the foramen mandibulae is of great importance in protecting the mandibular nerve, orthognathic surgery, treatment of mandibular trauma, removal of benign and malignant lesions, preprosthetic surgery, and the application of mandibular anesthesia. This study contributes to the literature on the positional characteristics of FM based on archaeological materials and provides reference data that can be used in surgical planning. It is also of value in the comparative evaluation of different races. Preoperative assessment of variations in this region using advanced imaging techniques can help prevent complications and increase clinical success.

Keywords: Foramen mandibulae, morphometry, mandibular anesthesia, Roman period, archaeological anatomy

ÖZET

Giriş ve Amaç: Bu çalışmanın amacı, Roma İmparatorluğu dönemine ait arkeolojik bireylerin mandibulalarında foramen mandibulae'nin (FM) lokalizasyonunu belirlemek ve morfometrik ölçümlerini yaparak klinik açıdan değerlendirmektir.

Gereç ve Yöntem: Çalışma, Kayseri ili Köşkdağı (Melikgazi, İç Anadolu, Türkiye) bölgesinde yer alan ve Roma İmparatorluğu dönemine (MS 218–244) tarihlendirilen mezarlardan elde edilen 15 insan kuru mandibulası üzerinde gerçekleştirilmiştir. FM ile caput mandibulae, ramus mandibulae'nın ön ve arka kenarı, corpus mandibulae'nın alt kenarı, incisura mandibulae ve angulus mandibulae arasındaki mesafeler dijital kumpas ile ölçülmüştür. Toplamda altı farklı anatomik referans noktasına göre morfometrik değerlendirme yapılmıştır.

Bulgular: Foramen mandibulae ile caput mandibulae, ramus mandibulae'nın arka kenarı, ramus mandibulae'nın ön kenarı, corpus mandibulae'nın alt kenarı, incisura mandibulae'nın en derin noktası ve angulus mandibulae'nın en çıkıntılı noktası arası ortalama uzaklıklar sırasıyla, sağda 40,61 ± 2,87 mm; 13,92 ± 1,89 mm; 12,67 ± 2,06 mm; 29,07 ± 4,01 mm; 22,97 ± 3,07 mm; 23,09 ± 4,11 mm ve solda 40,58 ± 2,79 mm; 14,01 ± 1,68 mm; 12,53 ± 1,99 mm; 28,69 ± 3,88 mm; 23,04 ± 2,89 mm; 22,79 ± 3,61 mm olarak ölçüldü. Ölçümlerde sağ ve sol taraf karşılaştırmasında değerler farklılık gösterse de istatistiksel olarak anlamlı fark bulunmadı.

Tartışma ve Sonuç: Foramen mandibulae'nin anatomik lokalizasyonunun bilinmesi; n. mandibularisin korunması, ortognatik cerrahi, mandibular travma tedavisi, benign ve malign lezyonların çıkarılması, preprotetik cerrahi ve mandibular anestezi uygulamaları açısından büyük önem taşımaktadır. Bu çalışma, arkeolojik materyaller üzerinden elde edilen verilerle, FM'nin konumsal özelliklerine dair literatüre katkı sunmakta ve cerrahi planlamalarda kullanılabilecek referans veriler sağlamaktadır. Aynı zamanda farklı ırkların değerlendirilmesinde de önem arz etmektedir. İleri görüntüleme teknikleri ile bu bölgenin varyasyonlarının preoperatif değerlendirilmesi, olası komplikasyonları önlemede klinik başarıyı artıracaktır.

Anahtar Sözcükler: Foramen Mandibulae, Morfometri, Mandibular Anestezi, Roma Dönemi, Arkeolojik Anatomi

GİRİŞ

Mandibula (alt çene kemiği), insan kafatasının tek hareketli kemiği olup, çiğneme, konuşma ve yüz ifadesi gibi temel fonksiyonlarda merkezi bir rol oynar. Bu kemik, dişlerin alt çenedeki yerleşimini sağlar, aynı zamanda önemli damar ve sinir yapıları için bir geçiş yolu görevi görür. Yüz iskeletinin alt bölümünü oluşturan bu kemik, kafa iskeletinin (işitme kemikçikleri hariç) tek hareketli kemiğidir. İki kısımda incelenen mandibula, coprus mandibulae ve ramus mandibulae'dan oluşmaktadır. Corpus ve ramusun birleşme bölgesine angulus mandibulae denir. (Unur ve ark., 2012; Moore ve ark.., 2018; Standring, 2021; Yıldırım & Kaya, 2017).

Corpus mandibulae, at nalı şeklinde olup, alveoler uzantıları aracılığıyla alt dişleri barındırır. Diş köklerinin olduğu kısma pars alveolaris, alt kısmına ise basis mandibulae denir. Mandibula'nın dış ve iç iki yüzü bulunur (Unur ve ark., 2012).

Mandibulanın dış yüzünde orta kısımda iki korpusun birleşim yerine sympshysis mandibulae denir. Ayrıca bu kısımda ikinci premolar diş hızasında bir delik bulunur foramen mentale denir. Arka yüzün orta kısımdaki çıkıntıya spina mentalis adı verilir. Yine bu yüzün en alt kısmı ile alt kenarın kesistiği noktadaki çukurluğa fossa digastrica denir. Fossa digastrica' dış kısmından yukarı uzanan çizgiye linea mylohyoidea denir. Bu çizginin iç kısmının yanında fovea subliungualis ve dış yanında fovea submandibularis vardır. Bu fovealara aynı isimi alan tükürük besleri oturmaktadır (Unur ve ark, 2012; Arıncı & Elhan, 2014; Drakeve ark., 2020).

Mandibula'nın ramus mandibulası'nın iç kısmındaki deliğe foramen mandibulae (FM) adı verilir. Bu delik yapı ile foramen mentale arasında bir kanal vardır ve canalis mandibulae denir. Ramus mandibulae'nın üst kenar kısmınıb önündeki çıkıntıya processus coronoideus arkasındaki çıkıntıya processus condylaris denir. İki processus arasındaki çentiğe incisura mandibulae denir. Caput mandibulae ise processus condylaris'in üst kısmında yer alan yapıdır. Caput mandibulae temporal kemikte yer alan fossa mandibularis ile eklem yapar (Netter, 2014; Öztürk, 2019).

Foramen Mandibula, özellikle diş hekimliği ve cerrahi açısından büyük önem taşır. Bu kanal, tek olduğunda trabeküler kemik boyunca, santral kesici dişin alveol seviyesine kadar öne doğru yay şeklinde ilerler. Her iki tarafta premolar dişler bölgesinde foramen mentalis bulunur. Bu kanal içinde arteria alveolaris inferior, vena alveolaris inferior ve nervus alveolaris inferior birlikte seyreder. Bu varyasyonlar, nervus alveolaris inferior bloğu gibi klinik prosedürlerde anestezi başarısını etkileyebileceğinden, cerrahi ve diş hekimliği uygulamalarında detaylı anatomik bilginin önemi büyüktür (Arıncı & Elhan, 2014).

Anatomistler ve tıp doktorları için FM'nin önemi, sadece klinik uygulamalarla sınırlı değildir; aynı zamanda insan varyasyonlarının anlaşılması, popülasyonlar arası morfolojik farklılıkların belirlenmesi ve evrimsel süreçlerin aydınlatılması açısından da kritik bir role sahiptir (Arıncı & Elhan, 2014). FM'nin konumu ve boyutları, yaşa, cinsiyete ve etnik kökene bağlı olarak değişkenlik gösterebilmektedir (Kqiku ve ark., 2012; Thangavelu & Paul, 2008). Bu tür morfometrik çalışmalar, farklı popülasyonlar için standart referans değerleri oluşturarak klinik uygulamaların daha güvenli ve etkili hale gelmesine yardımcı olur.

Arkeolojik materyaller üzerinde yapılan anatomik çalışmalar, güncel popülasyonlardan farklı yaşam koşullarına ve genetik yapılara sahip geçmiş toplumların biyolojik özelliklerini anlamak için fırsat sunar. Bu nedenle, Roma dönemine ait iskelet kalıntılarında FM'nin incelenmesi, hem tarihsel antropolojiye hem de klinik anatomiye değerli bilgiler sağlayacaktır.

Bu çalışmanın temel amacı, Kayseri ili Köşkdağı bölgesinden elde edilen Roma İmparatorluğu dönemine ait arkeolojik mandibula örneklerinde foramen mandibulae'nin lokalizasyonunu ve morfometrik özelliklerini belirleyerek, elde edilen verileri mevcut literatürdeki güncel popülasyonlarla karşılaştırmak ve diş hekimliği, anatomik ve tıbbi açıdan klinik çıkarımlar sunmaktır. Bu verilerin, gelecekteki cerrahi planlamalarda ve anestezi uygulamalarında bölgesel veya etnik farklılıkların dikkate alınmasına yardımcı olmasını amaçladık.

GEREÇ VE YÖNTEM

Bu çalışmada, Kayseri ili Melikgazi ilçesi Köşkdağı bölgesinde yürütülen arkeolojik kazılar sonucunda ortaya çıkarılan ve Roma İmparatorluğu dönemine (MS 218–244) tarihlendirilen mezarlardan elde edilen insan iskelet kalıntıları kullanılmıştır. Çalışma için etik kurul onayı alınmış ve materyallerin kullanımı için gerekli izinler temin edilmiştir. Çalışma örneklemini, iyi korunmuş ve ölçüm için uygun olan toplam 15 adet kuru insan mandibulası oluşturmuştur. Mandibulalar, makroskopik incelemelerle herhangi bir patolojik deformite veya travma belirtisi taşımadığı doğrulandı.

Resim1: Kayseri Bizans topluluğunun mandibula örnekleri



Foramen mandibulae'nin (FM) lokalizasyonunu ve morfometrik özelliklerini belirlemek amacıyla her bir mandibula üzerinde standardize edilmiş anatomik referans noktaları kullanılarak dijital kumpas (0.01 mm hassasiyetinde) ile hassas ölçümler gerçekleştirilmiştir. Ölçümler, her bir mandibula için hem sağ hem de sol tarafta bağımsız olarak yapılmış ve her ölçüm en az iki kez tekrarlanarak ortalamaları kaydedilmiştir. Ölçümler tek bir kişi tarafından yapılmıştır.

Belirlenen ölçüm noktaları ve ölçülen mesafeler şunlardır (Şekil 1):

1. FMCM: Foramen mandibulae iç kenarının en derin noktasından caput mandibulae üst kenarının iç köşesine olan uzaklık

2. FMRMP: Foramen mandibulae iç kenarının en derin noktasından ramus mandibulae posterior kenarına dik giden doğrunun uzunluğu,

3. FMRMA: Foramen mandibulae iç kenarının en derin noktasından ramus mandibulae anterior kenarına dik giden doğrunun uzunluğu,

4. FMRM: Foramen mandibulae iç kenarının en derin noktasından corpus mandibulae'nın alt kenarına dik inen doğrunun uzunluğu,

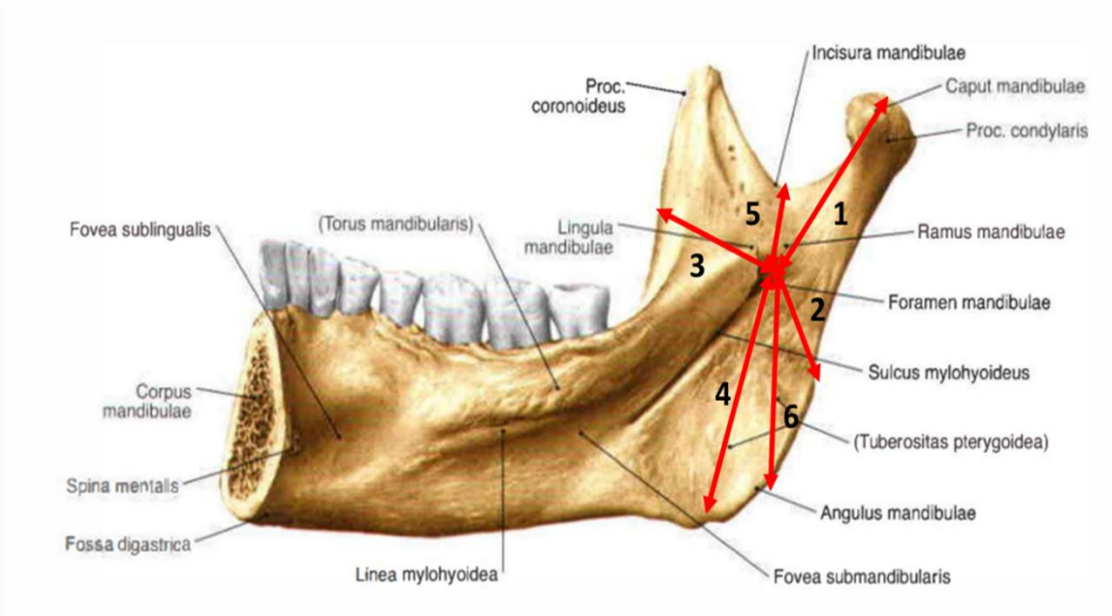
5. FMIM: Foramen mandibulae iç kenarının en derin noktasından incisura mandibulae'nın en derin noktasına olan uzaklık,

6. FMAM: Foramen mandibulae'nın iç kenarının en derin noktasından angulus mandibulae'nın en çıkıntılı noktasına olan uzaklık.

Ölçülen tüm veriler SPSS 22.0 programı (IBM SPSS Statistics for Windows) kullanılarak istatistiksel analizleri yapılmıştır. Tanımlayıcı istatistikler (ortalama, standart sapma, minimum ve maksimum değerler) her bir ölçüm için ayrı ayrı hesaplanmıştır. Sağ ve sol taraf arasındaki olası farklılıkları değerlendirmek amacıyla bağımsız örneklem t-testi kullanılmıştır. İstatistiksel anlamlılık düzeyi $p<0.05$ olarak kabul edilmiştir.

Şekil 1: Foramen mandibulanın konumu ve ölçüm noktaları (Sobotta Atlas of Human Anatomy cilt 1)

1. FMCM, 2. FMRMP, 3. FMRMA, 4. FMRM, 5. FMIM, 6. FMAM



BULGULAR

Çalışma sonucunda, Roma İmparatorluğu dönemine ait 15 adet cinsiyeti belirsiz insan mandibulası üzerinde foramen mandibulae'nin (FM) altı farklı anatomik referans noktasına göre morfometrik ölçümleri gerçekleştirilmiştir. Her bir ölçüm, sağ ve sol mandibulalar için ayrı ayrı analiz edilmiş ve ortalama ± standart sapma (SS) değerleri ile birlikte sunulmuştur. Bulgular Tablo 1'de özetlenmiştir.

Tablo 1: Foramen Mandibulae'nin Anatomik Referans Noktalarına Uzaklıklarının Ortalama ve Standart Sapma Değerleri (mm)

Ölçüm Noktası	Sağ Taraf (Ortalama ± SS)	Sol Taraf (Ortalama ± SS)	p Değeri
FM - Caput Mandibulae (CM)	40,61 ± 2,87	40,58 ± 2,79	0,937
FM - Ramus Arka Kenarı (RA)	13,92 ± 1,89	14,01 ± 1,68	0,865
FM - Ramus Ön Kenarı (RÖ)	12,67 ± 2,06	12,53 ± 1,99	0,821
FM - Corpus Alt Kenarı (CA)	29,07 ± 4,01	28,69 ± 3,88	0,772
FM - Incisura Mand. (İM)	22,97 ± 3,07	23,04 ± 2,89	0,911
FM - Angulus Mand. (AM)	23,09 ± 4,11	22,79 ± 3,61	0,847

Elde edilen ortalama uzaklık değerleri, sağ ve sol mandibula arasında çok küçük farklılıklar göstermiştir. FM ile caput mandibulae arasındaki mesafe sağda 40,61 ± 2,87 mm iken, solda 40,58 ± 2,79 mm olarak bulunmuştur. Benzer şekilde, FM ile ramus mandibulae'nin ön kenarı arasındaki mesafe sağda 12,67 ± 2,06 mm, solda ise 12,53 ± 1,99 mm olarak ölçülmüştür.

Yapılan istatistiksel analizler (bağımsız örneklem t-testi) sonucunda, ölçümlerde sağ ve sol taraf değerleri arasında gözlemlenen bu farkların hiçbirinde istatistiksel olarak anlamlı bir farklılık bulunmamıştır ($p > 0.05$). Bu durum, foramen mandibulae'nin morfolojik lokalizasyonunun Roma dönemine ait bireylerde sağ ve sol taraflar arasında simetrik bir dağılım gösterdiğini düşündürmektedir.

En kısa mesafe, hem sağ hem de sol tarafta FM ile ramus mandibulae'nin ön kenarı arasında (sırasıyla 12,67 mm ve 12,53 mm) ve FM ile ramus mandibulae'nin arka kenarı arasında (sırasıyla 13,92 mm ve 14,01 mm) kaydedilmiştir. En uzun mesafe ise FM ile caput mandibulae arasında (sırasıyla 40,61 mm ve 40,58 mm) ölçülmüştür. Bu bulgular, foramen mandibulae'nin anatomik olarak ramus mandibulae'nin orta kısmına yakın konumlandığını desteklemektedir. Standart sapma değerleri, ölçülen mesafelerde bireyler arasında belirli bir varyasyon olduğunu göstermekle birlikte, bu varyasyonun beklenen sınırlar içinde olduğu söylenebilir. Örneğin, FM-CA mesafesi hem sağda hem de solda nispeten yüksek standart sapma değerlerine (sırasıyla 4,01 mm ve 3,88 mm) sahip olup, bu mesafede bireyler arası varyasyonun diğer ölçümlere göre daha fazla olduğunu işaret etmektedir.

TARTIŞMA

Foramen mandibulae'nin (FM) anatomik lokalizasyonu ve morfometrik özellikleri, diş hekimliği, ağız, çene ve yüz cerrahisi, radyoloji ve adli tıp gibi birçok disiplin için kritik öneme sahiptir.

Mandibular anestezi (inferior alveolar sinir bloğu), alt çenedeki dişlerin ve çevre dokuların uyuşturulmasında en sık kullanılan lokal anestezi tekniklerinden biridir (Malamed, 2012). Yapılan çalışmalar, bu foramenin konumundaki bireysel farklılıkların anestezi başarısızlığının önemli bir nedeni olabileceğini göstermektedir (Kqiku et al., 2012). Örneğin, Joshi et al. (2014) tarafından yapılan bir çalışmada, farklı popülasyonlarda FM'nin konumunun değişebileceği ve bu durumun anestezi tekniklerinin adaptasyonunu gerektirebileceği vurgulanmıştır.

Ortognatik cerrahi (örneğin, sagital split osteotomi), mandibular travma tedavisi, kist veya tümörlerin rezeksiyonu ve dental implant uygulamaları gibi cerrahi prosedürlerde inferior alveolar sinirin korunması hayati önem taşır (Hupp et al., 2019).

Foramen mandibulae'nin morfometrik ve topografik özellikleri, insan varyasyonları, popülasyonlar arası morfolojik farklılıklar ve hatta evrimsel adaptasyonlar hakkında değerli bilgiler sunar (Yıldırım & Kaya, 2017). Örneğin, farklı coğrafi bölgelerdeki veya etnik gruplardaki bireylerde FM'nin konumunda belirgin farklılıklar gözlemlenmiştir. Al-Kadasi et al. (2017) Yemen popülasyonunda FM'nin konumunu incelerken, Kqiku et al. (2012) Kosova popülasyonunda benzer bir çalışma yürütmüştür. Bu çalışmaların sonuçları, FM'nin konumunun popülasyondan popülasyona değişebileceğini ve bu varyasyonların klinik uygulamalar için önemli olduğunu göstermektedir.

Literatürde foramen mandibulae'nin konumu üzerine birçok çalışma bulunmakla birlikte, Roma dönemine ait arkeolojik materyaller üzerindeki çalışmalar sınırlıdır. Genel olarak, FM'nin ramusun orta kısmına yakın konumlandığı kabul edilmektedir (Standring, 2021). Bizim bulgularımızdaki FM ile ramus ön ve arka kenarları arasındaki kısa mesafeler (sırasıyla ortalama 12,67 mm ve 13,92 mm), bu genel kabulü desteklemektedir. Ancak, güncel popülasyonlarla doğrudan karşılaştırma yapmak için daha fazla çalışmaya ihtiyaç vardır. Örneğin, bazı modern popülasyonlarda FM'nin konumu, yaşa bağlı olarak vertikal eksende yukarı doğru hareket edebildiği bildirilmiştir (Laskin et al., 1970). Arkeolojik materyallerde yaş tayini yapılabilse de, bu çalışmada bu tür bir alt grup analizi yapılmamıştır.

Çalışmamızın önemli bir bulgusu, sağ ve sol mandibulalar arasında FM'nin konumunda istatistiksel olarak anlamlı bir fark bulunmamasıdır. Bu, Roma dönemine ait bireylerde FM'nin konumunun simetrik olduğunu düşündürmektedir. Benzer şekilde, birçok güncel popülasyonda da bu simetri genellikle korunmaktadır, ancak bazı çalışmalarda hafif asimetriler bildirilmiştir (Öztürk, 2019).

SONUÇ

Bu çalışma, Roma İmparatorluğu dönemine ait arkeolojik mandibula örneklerinde foramen mandibulae'nin (FM) morfometrik ve topografik özelliklerini değerlendirmiştir. Elde edilen veriler, FM'nin belirli anatomik referans noktalarına olan ortalama uzaklıklarını ortaya koymuştur. Sağ ve sol taraf arasında istatistiksel olarak anlamlı bir farklılık bulunmaması, Roma dönemine ait bireylerde FM'nin konumunun bilateral simetri gösterdiğini işaret etmektedir.

Foramen mandibulae'nin anatomik lokalizasyonunun kesin olarak bilinmesi, günümüz diş hekimliği ve ağız, çene ve yüz cerrahisi uygulamaları için kritik bir önem taşımaktadır. Çalışmamız, arkeolojik materyallerden elde edilen verilerle, antik popülasyonların biyolojik çeşitliliğini anlamaya katkı sunmakta ve farklı etnik veya tarihsel gruplar için cerrahi planlamalarda kullanılabilecek referans veriler sağlamaktadır.

Bu tür arkeolojik anatomik çalışmalar farklı ırkların morfolojik yapılarını belirlemede katkı sağlasa da, ileri görüntüleme teknikleri kullanılarak daha güvenilir ve kapsamlı sonuçlar elde edilebileceği kanaatindeyiz.

KAYNAKÇA

Al-Kadasi, S. S., Al-Baidhani, Z. A., & Al-Amrani, A. H. (2017). Morphometric analysis of mandibular foramen in Yemeni population. *Journal of Clinical and Diagnostic Research, 11*(11), AC09-AC12.

Arıncı, K., & Elhan, A. (2014). Anatomi: Genel Anatomi ve Hareket Sistemi (7. Baskı). Güneş Tıp Kitabevleri.

Drake, R. L., Vogl, W., & Mitchell, A. W. M. (2020). *Gray's Anatomy for Students* (4th ed.). Elsevier.

Hupp, J. R., Ellis, E., & Tucker, M. R. (2019). *Contemporary Oral and Maxillofacial Surgery* (7th ed.). Elsevier.

Joshi, H. P., Kaur, A., & Gill, R. K. (2014). Morphometric analysis of mandibular foramen in dry adult human mandibles. *International Journal of Medical Research and Health Sciences, 3*(3), 677-681.

Kqiku, L., Filipović, M., Spahiu, L., & Gashi, L. (2012). Location of the mandibular foramen in a Kosovar population. *Medicina Oral, Patología Oral y Cirugía Bucal, 17*(1), e75-e78.

Laskin, D. M., Sarnat, B. G., & Schour, I. (1970). *Oral and Maxillofacial Surgery: A Text-Book of the American Association of Oral and Maxillofacial Surgeons*. The C.V. Mosby Company.

Malamed, S. F. (2012). *Handbook of Local Anesthesia* (6th ed.). Mosby Elsevier.

Moore, K. L., Dalley, A. F., & Agur, A. M. R. (2018). *Clinically Oriented Anatomy* (8th ed.). Wolters Kluwer.

Netter, F. H. (2014). *Atlas of Human Anatomy* (6th ed.). Saunders.

Öztürk, E. (2019). *Fonksiyonel Anatomi*. Nobel Tıp Kitabevleri.

Standring, S. (Ed.). (2021). *Gray's Anatomy: The Anatomical Basis of Clinical Practice* (42nd ed.). Elsevier.

Thangavelu, K., & Paul, S. (2008). Morphometric analysis of the mandibular foramen. *Journal of Clinical and Diagnostic Research, 2*(4), 1146-1149.

Unur E, Ülger H, Ekinci N. Anatomi. Erciyes Üniversitesi Tıp Fakültesi, Anatomi Anabilim Dalı, Kıvılcım Kitapevi, Kayseri 2015.

Yıldırım, M., & Kaya, B. (2017). *Klinik Anatomi*. Hipokrat Kitabevi.

ADAPTATION OF FARMERS IN THE TADLA PLAIN TO CLIMATE VARIATIONS: SOCIO-CULTURAL DIMENSIONS AND INNOVATIVE AGRICULTURAL STRATEGIES

Hasna JINNOU

Research Laboratory: Landscape Dynamics, Risks, and Heritage, Faculty of Arts and Humanities, Sultan Moulay Slimane University, Béni Mellal, Morocco

Said ARIF

Professor of Geography, Faculty of Arts and Humanities, Béni Mellal, Morocco

Mohamed Achraf HASNAI

Manager of the agricultural company Farmassist, specializing in agricultural service provision, Morocco

ABSTRACT

This study, conducted in the Tadla Plain in Morocco, examined the socio-cultural and behavioral dimensions of farmers' adaptation to the challenges posed by climate variations. The results show that farmers clearly perceive climate changes, particularly the decrease in rainfall and the rise in temperatures. In response, they have adopted various adaptation strategies, such as using groundwater for irrigation to preserve investments linked to these resources, diversifying crops, and adopting less invasive soil working techniques, such as using the chisel plow as a replacement for deep plowing, to limit water infiltration. Furthermore, the integration of new precision agriculture technologies, including the use of drones for applying pesticides, helps streamline water usage and optimize agricultural practices. However, the study also revealed socio-cultural obstacles hindering adaptation, such as deeply ingrained traditional practices and resistance to change. To overcome these challenges, it is crucial to strengthen farmers' skills through targeted training programs, promote participatory approaches involving local communities, and value traditional knowledge by integrating it into modern adaptation strategies. Therefore, effective adaptation of farmers in the Tadla Plain to climate variations requires a deep understanding of socio-cultural and behavioral dimensions, as well as an integrated approach combining traditional knowledge with technological innovations.

Keywords: Climate adaptation – Groundwater – Precision agriculture – Socio-cultural behaviors – Tadla Plain.

ERGONOMIC EFFICACY OF KNEELING CHAIRS: AN ANATOMICAL AND USER- PERCEPTION ANALYSIS FOR HEALTH-CENTRIC DESIGN

Dr. Nguyen Thi Bich Van

Faculty of Architecture Interior Design, University of Architecture Hochiminh City, Vietnam

Hoang Trong Duc

Institute of International Education, University of Architecture Hochiminh City, Vietnam

Abstract

Kneeling chairs are widely manufactured and marketed today, often promoted as ergonomic products offering health benefits to users. We acknowledge the inherent value in their innovative design and the potential health advantages this design aims to achieve. However, through a comprehensive synthesis of anatomical studies and user surveys, this paper critically evaluates whether kneeling chairs truly meet comprehensive ergonomic standards and safeguard human health as claimed. Our analysis indicates that, despite certain advantages, the kneeling chair's design can introduce potential health issues for users, sometimes conflicting with the fundamental ergonomic principles recognized by manufacturers. This paper emphasizes the necessity of establishing clearer, standardized guidelines for ergonomic evaluation of seating support products. Ultimately, we propose scientific assessment criteria and principles for optimal sitting posture to empower users in making informed choices and maintaining their well-being in the work environment.

Keywords: kneeling chair, ergonomic design, anatomy, sitting posture, product evaluation, human factor

Introduction

In the context of the increasing prevalence of office-related health issues — particularly back pain, shoulder and neck strain, and circulatory disorders — the demand for ergonomic solutions in the workplace has become urgent. Ergonomic chairs are widely promoted as a way to help maintain correct posture, reduce spinal load, and improve long-term health.

Among these, the kneeling chair stands out as a notable design, emerging in the late 20th century and now produced and distributed by many brands worldwide. Manufacturers often emphasize that kneeling chairs help maintain the natural lumbar lordosis, reduce the risk of slouching, and distribute body pressure more effectively than traditional office chairs. This design is considered an improvement in sitting posture, based on the idea of increasing the hip angle, reducing spinal load, and shifting part of the body weight onto knee supports.

However, despite being marketed as “ergonomic” and promising health benefits, scientific evidence verifying the effectiveness of kneeling chairs remains limited. Some studies on prolonged kneeling postures indicate potential risks such as reduced blood circulation in the lower limbs, increased pressure on the knees, and core muscle fatigue due to the lack of back support. Additionally, user feedback often reports initial positive effects, but also drawbacks such as numbness in the legs, difficulty maintaining the posture for long periods, or the lack of adjustability to accommodate different body types. Therefore, this study aims to

comprehensively evaluate the ergonomic effectiveness of kneeling chairs by synthesizing data from anatomical and biomechanical research, as well as user feedback. From this, the article seeks not only to conclude on the suitability of kneeling chairs as an alternative to traditional work chairs but also to propose scientific criteria and standard principles for designing, selecting, and using seating products that support proper sitting posture in the workplace.

What Make A Chair Ergonomic?

Ergonomic seating design aims to promote neutral body postures, minimize biomechanical strain, and maintain musculoskeletal health over prolonged sitting periods. Standards such as *ISO 9241-5:1998(E)* and *BIFMA G1-2002* outline core requirements for office seating, particularly for work with visual display terminals (VDTs). Key parameters include:

- **Seat height**: Adjustable to allow the user's feet to rest flat on the floor with knees at approximately 90°, preventing undue pressure on the thighs and supporting even weight distribution.
- **Seat angle**: A slight forward or backward tilt should be possible to facilitate postural variation and promote circulation.
- **Backrest design**: Lumbar support must sustain the spine's natural lordotic curve, ideally beginning below the sacral region and ending just under the shoulder blades to allow upper body mobility.
- **Armrest adjustability**: Should accommodate a wide range of users (5th to 95th percentile) without obstructing access to the chair.

Methodology

These standards emphasize the interplay between spinal alignment, muscle activation, and circulatory efficiency. As highlighted by *MoveSafe* (2023), chairs that fail to provide proper lumbar support or limit postural changes may lead to slouching, spinal stress, or compromised circulation over time. Biomechanical research supports these guidelines. Studies such as *Seidler et al.* (2008) demonstrate that prolonged kneeling or squatting increases compressive and shear forces on the knee joint, potentially leading to joint effusion or degenerative changes. *Lin et al.* (2021) show that lower-limb circulation is sensitive to sitting posture, with restricted blood flow contributing to discomfort and numbness. Similarly, *Walsh et al.* (2017) report significant reductions in popliteal artery endothelial function after just three hours of sustained knee flexion.

From an anatomical standpoint, *Olivier Girard* (2020) highlights that insufficient backrest support in certain chair designs can encourage "hollow back" posture—a hyperextension of the lumbar spine that, over time, may increase lower back strain despite initial improvements in upright posture. Together, these findings provide a clear evaluative framework: an ergonomic chair must balance spinal support, muscular endurance, joint safety, and circulatory health. This literature-based standard will guide the subsequent analysis of kneeling chairs in terms of their design intentions, biomechanical implications, and real-world user feedback.

Findings:

Kneeling Chair Analysis: Design Intentions

Kneeling chairs became widely introduced in the late 20th century as an alternative to traditional office chairs, with prominent claims of reducing slouching, alleviating spinal pressure, and improving posture. According to MoveSafe (2023), the design principle of this

chair type is based on tilting the seat forward by about 20°, while using knee pads to help support body weight, thereby opening the hip angle to 110°–120° compared to the conventional 90° sitting posture.

This idea stems from the observation that opening the hip angle helps the spine maintain its natural curvature (lumbar lordosis), reduces disc loading, and decreases the tendency for the pelvis to slide forward, which causes slouching. Some designers also suggest that distributing body weight between the buttocks and shins reduces concentrated pressure on the thighs and pelvic area.

However, when compared with ISO 9241-5 and BIFMA G1-2002 standards, several notable differences emerge:

- Kneeling chairs often do not allow height adjustment to ensure the feet touch the floor — a core requirement of the ISO standard.
- Fixed knee pads limit posture changes, contradicting the principle of encouraging movement to maintain blood circulation.
- They lack a backrest, or the backrest is merely symbolic, failing to meet the requirement for continuous lumbar support as defined by the standards.

In addition, Olivier Girard's (2020) video shows that although users may initially feel more upright, maintaining a "hollow back" posture for too long can place excessive strain on the erector spinae muscles and lumbar region. This indicates that the original design goals of kneeling chairs — improving posture and reducing spinal pressure — may not achieve lasting benefits if full ergonomic standards are not incorporated.

Kneeling Chair Analysis: Anatomy & Biomechanics

Spiral & Core

The kneeling chair promotes an open hip angle, typically around 110–120 degrees, compared to the standard 90-degree angle in conventional chairs. This posture facilitates a natural extension of the lumbar spine, reducing the forward pelvic tilt often associated with slouching. Anatomically, this position aligns the vertebral column closer to its natural S-curve, minimizing strain on the intervertebral discs. From a biomechanical standpoint, the open hip angle engages the erector spinae and transversus abdominis muscles in a mild, continuous activation. This activation is less intense than in standing posture yet more dynamic than in passive sitting, contributing to improved core stability over time. The design also reduces load concentration on the lower back, distributing it across the pelvis and thighs. As a result, spinal compression is decreased, and muscle fatigue in the lumbar region is less pronounced during short to moderate periods of use.

Kneecaps & Blood Circulation

While the kneeling chair offers notable benefits for spinal alignment, its pressure distribution presents biomechanical challenges, particularly at the knee contact points. The body weight partially shifts to the shins and kneecaps, which may compress the patellar tendon and infrapatellar fat pad if the padding is insufficient or prolonged use is enforced. Over extended durations, this can result in localized discomfort, numbness, or even mild bursitis in sensitive individuals.

From a circulatory perspective, the flexed position at the knee joint can restrict venous return from the lower legs. This mild compression of blood vessels, especially in the popliteal area, may slow circulation and contribute to swelling or tingling sensations. Although these effects are generally reversible with movement breaks, they highlight the importance of limiting continuous use and incorporating posture variation. The ergonomic value of the kneeling chair,

therefore, depends heavily on proper cushioning, adjustable seat angle, and user discipline in alternating positions throughout the workday.

Kneeling Chair Analysis: User Feedbacks

User feedback offers a clearer view of the long-term experience with kneeling chairs. Although not medically professional, these opinions reflect how the product affects the body in everyday use. Some users emphasize potential risks to the knees when using kneeling chairs for extended periods. One person shared:

"No. It places too much pressure on the posterior cruciate ligament in the knees which… will cause knee problems. Like many others have said, just do not stay in the same position too long. Get up and move around."

Another case reported more serious effects on the spine:

"I used this chair for several years and it caused spondylolisthesis with 2nd grade spinal stenosis. I don't recommend to use it all the time. Stand up sometimes and change the positions and chairs often."

However, not all feedback was negative. One user recounted an experience combining a kneeling chair with a standard office chair:

"It really was comfortable for my back, and I felt more energized if I used it for a few hours at a time. But it would start to hurt my knees and shins and I'd have to switch back to my normal chair. Changing chairs/positions halfway through the day was beneficial."

Overall, these experiences show that while kneeling chairs can offer certain benefits in the short term, continuous use without changing posture may put stress on the knees and lead to spinal issues. This reinforces the view that kneeling chairs should be used as a supplementary option rather than a complete replacement for standard office chairs.

Discussion

Overall Assessment

Overall, kneeling chairs present a mixed performance when it comes to ergonomics. Compared to conventional office chairs, they help maintain a straighter back posture and better lumbar lordosis, which can be beneficial in reducing early signs of slouching or kyphosis. The forward-sloping seat design also reduces disc pressure during short-term sitting, making them useful for brief posture adjustments throughout the day.

However, the absence of a backrest means that the core muscles are constantly engaged, leading to fatigue within 30–60 minutes for most users. Prolonged use can also cause pressure on the knees and shins, potentially leading to numbness and restricted blood circulation in the lower limbs. This makes them less ideal for long-duration sitting sessions.

From a practical perspective, kneeling chairs are compact and can serve as a supplementary seating option to promote posture variation in the workplace or home. Still, they cannot fully replace a well-designed ergonomic office chair for extended work periods. In addition, their design makes movement more difficult, and transitioning between sitting and standing positions can be inconvenient. In summary, kneeling chairs work best as a secondary seating solution, offering short-term posture benefits while requiring careful consideration of comfort and circulation over time.

Misused Ergonomics

While ergonomics is intended to enhance human comfort, efficiency, and health, the misuse or exaggeration of "ergonomic" claims can have serious consequences for consumers.

Many products are marketed under this label yet fail to meet genuine ergonomic standards. This often leads to two outcomes.

First, some users quickly recognize the shortcomings—experiencing discomfort, reduced productivity, or inconvenience—and abandon the product, resulting in wasted expenditure and diminished trust in truly ergonomic solutions. Second, and more concerning, other users remain unaware of the hidden flaws and continue prolonged use, gradually developing chronic health issues such as poor posture, muscle strain, or long-term joint damage. In today's market, the "ergonomic" label is frequently employed as a marketing strategy rather than a reflection of user-centered design. While such claims may sound appealing, their actual implementation often falls short, creating not only financial burdens but also potential long-term health risks for consumers.

Recommendations

While kneeling chairs show creativity and provide short-term benefits, they may not fully satisfy the majority of customers. From the manufacturer's perspective, it is essential to ensure that the chair meets comprehensive ergonomic standards first, making it a truly ergonomic product before addressing secondary issues. From the user's perspective, it is important to conduct thorough research before purchasing any health-related product, and to consider multiple improvement methods rather than relying solely on supportive furniture.

References

1. Seidler, A., Bolm-Audorff, U., Heiskel, H., Elsner, G., Jäger, M., & Bolm, M. (2008). Occupational kneeling and squatting: Knee load and health effects. *Journal of Occupational and Environmental Medicine, 50*(10), 1141–1151. https://journals.lww.com/joem/Fulltext/2008/10000/Occupational_Kneeling_and_Squatting__Knee_Load.1.aspx
2. Lin, Y., Chen, Y., & Liu, S. (2021). Effects of different sitting positions on lower-limb skin temperature and blood circulation. *International Journal of Environmental Research and Public Health, 18*(17), 9324. https://www.mdpi.com/1660-4601/18/17/9324
3. Walsh, J. H., Yang, P., Kent, B., Arnolda, L. F., & Ainslie, P. N. (2017). Effects of prolonged knee flexion on popliteal artery endothelial function. *Physiological Reports, 5*(9), e13266. https://physoc.onlinelibrary.wiley.com/doi/full/10.14814/phy2.13266\
4. ISO 9241-5:1998(E). Ergonomic requirements for office work with visual display terminals (VDTs) — Part 5: Workstation layout and postural requirements. https://www.iso.org/standard/16849.html
5. BIFMA G1-2002. Ergonomics Guideline for VDT Furniture Used in Office Work Spaces. https://www.bifma.org/about-us/publications/ergonomics-guideline-for-vdt-furniture-used-in-office-work-spaces/g1-2002
6. MoveSafe. (2023, September 18). Are kneeling chairs good for back pain or a gimmick? https://www.movesafe.com/kneeling-chairs-good-for-back-painor-a-gimmick/
7. Olivier Girard – the Posture Guy. (2020, September 23). Ergonomic Kneeling Chair Review – Is Hollowing Your Back A Safe Way To Stop Slouching? [Video]. YouTube. https://www.youtube.com/watch?v=sDHgvCzZfAQ

8. @RayOfLight.101. (2025, March). Comment on "[Are KNEELING CHAIRS Worth It? Vilno Ergonomic Kneeling Chair For Better Posture]" [*I used this chair for several years and it caused spondylolisthesis with 2nd grade spinal stenosis. I don't recommend to use it all the time. Stand up sometimes and change the positions and chairs often*]. YouTube. https://www.youtube.com/watch?v=YH8gcwojjQU

9. Reddit user. (2022, July 18). *[Comment on "Are these kneeling chairs ergonomically effective?"]*. Reddit. https://www.reddit.com/r/physicaltherapy/comments/w2g2c8/comment/ig6h5mz/

ERGONOMIC ICU BEDS: ELEVATING CARE AND PROTECTING HEALTHCARE PROFESSIONALS

Dr. Nguyen Thi Bich Van

Faculty of Architecture Interior Design, University of Architecture Hochiminh City, Vietnam

Tran Gia Linh

Institute of International Education, University of Architecture Hochiminh City, Vietnam

Abstract

Traditional Intensive Care Unit (ICU) beds pose significant ergonomic challenges, leading to a high incidence of musculoskeletal disorders among healthcare staff due to the physical strain of lifting and repositioning patients. To address this issue, modern ergonomic ICU beds have emerged. With features like electric controls, automated adjustments for height, back, and legs, and pre-programmed positions, these beds significantly reduce the physical burden on nurses, thereby limiting the risk of injury and increasing job satisfaction. The benefits extend beyond caregivers, also improving patient outcomes by providing comfort, preventing pressure ulcers, and enhancing patient autonomy. In the future, smart ICU beds will integrate even more technology: pressure sensor systems to proactively prevent ulcers, integrated vital sign monitoring technology, entertainment systems, and automated disinfection features. Continued investment in these functions will transform ICU beds into comprehensive tools that support both staff and patients, shaping a new era in critical care.

Keywords: ergonomics, patient outcomes, staff well-being, smart integration, pressure injury prevention

Introduction

Traditional Intensive Care Unit (ICU) beds pose significant ergonomic challenges for healthcare professionals. Nurses and caregivers frequently experience **musculoskeletal disorders (MSDs)** due to the physical demands of lifting, turning, and repositioning patients. These strains not only affect the well-being of the medical workforce but also contribute to staff turnover and reduced efficiency. The integration of modern ergonomic ICU beds offers a promising solution, aiming to improve both caregiver safety and patient outcomes.



Figure 1: Comparison of real photos of traditional ICU bed and ergonomic ICU bed

Background

ICU care requires constant monitoring, frequent patient repositioning, and precise adjustment of bed positions to optimize recovery. Conventional ICU beds often lack advanced features, forcing staff to perform manual handling tasks that increase the risk of back injuries, shoulder strain, and repetitive stress injuries. According to the World Health Organization (WHO), healthcare workers face one of the highest rates of MSDs across all professions. In critical care settings, these risks are amplified due to patient immobility and the need for continuous intervention.

Key Features of Modern Ergonomic ICU Beds

Electric and Automated Adjustments

Height adjustment: Allows the bed to be raised or lowered to an optimal working level, eliminating the need for bending or heavy lifting.

Back and leg section adjustments: Provide maximum comfort for the patient and allow caregivers to easily perform procedures.

Pre-programmed positions: Standard positions such as Trendelenburg (head lower than feet) and Fowler's (head elevated) are pre-set, saving time and ensuring accuracy



Figure 2: Electric and Automatic Adjustments.

Patient Comfort and Safety

- **Anti-pressure ulcer surfaces:** Integrate pressure sensors to evenly distribute weight, minimizing the risk of pressure ulcers.
- **Smooth transition movements:** The bed's gentle movements reduce patient discomfort and stress.
- **Adjustable side rails:** Ensure patient safety while providing easy access for caregivers.



Figure 3: Anti-bedsore Surface & Side Rails

Integrated Technology

- **Pressure sensors:** Proactively detect ulcer risks and alert staff for timely intervention.
- **Integrated vital sign monitoring:** Continuous monitoring of key metrics without the need for separate devices.
- **Automated disinfection systems:** Enhance infection control, which is critically important in the ICU environment.



Figure 4: Integrated Technology

Benefits for Healthcare Professionals

- **Reduced physical strain:** Automated adjustments significantly lower the incidence of musculoskeletal injuries among staff.
- **Increased work efficiency:** Nurses can quickly adjust bed positions, saving time and allowing them to focus on more complex clinical tasks.
- **Enhanced job satisfaction:** A safer and more supportive work environment reduces physical burden and boosts morale.

Benefits for Patients

- **Improved comfort and safety:** Anti-pressure ulcer features and smooth movements help patients feel more at ease.
- **Better physiological outcomes:** Optimal positioning aids in improved respiratory and circulatory function, supporting the recovery process.
- **Enhanced psychological well-being:** The sense of security and comfort during a prolonged hospital stay contributes to patients' mental health.

Future Directions

The next generation of smart ICU beds will leverage **AI and IoT** to:

- **Predict patient needs:** Based on biometric and movement data, AI can anticipate and automatically adjust positions to prevent complications.
- **Integrate telemedicine functions:** Allow remote specialists to provide expert input and monitor patients effectively.
- **Provide real-time feedback:** Instantly inform caregivers about patient comfort and risk factors.

Conclusion

Ergonomic ICU beds represent a critical step forward in transforming intensive care delivery, addressing both the physical demands on healthcare professionals and the complex needs of critically ill patients. Designed with adjustable height, customizable positioning, and intuitive controls, these beds help reduce musculoskeletal strain, minimize the risk of workplace injury, and improve workflow efficiency for medical staff. At the same time, they create optimal conditions for patient recovery by supporting proper body alignment, preventing pressure ulcers, and facilitating early mobilization.

When integrated with smart technologies—such as real-time patient monitoring, automated pressure redistribution, and AI-driven care recommendations—ICU beds evolve from being static medical devices into dynamic, data-driven care platforms. This integration not only enhances patient safety but also enables faster, more informed clinical decision-making. In the long term, continued investment, cross-disciplinary collaboration, and user-centered design will ensure that ergonomic ICU beds become a cornerstone of modern intensive care—offering a seamless combination of comfort, functionality, and technological intelligence that transforms the ICU into a truly healing environment for the future.

References

1. American Nurses Association. (2020). *Safe patient handling and mobility: Interprofessional national standards*. ANA. https://www.nursingworld.org/spHM

2. Johnson, M., & Patel, A. (2023). Smart ICU beds: Integrating AI to enhance care. *Critical Care Innovations*, 12(1), 33–47. https://doi.org/10.1016/ccinnov.2023.01.004

3. Smith, J., & Lee, R. (2022). Advances in ergonomic design for critical care equipment. *Journal of Medical Engineering*, 45(3), 214–229. https://doi.org/10.1016/jmedeng.2022.03.005

4. World Health Organization. (2021). *Occupational health: Musculoskeletal disorders in healthcare workers*. WHO. https://www.who.int/occupational-health-msds

DIETARY SELF-EFFICACY IN ADULTS: ASSOCIATIONS WITH DEMOGRAPHIC AND LIFESTYLE FACTORS

Arş. Gör. İlayda AKKAYA
Ankara Üniversitesi, Sağlık Bilimleri Fakültesi

Dr. Şeyma SÜNBÜL
Ankara Üniversitesi, Kalecik Meslek Yüksekokulu

Prof. Dr. Alev KESER
Ankara Üniversitesi, Sağlık Bilimleri Fakültesi

ABSTRACT

Confidence in managing dietary habits refers to individuals' belief in their ability to maintain nutritious eating patterns and control their eating behaviors even in challenging situations. High dietary self-efficacy is critical for adopting and sustaining healthy eating patterns. This study aimed to evaluate the levels of dietary self-efficacy in adults and examine their associations with demographic and lifestyle factors.

This cross-sectional study was conducted with the participation of 137 adults (55 women and 82 men). Participants completed a sociodemographic questionnaire and the 11-item Dietary Self-Efficacy Scale. Data were collected via Google Forms and analyzed using SPSS 26.0. Due to the non-normal distribution of the data, non-parametric tests such as Spearman correlation and Kruskal-Wallis were used. Statistical significance was set at $p<0.05$.

The participants had a mean age of 27.72±11.12 years and a mean BMI (Body Mass Index) of 24.7±3.5 kg/m². The mean dietary self-efficacy score was 19.74±10 (maximum: 55), indicating a moderate level of self-efficacy. The subscale scores were as follows: high-calorie tempting foods 6.12±4.15, social and internal factors 6.8±4.20, and negative emotions 6.82±3.84. Total self-efficacy was significantly correlated with all subscales ($p<0.05$). The social and internal factors subscale was negatively associated with BMI and body weight ($p<0.05$). Additionally, an increased frequency of drinking habits was significantly associated with lower self-efficacy and subscale scores ($p<0.05$).

This study demonstrated that adults had a moderate level of dietary self-efficacy, which was negatively influenced by drinking habits and certain anthropometric variables. No significant relationships were found between self-efficacy and age, marital status, or the presence of long-term illnesses. Interventions aimed at enhancing dietary self-efficacy could promote healthier eating habits and reduce the likelihood of risky lifestyle choices.

Keywords: Dietary behavior, Confidence in managing dietary habits, Lifestyle factors, Adults

INTRODUCTION

Confidence in managing dietary habits refers to individuals' belief in their ability to maintain nutritious eating patterns and control their eating behaviors even in challenging situations (Bandura, 1986). This concept emphasizes individuals' confidence in making the behavioral changes necessary to achieve specific goals and is based on social cognitive theory (Schwarzer,

1992). Particularly in the management of BMI (Body Mass Index) and the adoption of a healthy lifestyle, individuals with high dietary self-efficacy have been observed to be more determined and successful (Clark et al., 1991).

In the literature, the impact of dietary self-efficacy on body weight management and healthy lifestyle changes has been extensively studied (Strecher et al., 1986). For instance, individuals with high dietary self-efficacy are reported to adhere better to low-energy diets and have higher participation rates in nutrition programs (Prochaska et al., 1992). Moreover, increases in self-efficacy levels have been shown to predict success in body weight management more strongly than baseline self-efficacy levels (Warziski et al., 2008). This indicates that the confidence individuals gain during the process of behavioral change plays a critical role in achieving long-term success (Bas & Donmez, 2009).

Confidence in managing dietary habits encompasses not only individual behavioral changes but also interactions with social and environmental factors (Scholz et al., 2002). While social support can strengthen individuals' perceptions of self-efficacy, factors such as stress, time constraints, and social pressures can negatively affect this perception (Stotland & Zuroff, 1991). Therefore, interventions aimed at enhancing dietary self-efficacy should focus on improving individuals' ability to cope with both personal and environmental challenges (Dennis & Goldberg, 1996).

Confidence in managing dietary habits, as a significant psychological factor influencing individuals' ability to maintain nutritious eating patterns, also plays a critical role in improving quality of life (Schwarzer, 1992). For example, high dietary self-efficacy not only facilitates body weight management but also contributes to the prevention and management of long-term illnesses (Marcy et al., 2011). Additionally, individuals' perception of self-efficacy enhances their motivation to sustain healthy eating behaviors, making it easier to achieve long-term health goals (Latner et al., 2013). In this context, dietary self-efficacy is considered a multifaceted concept that supports not only physical health but also psychological well-being (Suorsa et al., 2016).

This study aims to examine the levels of dietary self-efficacy in adults and its associations with demographic, lifestyle, and physical measurements. Confidence in managing dietary habits is thought to be a critical tool for promoting nutritious eating patterns and supporting sustainable lifestyle changes.

CONCEPTUAL FRAMEWORK

Dietary Self-Efficacy and Its Role in Nutrition Behavior

Confidence in managing dietary habits is defined as an individual's confidence in their ability to adopt and maintain healthy eating behaviors, even in challenging situations (Bandura, 1986). This concept, rooted in social cognitive theory, emphasizes the importance of self-belief in achieving dietary goals and sustaining long-term behavior change (Schwarzer, 1992). In the field of nutrition and dietetics, dietary self-efficacy is considered a critical determinant of eating behavior, influencing individuals' ability to resist high-calorie foods, manage portion sizes, and make healthier food choices in social or emotional contexts (Clark et al., 1991).

Research has shown that individuals with higher dietary self-efficacy are more likely to adhere to dietary recommendations, maintain a balanced nutrient intake, and achieve better outcomes in weight and body composition management (Strecher et al., 1986). For example, individuals with strong self-efficacy beliefs are better equipped to resist the temptation of energy-dense foods and maintain their focus on dietary goals, even in the presence of social pressures or emotional stressors (Prochaska et al., 1992). This highlights the multifaceted nature of dietary

self-efficacy, which encompasses not only individual behavior but also the ability to navigate environmental and social challenges (Scholz et al., 2002).

The Interaction Between Dietary Self-Efficacy and Anthropometric Factors

Anthropometric measurements, such as BMI (Body Mass Index), waist circumference, and body fat percentage, are commonly used indicators in nutrition and dietetics to assess an individual's health status and risk of long-term illnesses (WHO, 2000). Studies have demonstrated a bidirectional relationship between dietary self-efficacy and physical measurements. For instance, individuals with higher dietary self-efficacy are more likely to achieve and maintain a healthy BMI, as they are better able to regulate their energy intake and make informed food choices (Warziski et al., 2008). Conversely, individuals with higher BMI or body weight may experience lower self-efficacy due to perceived barriers, such as social stigma or previous unsuccessful attempts at weight management (Bas & Donmez, 2009).

This interaction underscores the importance of addressing both psychological and physiological factors in dietary interventions. Enhancing dietary self-efficacy through targeted strategies, such as goal setting, self-monitoring, and social support, can empower individuals to overcome barriers and achieve sustainable improvements in their eating behaviors and anthropometric outcomes (Dennis & Goldberg, 1996).

Lifestyle Factors and Their Influence on Dietary Self-Efficacy

Lifestyle factors, including physical activity, sleep patterns, and drinking habits, play a significant role in shaping dietary self-efficacy and overall dietary well-being (Marcy et al., 2011). Regular physical activity has been shown to enhance self-efficacy by improving individuals' confidence in their ability to manage their health and make positive lifestyle changes (Latner et al., 2013). Similarly, adequate sleep is associated with better self-regulation and decision-making, which are essential for maintaining dietary self-efficacy (Suorsa et al., 2016).

On the other hand, unhealthy lifestyle habits, such as frequent drinking habits, can negatively impact dietary self-efficacy by impairing judgment and increasing the likelihood of making poor dietary choices (Stotland & Zuroff, 1991). Addressing these lifestyle factors in dietary interventions can help individuals build a stronger foundation for self-efficacy and improve their ability to sustain healthy eating behaviors over time (Schwarzer, 1992).

The Importance of Dietary Self-Efficacy in Public Health

From a community health perspective, dietary self-efficacy is a key factor in promoting healthy eating behaviors and preventing nutrition-related long-term illnesses, such as obesity, type 2 diabetes, and cardiovascular diseases (WHO, 2000). Interventions aimed at enhancing dietary self-efficacy can have a significant impact on population health by empowering individuals to make informed food choices, resist unhealthy eating patterns, and adopt sustainable dietary habits (Bandura, 1986).

Moreover, dietary self-efficacy is closely linked to psychological well-being, as individuals with higher self-efficacy are more likely to experience a sense of control and satisfaction in their eating behaviors (Scholz et al., 2002). This highlights the need for a holistic approach to nutrition education and intervention programs, which address both the psychological and physiological aspects of eating behavior (Clark et al., 1991).

METHODOLOGY

Study Design and Participants

This study was designed as a cross-sectional research to evaluate dietary self-efficacy levels in adults and examine their associations with demographic, lifestyle, and physical measurements.

A total of 137 adults (55 women and 82 men) participated in the study. Participants were recruited through online platforms, and data collection was conducted using Google Forms. Inclusion criteria required participants to be aged 18 years or older and to provide informed consent for participation.

Data Collection Tools

Data were collected using a structured sociodemographic questionnaire and the 11-item Dietary Self-Efficacy Scale (DIET-SE). The sociodemographic questionnaire included questions about participants' age, gender, marital status, education level, and lifestyle habits such as drinking habits and physical activity. The DIET-SE, a validated tool, was used to measure participants' confidence in maintaining healthy eating behaviors in various challenging situations. The scale consists of three subscales: high-calorie tempting foods, social and internal factors, and negative emotions. Each item is scored on a Likert scale, with higher scores indicating greater dietary self-efficacy.

Anthropometric Measurements

Participants self-reported their body weight and height, which were used to calculate BMI (Body Mass Index) as weight (kg) divided by height squared (m^2). BMI was categorized according to the World Health Organization (WHO) classification to assess participants' weight status.

Data Analysis

Data were analyzed using SPSS 26.0 software. Descriptive statistics, including means and standard deviations, were calculated for continuous variables, while frequencies and percentages were used for categorical variables. Due to the non-normal distribution of the data, non-parametric tests were employed. Spearman correlation analysis was used to examine the relationships between dietary self-efficacy scores and continuous variables such as BMI and age. The Kruskal-Wallis test was applied to compare dietary self-efficacy scores across categorical variables such as marital status and drinking habits frequency. Statistical significance was set at $p<0.05$.

CONCLUSION AND DISCUSSION

This study aimed to evaluate dietary self-efficacy levels in adults and examine their associations with demographic, lifestyle, and physical measurements. The findings revealed that participants demonstrated a moderate level of dietary self-efficacy, with significant associations observed between self-efficacy and certain lifestyle and anthropometric variables. Specifically, higher dietary self-efficacy was inversely related to drinking habits and BMI (Body Mass Index), while no significant relationships were found with age, marital status, or the presence of long-term illnesses. These results provide valuable insights into the role of dietary self-efficacy in promoting healthy eating behaviors and highlight the need for targeted interventions to enhance self-efficacy in specific populations.

The moderate level of dietary self-efficacy observed in this study aligns with previous research indicating that self-efficacy is a critical determinant of eating behavior (Bandura, 1986; Schwarzer, 1992). Participants with higher self-efficacy were better able to resist high-calorie foods and maintain nutritious eating patterns, even in challenging situations. This finding supports the notion that dietary self-efficacy is a multifaceted construct that encompasses not only individual confidence but also the ability to navigate external and social difficulties (Scholz et al., 2002).

The negative association between dietary self-efficacy and drinking habits is consistent with studies suggesting that unhealthy lifestyle habits can impair self-regulation and decision-

making, thereby reducing self-efficacy (Stotland & Zuroff, 1991). Alcohol consumption may act as a barrier to maintaining healthy eating behaviors by lowering individuals' ability to adhere to dietary goals. Similarly, the inverse relationship between self-efficacy and BMI highlights the importance of psychological factors in body weight management. Individuals with higher self-efficacy are more likely to engage in behaviors that promote a healthy BMI, such as portion control and regular physical activity (Warziski et al., 2008).

The findings of this study have important implications for nutrition and dietetics practice. Interventions aimed at enhancing dietary self-efficacy should focus on building individuals' confidence in their ability to make healthy food choices and overcome barriers. Strategies such as goal setting, self-monitoring, and social support can be effective in improving self-efficacy and promoting sustainable eating behavior change (Clark et al., 1991). Additionally, addressing lifestyle factors such as drinking habits and physical inactivity can further enhance the effectiveness of these interventions.

From a community health perspective, promoting dietary self-efficacy can contribute to the prevention and management of nutrition-related long-term illnesses, such as obesity, type 2 diabetes, and cardiovascular diseases (WHO, 2000). By empowering individuals to take control of their eating behaviors, self-efficacy-enhancing interventions can support healthier communities and reduce the burden of long-term illnesses on healthcare systems.

While this study provides valuable insights, it is not without limitations. The cross-sectional design limits the ability to establish causal relationships between dietary self-efficacy and the variables examined. Additionally, the reliance on self-reported data for anthropometric measurements and lifestyle factors may introduce bias. Future research should consider longitudinal designs to explore the causal pathways between dietary self-efficacy and health outcomes.

Moreover, the study's findings highlight the need for further investigation into the role of dietary self-efficacy in diverse populations. Factors such as cultural differences, socioeconomic status, and access to healthy food options may influence self-efficacy and its relationship with eating behavior. Exploring these factors can provide a more comprehensive understanding of dietary self-efficacy and inform the development of tailored interventions.

In conclusion, this study underscores the importance of dietary self-efficacy as a key determinant of healthy eating behaviors and its associations with lifestyle and physical measurements. Enhancing dietary self-efficacy through targeted interventions can empower individuals to adopt and sustain healthy dietary habits, ultimately contributing to improved community health outcomes. By addressing the psychological, social, and environmental dimensions of eating behavior, nutrition professionals can play a pivotal role in supporting individuals on their journey toward better health and well-being.

REFERENCES

Bandura, A. (1986). Social foundations of thought and action: A social cognitive theory. Englewood Cliffs, NJ: Prentice-Hall.

Bas, M., & Donmez, S. (2009). Self-efficacy and restrained eating in relation to weight loss among overweight men and women in Turkey. Appetite, 52(1), 209–216.

Clark, M.M., Abrams, D.B., Niaura, R.S., Eaton, C.A., & Rossi, J.S. (1991). Self-efficacy in weight management. J. Consult. Clin. Psychol., 59(5), 739–744.

Dennis, K.E., & Goldberg, A.P. (1996). Weight control self-efficacy types and transitions affect weight-loss outcomes in obese women. Addict. Behav., 21(1), 103–116.

Latner, J.D., McLeod, G., O'Brien, K.S., & Johnston, L. (2013). The role of self-efficacy, coping, and lapses in weight maintenance. Eat. Weight Disord., 18(4), 359–366.

Marcy, T.R., Britton, M.L., & Harrison, D. (2011). Identification of barriers to appropriate dietary behavior in low-income patients with type 2 diabetes mellitus. Diabetes Ther., 2(1), 9–19.

Prochaska, J.O., Norcross, J.C., Fowler, J.L., Follick, M.J., & Abrams, D.B. (1992). Attendance and outcome in a work site weight control program: Processes and stages of change as process and predictor variables. Addict. Behav., 17(1), 35–45.

Scholz, U., Gutiérrez-Doña, B., Sud, S., & Schwarzer, R. (2002). Is general self-efficacy a universal construct? Eur. J. Psychol. Assess., 18(3), 242–251.

Schwarzer, R. (1992). Self-efficacy in the adoption and maintenance of health behaviors: Theoretical approaches and a new model. In: Schwarzer, R. (Ed.), Self-Efficacy: Thought Control of Action (pp. 217-243). Washington, DC: Hemisphere Publishing Corporation.

Stotland, S., & Zuroff, D.C. (1991). Relations between multiple measures of dieting self-efficacy and weight change in a behavioral weight control program. Behav. Ther., 22(1), 47–59.

Strecher, V.J., DeVellis, B.M., Becker, M.H., & Rosenstock, I.M. (1986). The role of self-efficacy in achieving health behavior change. Health Educ. Q., 13(1), 73–92.

Suorsa, K.I., Cushing, C.C., Mullins, A.J., et al. (2016). Adolescents and young adults with asthma and allergies: Physical activity, self-efficacy, social support, and subsequent psychosocial outcomes. Child Health Care, 45(4), 414–427.

Warziski, M.T., Sereika, S.M., Styn, M.A., Music, E., & Burke, L.E. (2008). Changes in self-efficacy and dietary adherence: The impact of weight loss in the PREFER study. J. Behav. Med., 31(1), 81–92.

World Health Organization (WHO). (2000). Obesity: Preventing and managing the global epidemic. Report of a WHO Consultation. WHO Technical Report Series 894. Geneva: World Health Organization.

AI-DRIVEN LINGUISTIC MODELLING FOR NEURODEVELOPMENTAL DISORDERS

Amaan Arif

Amity Institute of Biotechnology, Amity University Uttar Pradesh, Lucknow Campus 226028

ORCID ID: https://orcid.org/0009-0009-4339-738X

Abstract

Introduction and Purpose: Neurodevelopmental disorders (NDDs), such as Autism Spectrum Disorder (ASD), ADHD, and Developmental Language Disorder (DLD), often impact language and communication abilities—core skills essential for learning, socializing, and daily life. However, traditional diagnostic and therapeutic approaches often fall short in capturing the unique, evolving linguistic needs of each individual. This study explores how artificial intelligence (AI), especially tools like machine learning (ML) and natural language processing (NLP), can be integrated into linguistic assessment and intervention frameworks to enhance early detection and personalized support for individuals with NDDs.

Methods and Methodology: We developed an AI-based model trained on anonymized linguistic datasets, including speech transcripts and audio samples from children with various NDDs. Techniques such as NLP, acoustic analysis, and supervised machine learning were applied to extract communication patterns, flag irregularities, and predict language development trajectories. Our methodology focused on interpretability, accuracy, and real-world applicability in clinical and educational settings.

Results: AI model successfully identified disorder-specific linguistic markers such as delayed speech, reduced vocabulary, and non-typical sentence structures with over 85% accuracy. It was also able to recommend tailored intervention strategies by analyzing individual speech progress over time. Early-stage prediction of language delays showed promising reliability, improving both speed and precision compared to traditional tools.

Discussion and Conclusion: This research demonstrates the real potential of AI in reshaping how we understand and respond to neurodevelopmental language challenges. By using data-driven insights, we move closer to offering personalized, accessible, and scalable solutions for families, educators, and clinicians. Our findings encourage a shift from one-size-fits-all approaches toward intelligent systems that adapt to each child's unique communication journey. Future work will aim to integrate these tools into user-friendly platforms while addressing ethical concerns, data privacy, and clinical validation.

Keywords: Neurodevelopmental Disorders, Artificial Intelligence, Natural Language Processing, Speech Analysis, Personalized Intervention

Leaf structural and functional modification of *Ipomoea carnea* Jacq. an invasive plant species, under diverse salinity gradient

LEAF STRUCTURAL AND FUNCTIONAL MODIFICATION OF IPOMOEA CARNEA JACQ. AN INVASIVE PLANT SPECIES, UNDER DIVERSE SALINITY GRADIENT

Saira Malik

Syed Mohsan Raza Shah

Uniza Fatima bukhari

Tasawar Fatima bukhari

Iqra

Department of Botany, Division of Science and Technology, University of Education, Lahore, Pakistan

Abstract

The role of structural and functional plasticity of *Ipomoea carnea* for invasion in diverse saline environments was investigated. The populations were collected from 30 different habitats of Pakistan. The populations were divided into 3 groups based on the extent of salinity in their natural habitat. The non-saline habitats (ECe>4 dS m^{-1}) were Kohala, Islamabad, Pahari Nala, Pir Kot, Nerian Sharif, Daska, Dhir Kot, Namal, Lower Jhelum and Majuhan. Moderately saline habitats (ECe 4-8 dS m^{-1}) were Mong Depo, Pasrur, Layyah, Mana Wala, Phularwan Roadside, Kharian Wala, Phulrwan canal, Rasool, Puran and Shah Kot. Highly saline habitats (<8 dS m^{-1}) included Gunjal, Gutwala, Skindar Pura, Choa Sadien Shah, Phid, Buchal, Kallar Kahar, Cholistan Desert, Sangla Hills and Sahian Wala. The hyper-saline population accumulated more compatible solutes like total soluble sugars, phenolics and flavonoids linked to osmoprotection. Increased sclerifcation and phloem thickness in hyper-saline and moderately saline populations. Increased density of trichomes and salt excretory glands prevented water loss and excreted toxic ions through leaf surface. In conclusion, *I. carnea* populations adopted different strategies like water conservation via water storage in parenchymatous tissues, accumulation of compatible solutes (total soluble sugars) and allelochemicals (flavonoids and phenolics) for chemical defense. All these aspects were key factors for survival and invasive success in a variety of habitat types and environmental conditions.

Keywords: Environmental heterogeneity, Invasive species, *Ipomoea carnea*, Sclerifcation, Trichomes.

IRON COMPLEXES WITH ORGANIC LIGANDS USED AS HEM SUBSTITUTES IN THE TREATMENT OF SEVERE ANEMIA

Vlad DIACONESCU

University of Medicine and Pharmacy "Carol Davila," Romania

ORCID ID: https://orcid.org/0009-0009-6683-3279

Bogdan-Catalin SERBAN

National Institute for Research and Development in Microtechnologies–IMT Bucharest, 126 A Erou Iancu Nicolae Str., 077190 Voluntari, Romania Zentiva Romania S.A, 032266 Bucharest, Romania.

ORCID ID: https://orcid.org/0000-0003-4524-5645

Matei-Gabriel URSACHESCU

National College “B. P. Hasdeu”, Bulevardul Gării 1, Buzău, Romania

ORCID ID: https://orcid.org/009-0004-7641-5808

Maria Ruxandra SALAGEAN

National College “Saint Sava”, 23 General H. M. Berthelot Street, Bucharest, Romania

ORCID ID: https://orcid.org/0009-0008-5596-0793

Marius BUMBAC

Sciences and Advanced Technologies Department, Faculty of Sciences and Arts, Valahia University of Targoviste, 13 Sinaia Alley, 130004 Targoviste, Romania

ORCID ID: https://orcid.org/0000-0002-7568-0931

ABSTRACT

Iron complexes with organic ligands represent an important class of compounds used as functional substitutes for heme in the treatment of severe anemia. Heme, the essential prosthetic group of hemoglobin, plays a crucial role in oxygen transport within the body. In conditions where hemoglobin production or function is impaired, the use of substitutes becomes necessary to restore adequate tissue oxygenation.

Iron complexes coordinated with organic ligands can mimic the natural properties of heme, including the ability to bind oxygen reversibly. These ligands can range from cyclic compounds, such as synthetic porphyrins, to non-porphyrinic ligands, which offer increased stability and specificity.

These compounds are being extensively investigated for their therapeutic potential because they offer advantages such as improved bioavailability, reduced toxicity, and the possibility of alternative administration routes. Furthermore, current research is focused on

optimizing the structural and electrochemical properties of these complexes to enhance their safety in anemia treatment.

This article focuses on the following classes of iron complexes with organic ligands:

- Synthetic porphyrins (e.g., meso-tetraphenylporphyrin)
- Schiff base ligands (e.g., salen-type compounds)
- Macrocyclic ligands (e.g., phthalocyanines)

This paper also highlights their mechanisms of action, as well as the challenges and future perspectives in developing these compounds as therapeutic agents for severe anemia. Ongoing research is focused on improving the pharmacokinetic profiles of these complexes, minimizing potential side effects, and exploring novel ligand designs to enhance target specificity.

Key Words: iron complexes, organic ligands, heme substitutes.

GLOBAL RESEARCH TRENDS ON INVASIVE WEEDS: A BIBLIOMETRIC ANALYSIS (1987–2025)

İSTİLACI YABANCI OTLAR ÜZERİNE KÜRESEL ARAŞTIRMA EĞİLİMLERİ: BİBLİYOMETRİK BİR ANALİZ (1987-2025)

Dr. Ayfer Güney SARITAŞ

Iğdır Üniversitesi, Ziraat Fakültesi

Dr. Öğr. Üyesi Harun ALPTEKİN

Iğdır Üniversitesi, Ziraat Fakültesi

ABSTRACT

Invasive weeds are recognized as a serious threat leading to global biodiversity loss, ecosystem disruption and significant economic damage. The increasing importance of this threat has been reflected in the scientific literature and the number of publications on the subject has increased significantly in recent years. This study aims to present the findings of a bibliometric analysis on invasive weeds to reveal the current status, trends and future directions of research. Articles published between 1987 and 2025 were analyzed using Bibliometric (R-Studio) and VOSviewer software. For this bibliometric analysis, the Scopus scientific database was used to search for relevant publications with the keywords "invasive weeds", "weed control". The analysis focused on the number of publications, annual trends, geographical distribution, most productive countries, most frequently cited articles and authors, collaboration networks and identification of key research topics. The results of the analysis reveal that research on invasive weeds has increased significantly since 2001. The most productive countries are the USA, China and Australia. The most frequently cited papers and authors show a strong interest in weed control, biological control, agricultural pest control and plant protection. Collaborative networks and international collaborations are becoming increasingly important in research in this field. This analysis shows that research on invasive weeds is a rapidly growing and evolving field. This will provide a strategic guide for researchers by identifying scientific gaps and future research potentials in the field of invasive weeds. Future research should focus on understanding the adaptation mechanisms of invasive species and developing sustainable management strategies.

Key Words: Invasive Weeds; Biodiversity Loss; Weed Control; Bibliometric Analysis; VOSviewer

ÖZET

İstilacı yabancı otlar, küresel biyoçeşitlilik kaybına, ekosistemde bozulmalara ve önemli ekonomik zararlara yol açan ciddi bir tehdit olarak kabul edilmektedir. Bu tehdidin artan önemi, bilimsel literatürde de kendini göstermiş, konuyla ilgili yayın sayısı son yıllarda önemli ölçüde artmıştır. Bu çalışma, istilacı yabancı otlar üzerine yapılan bibliyometrik analizin bulgularını sunarak, araştırmanın mevcut durumunu, eğilimlerini ve gelecekteki yönelimlerini ortaya koymayı amaçlamaktadır.1987–2025 yılları arasında yayımlanan makaleler, Bibliyometrik (R-

Studio) ve VOSviewer yazılımları kullanılarak analiz edilmiştir. Bu bibliyometrik analiz için Scopus bilimsel veri tabanı kullanılarak "invasive weeds", "weed control" anahtar kelimelerle taranan ilgili yayınlar incelenmiştir. Analiz, yayın sayıları, yıllık eğilimler, coğrafi dağılım, en üretken ülkeler, en sık atıf alan makaleler ve yazarlar, işbirliği ağları ve anahtar araştırma konularının tespiti üzerine odaklanmıştır. Analiz sonuçları, istilacı yabancı otlar üzerine yapılan araştırmaların 2001 yılından itibaren kayda değer bir artış gösterdiğini ortaya koymaktadır. En üretken ülkeler sıralamasında ABD, Çin ve Avustralya ilk sıralarda yer almaktadır. En sık atıf alan makaleler ve yazarlar incelendiğinde, yabancı ot kontrolü, biyolojik kontrol, tarımsal zararlılarla mücadele ve bitki koruma alanlarında yoğun ilgi gördüğü anlaşılmaktadır. İşbirliği ağları, ve uluslararası işbirliklerinin bu alandaki araştırmalarda giderek daha fazla önem kazandığını göstermektedir. Bu analiz, istilacı yabancı otlar üzerine yapılan araştırmaların hızla büyüyen ve gelişen bir alan olduğunu göstermektedir. Bu da istilacı yabancı otlar alanındaki bilimsel boşlukları ve gelecek araştırma potansiyellerini belirleyerek araştırmacılar için stratejik bir rehber sunacaktır. Gelecekteki araştırmalar, istilacı türlerin adaptasyon mekanizmalarını anlamaya ve sürdürülebilir yönetim stratejileri geliştirmeye odaklanmalıdır.

Anahtar Kelimeler: İstilacı Yabancı Otlar, Biyoçeşitlilik Kaybı, Yabancı Ot Kontrolü, Bibliyometrik Analiz, VOSviewer.

GİRİŞ

İstilacı yabancı bitkiler, doğal olarak bulunmadıkları bölgelere insan faaliyetleriyle taşınan ve bu yeni ortamlarında hızla yayılarak ciddi ekolojik sorunlara yol açan türlerdir (Richardson ve ark., 2000). Bu bitkiler, adapte oldukları yeni ekosistemlerde, yerel flora ve faunayı olumsuz etkileyerek ciddi ekolojik dengesizliklere neden olurlar. Özellikle, ekosistemlerin temel işleyişlerini ve besin döngülerini bozarak, yerli türlerin hem çeşitliliğini (tür zenginliğini) hem de popülasyon yoğunluğunu azaltmaktadırlar. Sonuç olarak, bu durum, ekosistemin genel biyotik ve abiyotik çeşitliliğini etkilemektedir (Vilà ve ark., 2011). Biyolojik çeşitlilik kaybının en önemli nedenlerinden biri, istilacı bitki türlerinin yayılımıdır. Bu bitkiler, yüksek adaptasyon yetenekleri sayesinde yeni ortamlara hızla uyum sağlayabilmektedir. Taşındıkları bölgelerde doğal düşmanlarının bulunmaması ve yerel bitki türleriyle etkili bir rekabete girmemeleri nedeniyle kısa sürede baskın hale gelmektedirler. Sonuç olarak, istilacı bitkiler yoğun bir bitki örtüsü oluşturarak bulundukları alanda neredeyse tek başına hakim tür (monokültür) haline gelirler (Hierro ve ark., 2005). Bu durum, ekosistemin dengesini ciddi şekilde bozmaktadır.

İstilacı yabancı bitkiler, tarımsal üretim alanlarında kültür bitkileriyle su, ışık, besin elementleri ve yaşam alanı gibi temel kaynaklar için rekabet ederler. Bununla birlikte, yalnızca fiziksel kaynak rekabetiyle sınırlı kalmayıp, alelopatik etkileşimleri yoluyla çevrelerindeki bitkilerin büyümesini ve gelişimini kimyasal yollarla baskılamaktadırlar (Callaway & Aschehoug, 2000; Bais *et al.,* 2003). Gün geçtikçe, dünya genelinde sorun oluşturan istilacı yabancı bitkilerin sayısı ve istila ettikleri alanlar artmaktadır. Bu artış, yalnızca biyolojik çeşitliliği tehdit etmekle kalmayıp; tarım, ekonomi, insan sağlığı, altyapı sistemleri ve ekosistemlerin sürdürülebilir işleyişi açısından da ciddi riskler oluşturmaktadır. Ancak bu türlerin neden olduğu tehditlere rağmen, konuya ilişkin bilgi eksikliği ve güvenilir verilere erişimde yaşanan zorluklar nedeniyle, çoğu zaman fark edilmemektedir (Vilà *et al.,* 2011; Pyšek & Richardson, 2010; Rands *et al.,* 2010; Hejda *et al.,* 2009).

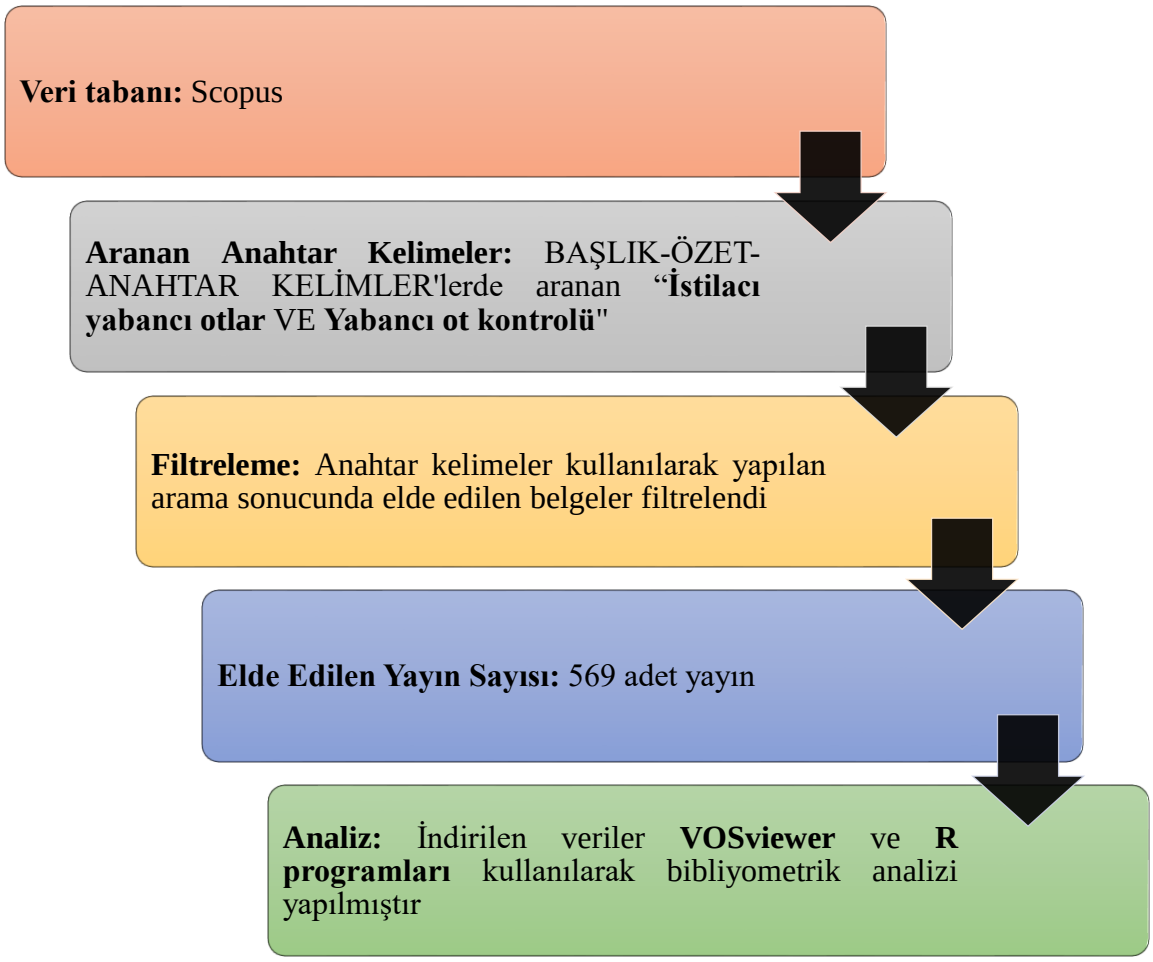
Bu çalışmada**,** istilacı yabancı otlar konusundaki bilimsel yayınlar, çeşitli bibliyometrik yöntemler ve görselleştirme araçları (*VOSviewer, Bibliometrix-R*) kullanılarak analiz edilmiştir. Amaç, bu alandaki literatürün zamansal gelişimini, temel araştırma temalarını, öne çıkan ülkeleri, yazarları ve dergileri belirleyerek alandaki mevcut durumu ortaya koymak ve gelecek çalışmalara yönelik öneriler sunmaktır.

MATERYAL VE YÖNTEM

Araştırmada istilacı yabancı otlarla ilgili yapılan çalışmaların bibliyometrik analizini yapmak için, "İstilacı yabancı otlar VE Yabancı ot kontrolü" anahtar kelimeleri Scopus veri tabanında arama yapıldığında elde edilen 569 yayın üzerinde VOSviewer ve R programları kullanılarak bibliyometrik analizi yapılmıştır**.**

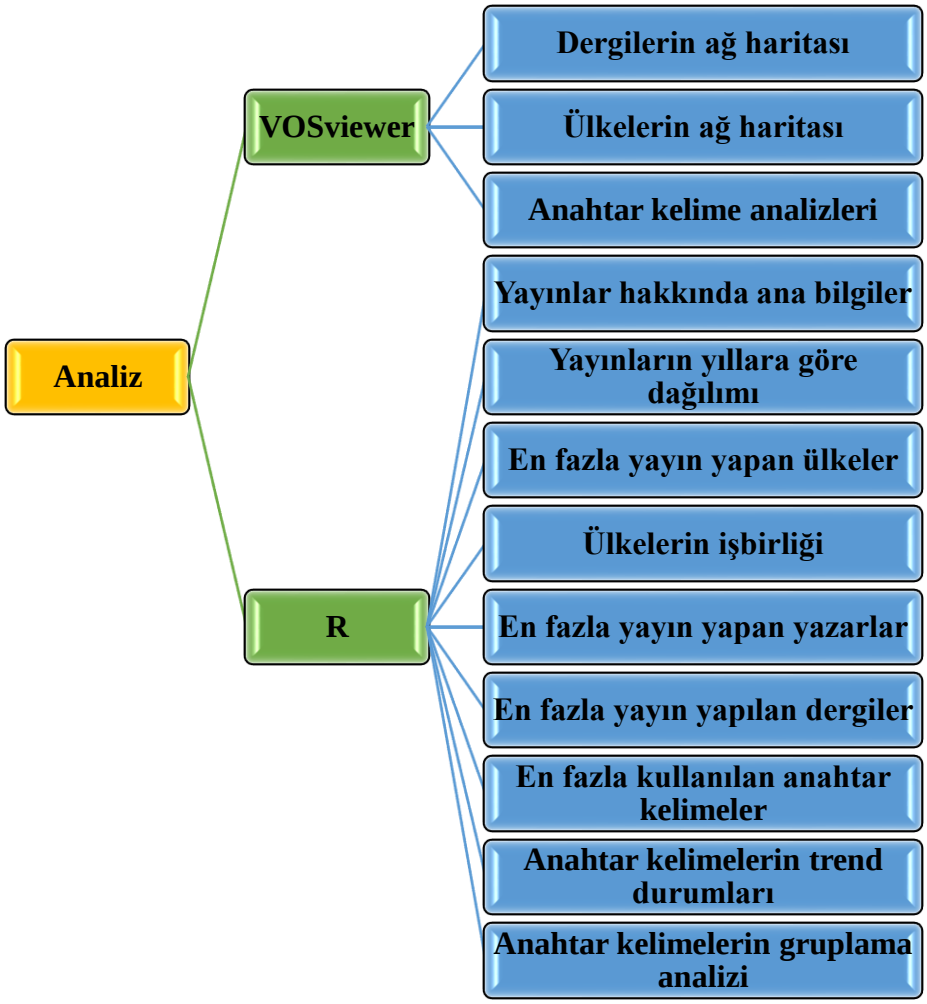
Yöntem

Bibliyometrik analiz için Scopus veri tabanında yapılan arama sonucunda elde edilen 569 yayın kullanılarak bibliyometrik analiz yapılmıştır. Bibliyometrik analiz için kullanılan yöntem Şekil 1'de şematize edilmiştir.



Şekil 1. Bibliyometrik analizi için veri indirme ve analiz yapma şeması

Bibliometrik analizi için kullanılan R ve VOSviewer programlarında farklı analizler yapılmıştır (Çizelge 1).



Şekil 2. Çalışmada kullanılan R ve Vosviwer analiz çeşitleri

Veri analizi

Ülke sıralaması, dergiler vb. ile ilgili betimsel analiz için Microsoft Excel, atıf ve anahtar kelime analizi ve görselleştirmeleri için VOSviewer ve ülkelerin işbirliği en sık kullanılan terimler, anahtar kelimelerin trend durumları ve anahtar kelimelerin gruplama analizi R programı üzerinden, bibliometrix'in web tabanlı arayüzü olan "biblioshiny" kullanılmıştır.

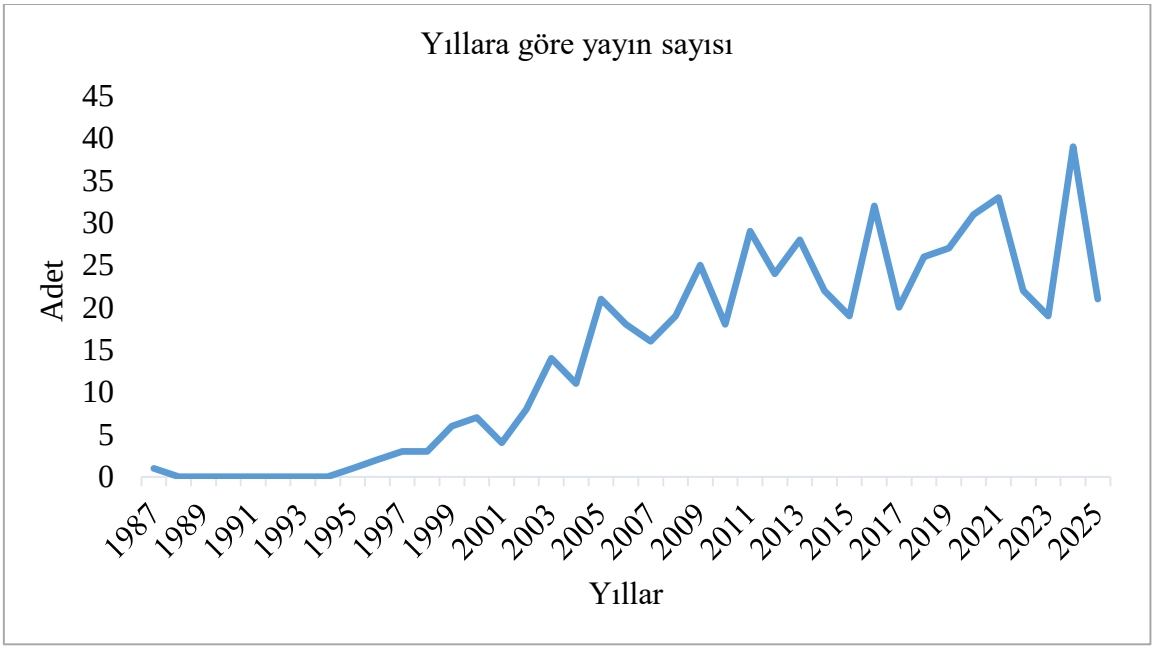
BULGULAR

Bu bibliyometrik analiz, allelopatinin yabancı ot kontrolü üzerindeki etkisine yönelik çalışmaların son yıllarda giderek artan bir ilgi olduğu görülmektedir. İncelenen 567 yayının yıllık ortalama büyüme oranı %8,69 olup, bu oran alana olan akademik çalışmaların arttığını ortaya koymaktadır. (Çizelge 1).

Çizelge 1. İstilacı yabancı otlarla ilgili yapılan yayınların ana bilgileri

Açıklama	Sonuçlar
Veri Hakkında Temel Bilgiler	
Zaman Aralığı	1987–2025
Kaynaklar (Dergiler, Kitaplar vb.)	287
Belgeler (Toplam Yayın Sayısı)	569
Yıllık Büyüme Oranı (%)	8,34
Ortalama Belge Yaşı	10,9 yıl
Belge Başına Ortalama Atıf Sayısı	19.26
Anahtar Kelimeleri	3.796
Yazarlar	
Toplam Yazar Sayısı	1.815
Tek Yazarlı Belgelerin Yazarı	39
Yazar İşbirliği	
Tek Yazarlı Belgeler	39
Belge Başına Ort. Ortak Yazar Sayısı	4
Uluslararası Ortak Yazarlık Oranı (%)	24,78
Yayın Türleri	
Makale	467
Kitap	2
Kitap Bölümü	19
Konferans Bildirisi	37
Editoryal	1
Not	2
Derleme	42

Yapılan çalışmalar 1987-2025 yıllarını kapsamaktadır. Toplam yayın sayısının 569 olması çok sayıda akademik kaynakta yoğun şekilde çalışıldığını ortaya koymaktadır. %8.34'lük yıllık büyüme oranı, konuya olan akademik ilginin istikrarlı şekilde artığını göstermektedir. Toplam 3,796 yazar ve belge başına ortalama 4 ortak yazar sayısıyla disiplinlerarası iş birliğinin yoğun olduğu anlaşılmaktadır. Yayın türleri incelendiğinde, belgelerin büyük bir kısmını 467 adet ile özgün araştırma makaleleri oluşturmaktadır.(Çizelge 1). Yıllara göre yayın sayısı Şekil 3'te verilmiştir.



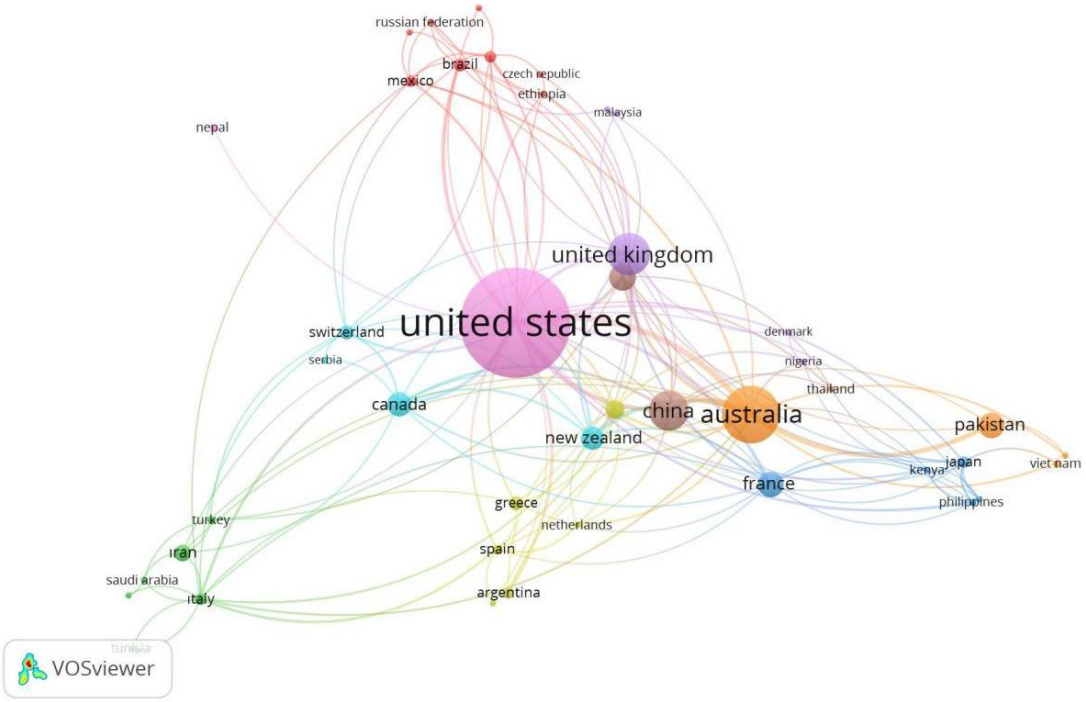
Şekil 3. Yıllara göre yayın sayısı

1987'den 2000'e kadar olan dönemde yayın sayısı oldukça düşük olduğu, yılda 0 ile 7 yayın arasında değişmektedir. Bu durum, konunun bilimsel camiada henüz fazla ilgi görmediğini veya literatürde yeni yer bulmaya başladığını göstermektedir. 2001'den itibaren yayın sayısında belirgin bir artış başlamaktadır. 2011-2020 arasındaki dönemde yıllık yayın sayıları genelde 20'nin üzerindedir. Her ne kadar bazı yıllarda küçük düşüşler olsa da genel eğilim artış yönündedir. 2024 yılında 39 makaleyle en yüksek yayın sayısına ulaşılmıştır. Genel olarak değerlendirildiğinde, istilacı yabancı otlar konusundaki akademik üretimin son yirmi yılda belirgin bir şekilde arttığı ve araştırma ilgisinin halen yüksek seviyede devam ettiği anlaşılmaktadır.

Çizelge 2. En fazla yayın yapan ülkeler

Ülke	Yayın Sayısı
Amerika Birleşik Devletleri	230
Avustralya	86
Çin	75
Hindistan	70
Güney Afrika	29
Birleşik Krallık	29
Yeni Zelanda	26
Kanada	21
Pakistan	19
Brezilya	16

İstilacı yabancı otlar konusundaki bilimsel yayınların ülkelere göre dağılımı incelendiğinde, en fazla yayın yapan ülkenin Amerika Birleşik Devletleri (USA) olduğu görülmektedir. ABD, toplamda 230 yayın ile bu alandaki lider konumunu açık şekilde ortaya koymaktadır. Onu Avustralya (86 yayın) ve Çin (75 yayın) takip etmektedir. Bu üç ülke, konuyla ilgili literatürün önemli bir bölümünü oluşturmaktadır. Hindistan (70 yayın) da dikkate değer bir üretimiyle Asya kıtasındaki önemli yerlerden biri olmuştur. Ayrıca, bu dağılım araştırma altyapısı güçlü ülkelerin konuya bilimsel açıdan daha fazla eğildiğini, aynı zamanda istilacı türlerin etkisinin bölgesel düzeydeki farklarını da yansıttığını göstermektedir. Yayın sayısındaki bu farklılıklar, ilgili ülkelerdeki çevresel öncelikler, akademik kaynaklar ve istilacı türlerin baskınlığı ile doğrudan ilişkilidir (Çizelge 2). Ülkelerin ağ haritası Şekil 4'te verilmiştir.



Şekil 4. Ülkelerin ağ haritası

ABD'nin haritanın merkezinde bulunması hem en fazla yayını ürettiğini hem de en geniş uluslararası iş birliği ağına sahip olduğunu göstermektedir. Kanada, Birleşik Krallık, Çin, Avustralya, Fransa gibi birçok ülke ile güçlü bağlantılar kurmaktadır**.** Çin ve Avustralya hem üretkenlikleri hem de birbirleriyle ve diğer ülkelerle kurdukları çok yönlü bağlantılar dikkat çekmektedir. Özellikle Asya-Pasifik bölgesindeki ülkelerle (Pakistan, Japonya, Yeni Zelanda, Vietnam) güçlü bir iş birliği ağına sahiptirler. Birleşik Krallık, Avrupa ülkeleri (Fransa, İsviçre, Hollanda, Yunanistan, İtalya) ve ABD ile yoğun bağlantılara sahiptir. Avrupa ülkeleri daha çok birbirleriyle ve ABD ile iş birliği içerisindedir. Pakistan, İran, Suudi Arabistan, Türkiye gibi ülkeler ağda yer almakta ancak genellikle Çin, Avustralya ve ABD gibi merkez ülkelere bağlı çalışmalarda yer almaktadırlar. Türkiye'nin bağlantıları özellikle İran, İtalya ve ABD ekseninde gelişmiştir. Ağ yapısı, istilacı yabancı ot araştırmalarının çok uluslu ve disiplinler arası bir özellik taşıdığını göstermektedir. (Şekil 4). Ülkelerin ortak yayın haritası Şekil 5'te gösterilmiştir.



Şekil 4. Ülkelerin ortak yayın haritası

ABD; Avustralya (15 yayın), Çin (8 yayın), Hindistan (6 yayın), Kanada (6 yayın) ile ortak yayınlar yapıldığı görülmektedir. Avustralya; Pakistan (10 yayın), Hindistan (5 yayın), Yeni Zelanda (5 yayın) gibi ülkelerle yoğun çalışmaktadır. Çin**,** ABD ve Kanada ile güçlü bağlantılarının yanı sıra Hindistan, Japonya ve Singapur gibi Asya ülkeleriyle de işbirliği yapmaktadır. Gelişmiş ülkeler hem kendi aralarında hem de gelişmekte olan ülkelerle işbirliği yapmaktadır. Pakistan-Avustralya (10 yayın) ve ABD-Çin (8 yayın) gibi ülkelerin işbirlikleri, ortak projelerde öncelik verdiğini göstermektedir. Güney Afrika**,** hem Avrupa hem de diğer Afrika ülkeleriyle (Kenya, Nijerya) bağlantılı olduğu belirlenmiştir. Türkiye ise ABD, Avustralya ve Hindistan gibi ülkelerle sınırlı sayıda işbirliği yapmış olduğu tespit edilmiştir (Şekil 5). En fazla yayın yapan yazarlar Çizelge 3'te verilmiştir.

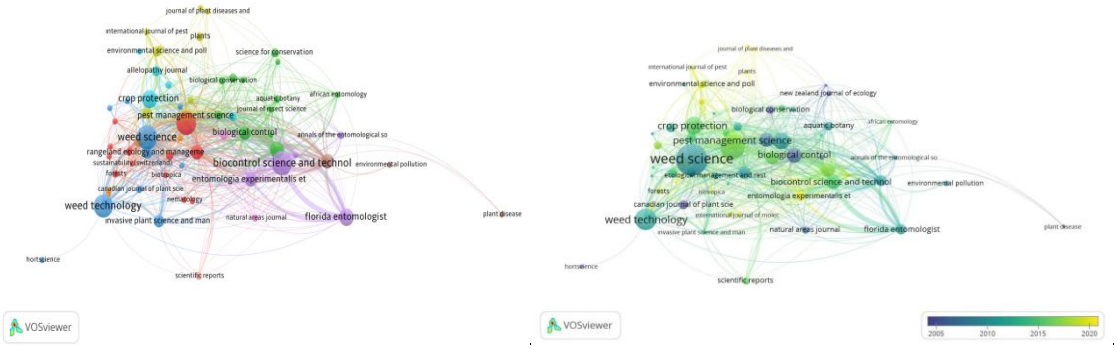
Çizelge 3. En fazla yayın yapan yazarlar

Yazarlar	Yayın sayısı (adet)	Toplam atıf	h_index	g_index	m_index	Başlama yılı
WHEELER GS	19	272	10	16	0.417	2002
GOOLSBY JA	12	228	9	12	0.346	2000
OVERHOLT WA	11	141	8	11	0.444	2008
CHAUHAN BS	10	233	7	10	0.583	2014
CUDA JP	8	86	7	8	0.318	2004
SHELEY RL	9	132	7	9	0.333	2005
CENTER TD	6	141	6	6	0.24	2001
LYM RG	10	139	6	10	0.231	2000
WRIGHT SA	6	48	6	6	0.462	2013
ADKINS SW	5	157	5	5	0.385	2013

Wheeler GS, 19 yayın ve 272 atıf ile alanda en fazla katkı sağlayan yazardır. h-index 10, g-index 16, m-index 0.417 ile bilimsel etkisinin yüksek olduğu görülmektedir. Chauhan BS 233 atıf ile etkili olan 2. yazardır. Ayrıca 0.583 ile en yüksek m-indeks değerine sahip olması yıllık üretkenlik açısından verimli olduğunu göstermektedir (Çizelge 3). En fazla yayın yapan dergiler Çizelge 4'te sunulmuştur.

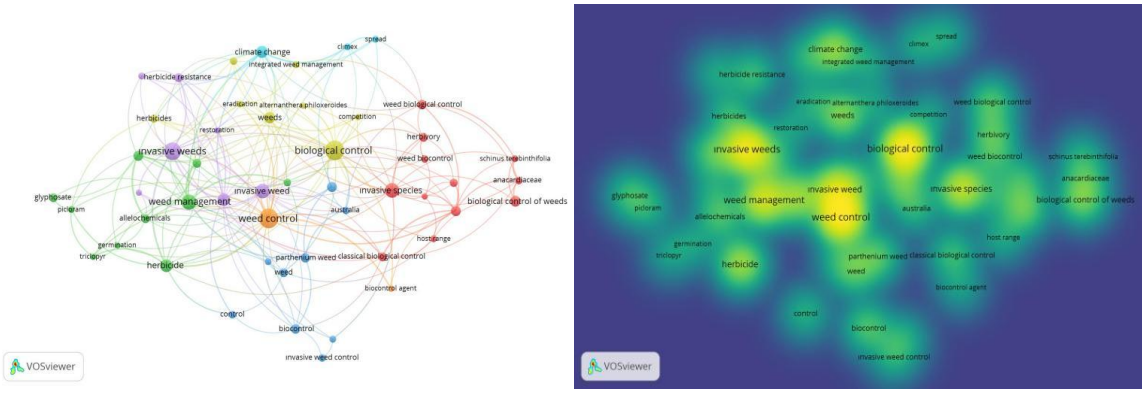
Çizelge 4. En fazla yayın yapan dergiler

Element	h_index	g_index	m_index	Atıf	Yayın sayısı	Başlama yılı
Weed Science	17	26	0.63	1352	26	1999
Weed Research	12	25	0.444	779	25	1999
Crop Protection	10	15	0.435	434	15	2003
Weed Technology	10	24	0.385	599	24	2000
Biocontrol Science and Technology	9	15	0.45	268	26	2006
Biological Invasions	8	10	0.364	196	10	2004
Environmental Entomology	8	10	0.364	165	10	2004
Florida Entomologist	8	11	0.348	144	14	2003
Pest Management Science	8	11	0.348	387	11	2003
Biocontrol	6	13	0.25	250	13	2002



Şekil 7. Dergilerin atıf ağ haritası ve zaman haritası

Bu harita**,** istilacı yabancı otlar alanındaki bilimsel yayınların en sık yayımlandığı dergileri, bu dergiler arası atıf ilişkilerini ve zaman içindeki gelişim eğilimlerini göstermektedir. Renk skalası, ilgili dergilerdeki çalışmaların ortalama yayın yılını göstermektedir. Mor-mavi tonlar eski yayınları (2005 öncesi), yeşil tonlar 2010–2015 arası, sarıya yakın tonlar ise yeni yayınları (2018–2020) göstermektedir. Yayınlar arası atıf bağlantıları çizgilerle gösterilmiştir."Weed Science"**,** "Weed Technology"**,** "Biological Control"**,** "Crop Protection", ve "Pest Management Science" gibi dergiler literatürde yüksek atıf aldığı veya sık atıfta bulunulduğu görülmektedir. Yayın faaliyetleri, 2010 sonrası artış göstermiş ve daha fazla disiplinlerarası dergide yayımlanmaya başlamıştır. Harita, bu alanda çalışacak araştırmacılar için hedef dergileri ve gelişimleri hakkında yol gösterici olmaktadır (Şekil 6). Anahtar kelime analizi Şekil 7'de verilmiştir.



Şekil 6. Anahtar kelime analizi ve yoğunluk haritası

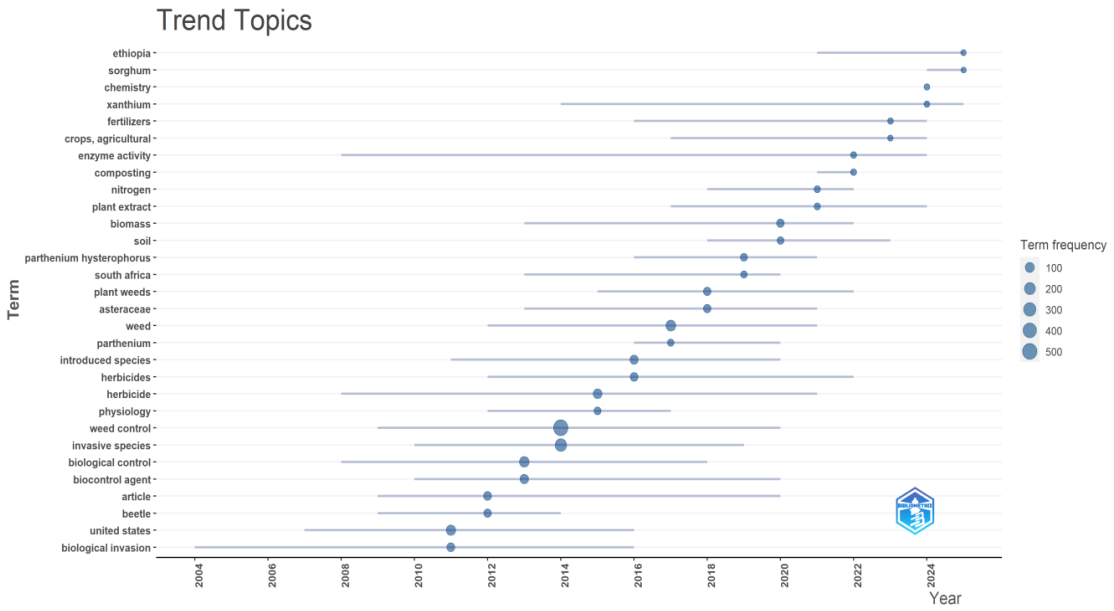
"Weed control" (yabancı ot kontrolü) ve "biological control" (biyolojik kontrol) gibi merkezi terimler, bu alandaki temel odak noktalarını vurgulamaktadır. "Weed Control" (Yabancı Ot Kontrolü) haritanın merkezinde yer alan bu terim, istilacı yabancı otlarla mücadelede genel stratejileri ifade etmektedir. "Biological Control" (Biyolojik Kontrol) "Weed control" ile güçlü bir şekilde bağlantılı olan biyolojik kontrol de haritanın yoğun bir bölgesini oluşturmaktadır. "Weed biocontrol", "biocontrol agent", "biological control of weeds" gibi terimler bu kümeyi desteklemektedir. "Invasive Weeds" (İstilacı Yabancı Otlar), "Invasive Species" (İstilacı Türler) gibi terimler, çalışmanın ana konusunu doğrudan ifade eder ve haritada belirgin kümeler halinde yer alır.

"Weed control", "biological control", "invasive weeds", "weed management" gibi terimlerin etrafındaki parlak sarı alanlar, bu kavramların araştırma alanında en çok vurgulanan ve merkezi konular olduğunu açıkça göstermektedir. Herbisitler ve ilgili terimlerin olduğu sol alttaki parlaklık, kimyasal kontrolün de önemli bir araştırma başlığı olduğunu teyit eder. "Invasive species" ve "biological control of weeds" etrafındaki yoğunluk, istilacı türlerin biyolojik kontrolünün önemli bir odak noktası olduğunu daha vurgulamaktadır.



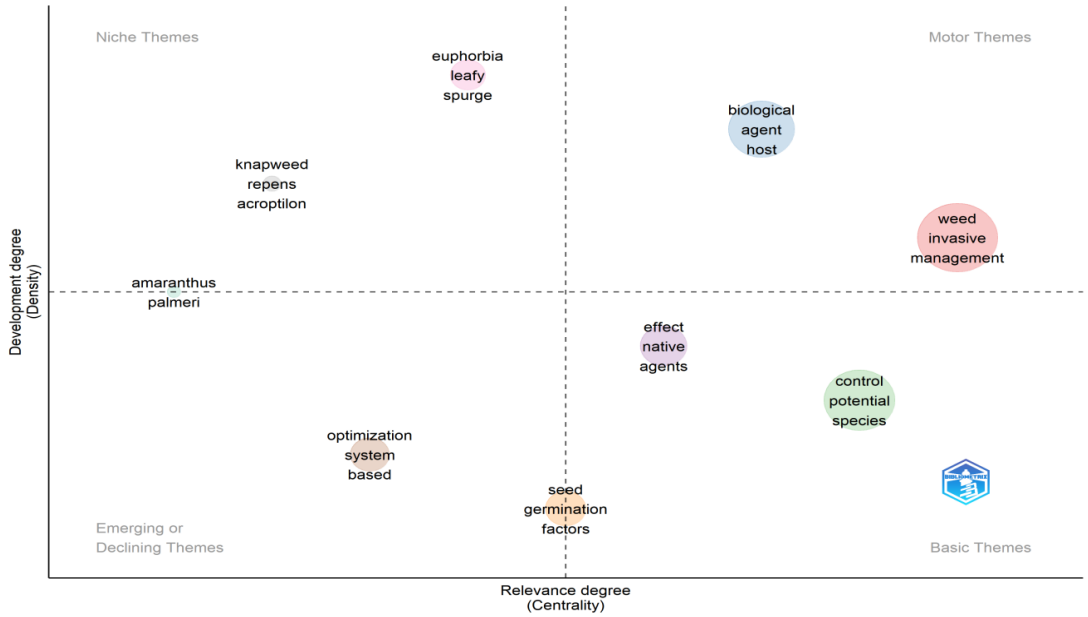
Şekil 7. En fazla kullanılan anahtar kelimeler

"Weed control" ifadesi, 507 kez kullanılarak çalışmanın merkezinde yer alan kavram olduğunu göstermektedir. Konunun temelini oluşturan "Invasive species" ifadesi, 238 kez kullanılması araştırmaların odak noktasının istilacı türlerin etkileri olduğunu yansıtmaktadır. Biyolojik kontrol terimlerinin sıklığı, çevre dostu çözümlere ilginin arttığını göstermektedir. "Herbicide" (85 kez) kullanılması kimyasal mücadelenin hâlâ yaygın olduğunu ortaya koymaktadır. "United States" (115 kez) ifadesi verilerin büyük ölçüde ABD kaynaklı olduğuna işaret etmektedir. Bu durumda, ABD'nin istilacı türlerle mücadelede öncü ülkelerden biri olduğunu düşündürmektedir.



Şekil 9. Anahtar kelimelerin trend durumları

İstilacı yabancı ot kontrolü ile ilgili yayınlarda kullanılan anahtar kelimelerin trend analizine göre, bazı anahtar kelimeler belirli dönemlerde daha yoğun bir kullanıma sahipken, bazıları son yıllarda popülaritesini artırmıştır. "Biological invasion" (Biyolojik istila) terimi, 2010'lu yılların başından itibaren nispeten daha düşük bir frekansta olmakla birlikte, sonrasında bir yoğunlaşma görünmektedir. "Invasive species" (İstilacı türler), "Weed control" (Yabancı ot kontrolü), "Biological control" (Biyolojik kontrol), "Biocontrol agent" (Biyolojik kontrol ajanı) gibi terimler, özellikle 2012-2016 yılları arasında belirgin bir yoğunluk göstermektedir. "Herbicides" (Herbisitler), "Herbicide" (Herbisit): Bu terimler de 2012-2016 yılları arasında yoğunlaştığı görülmektedir. "Sorghum" (Sorgum): Özellikle 2022-2024 yılları arasında daha yüksek bir frekansa ulaştığı ve sorgum ile ilgili araştırmalara artan bir ilginin olduğunu göstermektedir (Şekil 9). Anahtar kelimelerin gruplama analizi Şekil 10'de verilmiştir.



Şekil 10. Anahtar kelimelerin gruplama analizi

Yapılan harita analizinde, araştırma alanındaki anahtar kelimelerin dört farklı temada toplandığını göstermektedir. Motor temalarda yer alan "weed", "invasion", "management" ve

"biological", "agent–host" başlıkları, istilacı yabancı otların yönetimi ve biyolojik kontrol stratejileri açısından literatürün odak noktası durumundadır. Niche temalarda bulunan "Knapweed", "repens", "acroptilon", "euphobia", "leafy" ve "spurge" gibi anahtar kelimeler, kendi içerisinde yüksek gelişmişlik düzeyine sahip olup belirli türler veya ekosistemler üzerine yoğunlaşmış spesifik çalışmaların odağında yer almaktadır. Ancak merkeziliklerinin düşük olması, bu temaların genel literatürle sınırlı bağlantılara sahip olduğunu göstermektedir. Emerging/declining temalarda "optimization" ve "system-based" gibi kavramlar ya gelişmekte olan yeni konuları ya da literatürde ilgi kaybeden yöntemleri yansıtmaktadır. Basic temalar arasında yer alan "control", "potential" "species" ve "effect" "native" "agents" anahtar kelimeleri ise düşük merkezilik ve gelişmişlik değerlerine sahiptir. Bu durum, söz konusu temaların literatürde yeterince işlenmediğini ve geliştirilmesi gerektiğini göstermektedir.

SONUÇ

Bibliyometrik analiz, istilacı bitkiler konusundaki bilimsel yayın sayısında yıllar içinde artış olduğunu göstermektedir. Bu durum, biyoçeşitlilik kaybı ve ekosistem üzerindeki olumsuz etkilerini ve bilim dünyasının dikkatini çekmeye devam ettiğini ortaya koymaktadır. İstilacı bitkilerle ilgili araştırmaların Güney Afrika ve ABD gibi belirli coğrafi bölgelerde daha fazla araştırma odağı olduğu belirlenmiştir. Fakat küresel bir dağılım gösterdiğini de ortaya koymaktadır. Ancak, küresel ticaret ve insan hareketliliği arttıkça, istilacı tür sorunları her geçen gün daha fazla ülkenin gündemine girmekte ve araştırma alanlarını genişletmektedir. İstilacı bitkiler konusunun disiplinlerarası bir yaklaşım gerektirdiğini net bir şekilde gösterilmektedir. Ekoloji, botanik, çevre bilimleri, ziraat, ormancılık ve hatta sosyoekonomik çalışmalar gibi farklı disiplinlerden gelen yayınların varlığı, istilacı bitkilerin sadece biyolojik değil, aynı zamanda ekonomik ve sosyal boyutları olan bir sorun olduğunu ortaya koymaktadır. İstilacı bitkilerle ilgili yapılan araştırmaların zaman içindeki değişimlerine baktığımızda başlangıçta tür tanımlaması ve yayılış alanları gibi temel ekolojik konular ağırlıktadır. Günümüzde ise yönetim ve kontrol stratejileri, iklim değişikliği ile etkileşimler, ekosistem hizmetleri üzerindeki etkiler ve erken teşhis sistemleri gibi daha karmaşık ve uygulamaya yönelik konulara doğru bir kayma görülmektedir. Bu çalışmada, istilacı bitki araştırmalarında yer alan öncü araştırmacıları, kurumları ve ülkelerarası işbirliği ağlarını ortaya koymaktadır. Belirli ülkelerin bu alandaki bilgi üretimine önemli katkılar sağladığı, uluslararası işbirliklerinin ise bilginin yayılması ve küresel sorunlara ortak çözümler üretilmesi açısından kritik bir rol oynadığı gözlemlenmektedir. Sonuç olarak, istilacı bitkilerin bilimsel literatürde giderek artan bir öneme sahip olduğunu, disiplinlerarası bir yaklaşımla ele alındığını ve gelecekteki araştırmaların özellikle yönetim, adaptasyon ve küresel değişimle ilişkili konulara odaklanacağını işaret etmektedir.

KAYNAKLAR

Bais, H. P., Vepachedu, R., Gilroy, S., Callaway, R. M., & Vivanco, J. M. (2003). Allelopathy and exotic plant invasion: from molecules and genes to species interactions. *Science, 301*(5638), 1377-1380.

Callaway, R. M., & Aschehoug, E. T. (2000). Invasive plants versus their new and old neighbors: a mechanism for exotic invasion. *Science, 290*(5491), 521-523.

Hejda, M., Pyšek, P., & Jarošík, V. (2009). Impact of invasive plants on the species richness, diversity and composition of invaded communities. *Journal of ecology*, *97*(3), 393-403.

Hierro, J. L., Maron, J. L., & Callaway, R. M. (2005). A biogeographical approach to plant invasions: the importance of studying exotics in their introduced and native range. *Journal of ecology*, *93*(1), 5-15.

Rands, M. R., Adams, W. M., Bennun, L., Butchart, S. H., Clements, A., Coomes, D., ... & Vira, B. (2010). Biodiversity conservation: challenges beyond 2010. *science*, *329*(5997), 1298-1303.

Richardson, D. M., Pyšek, P., Rejmanek, M., Barbour, M. G., Panetta, F. D., & West, C. J. (2000). Naturalization and invasion of alien plants: concepts and definitions. *Diversity and distributions*, *6*(2), 93-107.

Vilà, M., Espinar, J. L., Hejda, M., Hulme, P. E., Jarošík, V., Maron, J. L., ... & Pyšek, P. (2011). Ecological impacts of invasive alien plants: a meta-analysis of their effects on species, communities and ecosystems. *Ecology letters*, *14*(7), 702-708.

KLIPPEL–TRENAUNAY SYNDROME IN A PEDIATRIC PATIENT: A STRIKING UNILATERAL PRESENTATION

Uzm. Dr. Mehmet Enes GÜNER

Besni Devlet Hastanesi, Clinic of Dermatology, Adıyaman

ORCID ID: https://orcid.org/0000-0001-5424-4674

ABSTRACT

Introduction and Purpose: Klippel–Trenaunay syndrome (KTS) is a rare congenital disorder characterized by the clinical triad of capillary malformations, venous anomalies, and soft tissue and/or bone hypertrophy. Early recognition is essential for long-term management and functional prognosis. We report a pediatric case of KTS with prominent unilateral involvement.

Materials and Methods: An 8-year-old girl presented to our dermatology clinic with asymmetry of the right upper and lower limbs, noted since infancy but slowly progressing. There was no history of trauma, systemic symptoms, or family history of vascular malformations. Physical examination revealed extensive purplish capillary stains over the right upper limb, flank, and lower limb, along with notable soft tissue hypertrophy of the right hand, forearm, thigh, and foot. The left side was unaffected. Doppler ultrasound showed superficial venous dilation without deep venous insufficiency. No arteriovenous malformations were identified.
Representative clinical images are provided in Figures 1 and 2.

Results: The findings were consistent with classical KTS. The patient was referred for multidisciplinary management involving pediatric vascular surgery, orthopedics, and physical therapy. As there were no urgent complications, a conservative follow-up approach was chosen.

Discussion and Conclusion: KTS is a rare but impactful condition that may be underdiagnosed in early stages. Recognizing the cutaneous and structural features, even in the absence of systemic signs, is critical for diagnosis and appropriate surveillance. Imaging complements clinical suspicion, but diagnosis remains predominantly clinical.



Fig.1 Asymmetric enlargement and port-wine stain of upper extremities



Fig.2 Asymmetric enlargement and port-wine stain of lower extremities

References

1. John, P.R. (2019). Klippel-Trenaunay Syndrome. *Techniques in vascular and interventional radiology*, 22(4), 100634.

Keywords: Klippel–Trenaunay syndrome, vascular malformation, limb asymmetry, pediatric dermatology, port-wine stain

SIZE DEPENDENT EFFECTS OF ALUMINUM OXIDE PARTICLES ON ANTIOXIDANT ENZYMES OF *Oreochromis niloticus*

Mustafa TUNÇSOY

Department of Biology, Faculty of Science and Letter, Cukurova University, Adana, Turkey

ORCID ID: 0000-0001-7306-0539

Benay TUNÇSOY

Department of Bioengineering, Faculty of Engineering, Adana Alparslan Turkes Science and Technology University, Adana, Turkey

ORCID ID: 0000-0003-4361-3475

ABSTRACT

Introduction and Purpose:. The Al ion has no known physiological role in metabolic processes; however, this metal can exert toxic effects following exposure due to natural or anthropogenic sources. In this study, SOD, CAT and GPx enzyme activities levels in liver tissue of *O.niloticus* were determined under the influence of 10 mg/L concentrations of micro and nano sizes of Al_2O_3 for 7 days.

Materials and Methods: In the study, two different particle sizes of aluminum oxide (Al_2O_3) were used: micro-sized (45–75 µm, Nanografi) and nano-sized (<50 nm, Sigma-Aldrich), with final concentrations adjusted to 10 mg/L. Nine fish were placed in each aquarium. The experiments were conducted in triplicate, using 3 fish per replicate, resulting in a total of 27 fish used in the study.

Results: It was observed that there was a significant increase in SOD, CAT and GPx enzyme activities of liver tissue examined under the effect of both forms of Al_2O_3 compared to the control. Overall, Al_2O_3 NPs are more effective than Al_2O_3 MP in terms of liver enzyme activities.

Discussion and Conclusion: In conclusion, the increase in enzyme activities is probably due to an increase in ROS. The increase in reactive oxygen species increases the liver enzyme activities, which increases SOD activity as a result of the increase in catalysis of superoxide radical to H_2O_2, and increase in CAT and GPx activities is a result of catalysis of increased amount of H_2O_2 to H_2O and O_2. It was concluded that Al NP are more effective than Al MP to *O. niloticus* keeping their effects on enzyme activities.

Keywords: Size, Micro, Nano, Aluminum, Accumulation, *O. niloticus*

Acknowledgements: This work was supported by Çukurova University, Scientific Research Projects Coordination Unit (Project ID: FBA-2022-15299).

SUSTAINABLE GREEN SYNTHESIS OF A NOVEL CHITOSAN@EDTA@CELLULOSE COMPOSITE DERIVED FROM SHRIMP SHELL CHITOSAN AND CACTUS-BASED CELLULOSE FOR EFFICIENT METHYL ORANGE DYE REMOVAL: COMPREHENSIVE CHARACTERIZATION, ADSORPTION OPTIMIZATION VIA RESPONSE SURFACE METHODOLOGY, REUSABILITY ASSESSMENT, AND DFT-BASED MECHANISTIC ELUCIDATION

Soukaina El Bourachdi

Laboratory of Engineering, Electrochemistry, Modelling and Environment, Faculty of Sciences Dhar El Mehraz, Sidi Mohamed Ben Abdellah University, Fez, Morocco

Yassine Rakcho

Laboratory Materials, Processes, Environment and Quality, National School of Applied Sciences, Cadi Ayyad University (UCA), Route Sidi Bouzid BP 63, 46000 Safi, Morocco

Amal Lahkimi

Laboratory of Engineering, Electrochemistry, Modelling and Environment, Faculty of Sciences Dhar El Mehraz, Sidi Mohamed Ben Abdellah University, Fez, Morocco

ABSTRACT

In this study, a novel eco-friendly composite material, Chitosan@EDTA@Cellulose, was synthesized through a green and sustainable route using biopolymers derived from shrimp shell waste and cactus-based cellulose. The composite was engineered to effectively remove Methyl Orange (MO), a model anionic dye, from aqueous solutions. The synthesis strategy involved the chemical crosslinking of chitosan with ethylenediaminetetraacetic acid (EDTA) and subsequent incorporation with cellulose extracted from *Opuntia ficus-indica* (cactus cladodes), aiming to enhance the adsorption capacity and stability of the resulting material.

Comprehensive physicochemical characterizations were performed using Fourier-transform infrared spectroscopy (FTIR), scanning electron microscopy (SEM), X-ray diffraction (XRD), Brunauer–Emmett–Teller (BET) surface area analysis, and point of zero charge (pHpzc) determination. Adsorption experiments were optimized using Response Surface Methodology (RSM) based on a Box–Behnken Design (BBD), evaluating the influence of key factors such as pH, initial MO concentration, and adsorbent dosage on removal efficiency. The composite exhibited excellent adsorption capacity, with optimal performance achieved at pH 4.5, an initial dye concentration of 100 mg/L, and an adsorbent dose of 0.5 g/L, resulting in over 95% dye removal.

Keywords: Chitosan composite beads; Box–Behnken design; DFT analysis; Wastewater treatment; Green synthesis.

MARINE POLLUTION AND ENVIRONMENT: A LOOMING CRISIS

Mrs. E.Elavarasi

Yuvaraj AR

J.Jayadurka

Dr. R.Srimivasan

Faculty of pharmacy, Bharath institute of higher education and research chennai -73

Abstract

Marine pollution, the introduction of harmful substances or energy into the ocean, poses a significant threat to the health and biodiversity of marine ecosystems and has far-reaching consequences for human well-being. This abstract highlights the multifaceted nature of this environmental crisis, driven by land-based activities, maritime transport, and atmospheric deposition. Pollutants range from plastic debris and chemical contaminants to excess nutrients and noise, each exerting unique pressures on marine life. Plastic pollution, particularly microplastics, persists in the environment, impacting organisms through ingestion and entanglement. Chemical pollutants, including heavy metals and pesticides, bioaccumulate in food webs, potentially affecting human health through seafood consumption. Nutrient pollution leads to eutrophication and the creation of oxygen-depleted dead zones, disrupting marine habitats. Furthermore, underwater noise from shipping and seismic surveys can disrupt marine animal communication and behavior. Addressing marine pollution requires integrated strategies encompassing source reduction, improved waste management, stricter regulations, and international cooperation to safeguard the ecological integrity and the crucial services provided by our oceans.

Keywords: Marine pollution, environmental impact, plastic pollution, chemical contamination, nutrient pollution, underwater noise, marine ecosystems, biodiversity, conservation.

Introduction

Marine pollution represents a profound and escalating global environmental crisis, casting a long shadow over the health, resilience, and intrinsic value of our planet’s vast oceanic realm. This insidious threat, characterized by the introduction of harmful substances or energy into the marine environment, transcends geographical boundaries, impacting coastal ecosystems, the open ocean, and the myriad life forms that inhabit these diverse and interconnected habitats. The sources of marine pollution are numerous and often intertwined with human activities, stemming from land-based discharges, maritime transport, offshore industrial operations, and even atmospheric deposition. The sheer diversity of pollutants, ranging from persistent plastic debris and toxic chemical contaminants to excess nutrients and disruptive noise, underscores the complexity of this challenge and the urgent need for comprehensive and coordinated action.

At its core, marine pollution disrupts the delicate balance of marine ecosystems, undermining their capacity to provide essential ecological services that are vital not only for marine life but also for human societies. These services include climate regulation through carbon sequestration, oxygen production, nutrient cycling, and the provision of food and livelihoods for billions of people worldwide. The degradation of marine environments through pollution weakens their ability to withstand other anthropogenic pressures, such as climate change and overfishing, creating a synergistic effect that further exacerbates ecological decline.

One of the most visible and pervasive forms of marine pollution is plastic debris. The staggering amount of plastic entering the ocean each year, estimated in millions of tons, originates from inadequate waste management on land, fishing gear, and maritime activities. This plastic persists in the marine environment for centuries, breaking down into smaller fragments known as microplastics. These microplastics are ubiquitous, found in every corner of the ocean, from the surface waters to the deep-sea sediments, and have been ingested by a wide range of marine organisms, from zooplankton to whales. The consequences of plastic ingestion can include physical blockage of the digestive tract, false satiation leading to starvation, and the leaching of toxic additives into tissues. Furthermore, larger plastic items, such as discarded fishing nets and plastic bags, pose a significant entanglement risk to marine animals, leading to injury, suffocation, and death. The long-term ecological impacts of this plastic deluge are still being fully understood, but the pervasive presence and known physical and potential toxic effects raise serious concerns about the future health of marine ecosystems.

Beyond the tangible threat of plastic, chemical pollution represents another critical dimension of this crisis. A vast array of chemical contaminants, originating from industrial discharges, agricultural runoff, and domestic wastewater, find their way into the marine environment. These include heavy metals such as mercury, lead, and cadmium, persistent organic pollutants (POPs) like PCBs and DDT, pharmaceuticals, and personal care products. Many of these substances are toxic and can accumulate in the tissues of marine organisms through a process called bioaccumulation, where concentrations increase at higher trophic levels in the food web. This poses a direct threat to the health of marine life, affecting their physiology, reproduction, and immune systems. Moreover, the biomagnification of these toxins can ultimately impact human health through the consumption of contaminated seafood. The insidious nature of chemical pollution lies in its often-invisible presence, making it challenging to detect and trace, yet its long-term and potentially irreversible effects on marine ecosystems and human health are profound.

Nutrient pollution, primarily driven by agricultural runoff containing fertilizers and sewage discharge, is another significant stressor on marine environments, particularly coastal areas. While nutrients are essential for primary production, an excess of nitrogen and phosphorus can lead to eutrophication. This process triggers excessive growth of algae, resulting in algal blooms. When these blooms decompose, they consume large amounts of dissolved oxygen, leading to the formation of hypoxic or anoxic “dead zones” where most marine life cannot survive. These oxygen-depleted areas can decimate benthic communities and disrupt entire food webs, impacting fisheries and the overall health of coastal ecosystems. The increasing scale of agricultural activities and urbanization has exacerbated nutrient pollution, making it a widespread problem in coastal waters around the globe.

Furthermore, the introduction of underwater noise pollution has emerged as a growing concern for marine animal welfare. Anthropogenic noise from sources such as shipping traffic, seismic surveys for oil and gas exploration, naval sonar, and construction activities can travel long distances underwater and interfere with the natural soundscapes that many marine animals rely on for communication, navigation, foraging, and predator avoidance. Marine mammals, such as whales and dolphins, are particularly sensitive to noise, as they use sound extensively for these vital life functions. Elevated noise levels can lead to behavioral changes, such as avoidance, disruption of feeding and breeding activities, and even physical harm, including hearing damage. The increasing industrialization of the oceans has amplified underwater noise levels, raising concerns about the long-term impacts on marine animal populations and the integrity of marine acoustic environments.

In conclusion, marine pollution is a complex and multifaceted crisis with far-reaching ecological, economic, and social consequences. The relentless influx of plastic debris, toxic chemicals, excess nutrients, and disruptive noise is degrading marine habitats, threatening biodiversity, and undermining the vital services that the ocean provides. Addressing this

looming crisis requires a fundamental shift in how we interact with the marine environment, demanding concerted efforts at local, national, and international levels. This includes implementing stricter regulations on waste disposal and industrial discharges, promoting sustainable consumption and production patterns, investing in innovative technologies for pollution prevention and remediation, and fostering greater public awareness and engagement. Only through a comprehensive and collaborative approach can we hope to mitigate the impacts of marine pollution and safeguard the health and future of our oceans.

Marine pollution, a multifaceted and escalating crisis confronting our planet's oceans, infiltrates these vital ecosystems through a complex web of interconnected pathways, introducing a diverse spectrum of harmful contaminants. The routes by which pollutants reach the marine environment are varied, each contributing uniquely to the overall burden. Arguably the most substantial contributor is land-based runoff, an insidious pathway where rainfall and snowmelt act as vectors, carrying a cocktail of pollutants from terrestrial sources directly or indirectly into the sea. Agricultural lands, often treated with pesticides, herbicides, and fertilizers, release these chemicals and nutrient-rich animal waste into waterways that eventually converge with the ocean. Urban areas contribute a significant load of pollutants through stormwater systems, which flush oil residues, heavy metals from vehicle emissions, litter, and various chemicals from streets and industrial sites into coastal waters. Even seemingly innocuous household waste, if not properly managed, can find its way into rivers and ultimately the ocean. Direct discharge from coastal industries and wastewater treatment plants represents another significant route. While environmental regulations in many developed nations have mandated improvements in effluent treatment, the direct release of treated or, in some cases, untreated, industrial and domestic wastewater remains a source of considerable pollution, particularly in regions where environmental oversight is less stringent. This can introduce a wide range of chemical contaminants, pathogens, and excess nutrients directly into marine environments.

Furthermore, the atmosphere serves as a significant, albeit sometimes less obvious, conduit for marine pollution through atmospheric deposition. Airborne pollutants, including nitrogen oxides and sulfur dioxide from fossil fuel combustion, particulate matter from industrial processes and vehicle emissions, and even pesticides that volatilize and travel long distances, can be deposited onto the ocean surface through dry deposition or via precipitation. This pathway can transport pollutants to even the most remote oceanic regions, highlighting the interconnectedness of global environmental systems. Maritime activities also play a crucial role in introducing pollutants into the marine environment. Oil spills, whether catastrophic accidents involving tankers or chronic operational discharges from ships and offshore platforms, release vast quantities of hydrocarbons that can devastate marine life, smother habitats, and persist in the environment for extended periods. The routine operation of vessels also generates various forms of waste, including sewage, garbage (especially plastics), and ballast water. While regulations exist for the management of these wastes, improper disposal can introduce pollutants and, critically, invasive species into new marine environments. The issue of lost or discarded fishing gear, often referred to as "ghost gear," is a particularly insidious form of pollution from maritime activities, as abandoned nets, lines, and traps continue to indiscriminately entangle and kill marine animals long after they have been discarded. Finally, ocean dumping, the deliberate disposal of waste at sea, directly introduces pollutants into the marine environment. While international agreements like the London Convention and Protocol aim to control and restrict this practice, the dumping of materials such as industrial waste, dredged sediments, and decommissioned vessels has historically contributed to marine pollution and, regrettably, may still occur illegally in some areas.

The types of pollutants that enter the ocean through these routes are diverse, each posing unique threats to marine ecosystems. Plastic pollution has emerged as a particularly pervasive and visually striking form of marine degradation. From macroscopic debris like plastic bottles, bags, and fishing nets to ubiquitous microplastics (plastic particles smaller than 5mm resulting from

the fragmentation of larger items or directly manufactured), plastics are now found in virtually every marine environment, from the surface to the deepest trenches. Marine organisms ingest these plastics, leading to physical blockage, false satiation, and the potential transfer of toxic additives. Larger plastic items also pose a significant entanglement risk to marine animals. Chemical pollution encompasses a vast array of toxic substances. Heavy metals, such as mercury, lead, and cadmium, originating from industrial discharges, mining runoff, and atmospheric deposition, can bioaccumulate in marine organisms, leading to neurological damage, reproductive impairment, and posing risks to human health through seafood consumption. Persistent Organic Pollutants (POPs), including pesticides like DDT, industrial chemicals like PCBs, and dioxins, are characterized by their persistence in the environment, their ability to bioaccumulate, and their toxicity, posing long-term threats to marine ecosystems and human health. Increasingly, pharmaceuticals and personal care products (PPCPs), entering the marine environment primarily through wastewater, are recognized as emerging contaminants with potential endocrine-disrupting effects on marine life.

Another critical type of marine pollution is nutrient pollution. Excessive inputs of nitrogen and phosphorus, primarily from agricultural runoff containing fertilizers and sewage discharge, trigger a process called eutrophication. This leads to the rapid proliferation of algae, resulting in harmful algal blooms. When these blooms decompose, they consume large amounts of dissolved oxygen, creating hypoxic or anoxic "dead zones" where most marine life cannot survive. Some algal blooms also produce potent toxins that can harm marine animals and humans. Oil pollution, resulting from spills and operational discharges, can have immediate and devastating impacts, smothering marine organisms, contaminating habitats, and disrupting food webs. The volatile components of oil are toxic, and the long-term effects of oil contamination can persist for decades. Sediment pollution, often stemming from deforestation, construction, and agricultural erosion, can cloud coastal waters, reducing light penetration essential for photosynthetic organisms and smothering benthic communities. Thermal pollution, the discharge of heated water from power plants and industrial facilities, can alter water temperatures, affecting the physiology and reproductive cycles of marine organisms and reducing dissolved oxygen levels. Finally, noise pollution from shipping, seismic surveys, and naval activities is increasingly recognized as a significant stressor, disrupting marine animal communication, navigation, and foraging, particularly impacting marine mammals that rely heavily on sound. In essence, marine pollution is a complex and multifaceted problem arising from diverse human activities, introducing a wide range of contaminants through various pathways, each with the potential to inflict significant harm on the delicate balance and health of our ocean ecosystems. Addressing this crisis demands a comprehensive understanding of these routes and types of pollution to implement effective and targeted mitigation strategies.

Conclusion

In conclusion, the pervasive and multifaceted issue of marine pollution stands as a stark testament to the profound and often detrimental impact of human activities on the global ocean. As we have explored, the routes by which pollutants enter the marine environment are diverse and interconnected, ranging from the insidious creep of land-based runoff carrying agricultural, urban, and industrial contaminants to the more dramatic and localized impacts of oil spills and direct discharges. Atmospheric deposition further underscores the far-reaching nature of pollution, delivering airborne contaminants to even remote oceanic regions. The activities of the maritime industry, while vital for global commerce and sustenance, also contribute significantly through waste discharge, the persistent threat of ghost gear, and the potential for catastrophic accidents. Ultimately, these pathways converge to introduce a staggering array of pollutants into the marine realm, each with its own suite of ecological and potential human health consequences.

The types of marine pollution are ”qual’y varied and concerning. The ubiquitous presence of plastic, from macro-debris to microscopic fragments, poses a long-lasting threat through ingestion, entanglement, and the potential for toxic transfer. Chemical pollution, encompassing heavy metals, persistent organic pollutants, and emerging contaminants like pharmaceuticals, introduces insidious toxins that can bioaccumulate and biomagnify within marine food webs, ultimately impacting top predators and human consumers. Nutrient pollution, while stemming from essential elements, wreaks havoc in excess, triggering eutrophication and the creation of oxygen-depleted dead zones that decimate marine life. Oil spills inflict immediate and often devastating damage, while chronic low-level contamination poses a persistent threat. Sediment pollution can smother habitats and reduce light penetration, and the often-overlooked issue of noise pollution disrupts the acoustic environment crucial for many marine species. The introduction of non-native species through biological pollution further complicates the picture, threatening native biodiversity and ecosystem stability.

The cumulative effect of these diverse pollutants, entering through multiple pathways, Is a significant and growing degradation of marine ecosystems worldwide. Coral reefs bleach and crumble under the combined stress of pollution and climate change. Fish populations decline due to habitat loss, contamination, and the disruption of food webs. Marine mammals and seabirds become entangled in plastic debris or succumb to the toxic effects of ingested pollutants. The very health and resilience of the ocean, upon which so much life on Earth depends, is being eroded by this relentless onslaught of human-generated waste and harmful substances.

Moreover, the consequences of marine pollution extend far beyond the purely ecological. Coastal communities that rely on fishing and tourism suffer economic losses as waters become contaminated and marine life diminishes. Human health is increasingly at risk through the consumption of seafood contaminated with heavy metals and other toxins, and through exposure to pathogens in polluted coastal waters. The intrinsic beauty and recreational value of marine environments are diminished by the presence of plastic debris and other forms of pollution, impacting our cultural and aesthetic connection to the ocean.

Addressing this complex crisis demands a fundamental shift in our relationship with the ocean. It requires a multi-pronged approach that tackles pollution at its source, promotes sustainable practices across industries and individual behaviors, and fosters international cooperation to manage this global challenge effectively. Stricter regulations on industrial discharges and waste management are essential, coupled with investments in innovative technologies for pollution prevention and remediation. Promoting a circular economy to reduce plastic production and improve recycling, transitioning to more sustainable agricultural practices to minimize nutrient runoff, and implementing measures to reduce noise pollution from maritime activities are all crucial steps. Furthermore, raising public awareness and fostering a sense of stewardship towards the ocean are vital to driving the necessary changes in behavior and policy.

Ultimately, the future health of our oceans, and indeed our planet, hinges on our collective will and ability to confront the challenge of marine pollution with urgency and determination. The looming crisis we have described is not an insurmountable one, but it demands immediate and sustained action. By understanding the intricate routes and diverse types of pollution, we can better target our efforts and work towards a future where our oceans are clean, healthy, and teeming with life, continuing to provide the essential services that underpin our own well-being and the health of the planet for generations to come. The time for decisive action is now, before the tide of pollution overwhelms the delicate balance of our marine world beyond repair.

REFERENCES

Fadare, O. O. & Okofo, E. D. Covid-19 face masks: A potential source of microplastic fbers in the environment. Sci. Total Environ. 737, 140279 (2020).

5. United Nations Environment Assembly of the United Nations Environmental Programme. Ad hoc Open-Ended Expert Group on

Marine Litter and Microplastics. Fourth meeting. Report No. UNEP/AHEG/4/7. (United Nations, 2020).

6. Watson, R. A. et al. Marine foods sourced from farther as their use of global ocean primary production increases. Nat. Commun. 6, 795 (2015).

7. Barnes, D. K. A., Galgani, F., Tompson, R. C. & Barlaz, M. Accumulation and fragmentation of plastic debris in global environ-

Ments. Philos. Trans. R. Soc. B Biol. Sci. 364, 1985–1998 (2009).

8. Tanaka, K. & Takada, H. Microplastic fragments and microbeads in digestive tracts of planktivorous fsh from urban coastal waters. Sci. Rep. 6, 768 (2016).

9. Galloway, T. S., Cole, M. & Lewis, C. Interactions of microplastic debris throughout the marine ecosystem. Nat. Ecol. Evol. 1, 1240 (2017).

10. Walkinshaw, C., Lindeque, P. K., Tompson, R., Tolhurst, T. & Cole, M. Microplastics and seafood: Lower trophic organisms at

Highest risk of contamination. Ecotoxicol. Environ. Saf. 190, 110066 (2020).

11. Lusher, A. In Marine Anthropogenic Litter (eds. Bergmann, M., Gutow, L. & Klages, M.) 245–307 (Springer International Publish- Ing, 2015).

12. Collard, F. et al. Morphology of the fltration apparatus of three planktivorous fshes and relation with ingested anthropogenic Particles. Mar. Pollut. Bull. 116, 182–191 (2017).

13. Espinoza, P. & Bertrand, A. Revisiting Peruvian anchovy (Engraulis ringens) trophodynamics provides a new vision of the Humboldt Current system. Prog. Oceanogr. 79, 215–227 (2008).

14. Barboza, L. G. A., Vethaak, A. D., Lavorante, B. R. B. O., Lundeye, A.-K. & Guilhermino, L. Marine microplastic debris: An emerg-Ing issue for food security, food safety and human health. Mar. Pollut. Bull. 133, 336–348 (2018).

15. Lindeque, P. K. et al. Are we underestimating microplastic abundance in the marine environment? A comparison of microplastic Capture with nets of diferent mesh-size. Environ. Pollut. 265, 114721 (2020).

16. Cole, M. et al. Isolation of microplastics in biota-rich seawater samples and marine organisms. Sci. Rep. 4, 4528 (2014).

17. Mercogliano, R. et al. Occurrence of microplastics in commercial seafood under the perspective of the human food chain. A review. J. Agric. Food Chem. https://doi.org/10.1021/acs.jafc.0c01209 (2020).

18. Wang, W., Gao, H., Jin, S., Li, R. & Na, G. Te ecotoxicological efects of microplastics on aquatic food web, from primary producer To human: A review. Ecotoxicol. Environ. Saf. 173, 110–117 (2019).

19. Engler, R. E. Te complex interaction between marine debris and toxic chemicals in the ocean. Environ. Sci. Technol. 46, 12302–12315 (2012).

20. Mathieu-Denoncourt, J., Wallace, S. J., de Solla, S. R. & Langlois, V. S. Plasticizer endocrine disruption: Highlighting developmental And reproductive efects in mammals and non-mammalian aquatic species. Gen. Comp. Endocrinol. 219, 74–88 (2015).

21. Cózar, A. et al. Plastic debris in the open ocean. Proc. Natl. Acad. Sci. 111, 10239–10244 (2014).

22. Lehner, R., Weder, C., Petri-Fink, A. & Rothen-Rutishauser, B. Emergence of nanoplastic in the environment and possible impact On human health. Environ. Sci. Technol. https://doi.org/10.1021/acs.est.8b05512 (2019).

23. Bouwmeester, H., Hollman, P. C. H. & Peters, R. J. B. Potential health impact of environmentally released micro- and nanoplastics In the human food production chain: Experiences from nanotoxicology. Environ. Sci. Technol. 49, 8932–8947 (2015).

24. Rochman, C. M. et al. Classify plastic waste as hazardous. Nature 494, 169–171 (2013).

25. Law, K. L. et al. Plastic accumulation in the North Atlantic subtropical gyre. Science 329, 1185–1188 (2010).

26. Ory, N. et al. Low prevalence of microplastic contamination in planktivorous fsh species from the southeast Pacifc Ocean. Mar. Pollut. Bull. 127, 211–216 (2018).

27. Law, K. L. et al. Distribution of surface plastic debris in the Eastern Pacifc Ocean from an 11-year data set. Environ. Sci. Technol.https://doi.org/10.1021/es4053076 (2014).

28. Kooi, M., van Nes, E. H., Schefer, M. & Koelmans, A. A. Ups and downs in the ocean: Efects of biofouling on vertical transport Of microplastics. Environ. Sci. Technol. 51, 7963–7971 (2017).

29. Lusher, A. Microplastics in the marine environment: Distribution, interactions and efects. Link.springer.com 245–307 (2015). https://doi.org/10.1007/978-3-319-16510-3_10.

30. van Sebille, E. et al. Basin-scale sources and pathways of microplastic that ends up in the Galápagos Archipelago. Ocean Sci. 15, 1341–1349 (2019).

31. Jensen, J. L., Schjønning, P., Watts, C. W., Christensen, B. T. & Munkholm, L. J. Soil texture analysis revisited: Removal of organic Matter matters more than ever. PLoS ONE 12, e0178039 (2017).

32. Fischer, A. H., Jacobson, K. A., Rose, J. & Zellers, R. Hematoxylin and eosin staining of tissue and cell sections. CSH Protoc. 2008,(2008).

33. Minitab 17 Statistical Sofware (2010). [Computer sofware]. State College, PA: Minitab, Inc. www.minitab.com.

34. ESRI. ArcGIS Desktop: Release 10 (Environmental Systems Research Institute, 2011).

35. Alfaro-Núñez, A. & Bermúdez, R. Te scientifc problem of plastic pollution: An ocean of reports with little standardization of Procedures. Bionatura 3, 639–640 (2018).

36. Tompson, R. C. et al. Lost at sea: Where is all the plastic?. Science 304, 838–838 (2004).

37. Galgani, F., Souplet, A. & Cadiou, Y. Accumulation of debris on the deep sea foor of the French Mediterranean coast. Mar. Ecol. Prog. Ser. 142, 225–234 (1996).

38. Long, M. et al. Interactions between polystyrene microplastics and marine phytoplankton lead to species-specifc hetero-aggre-Gation. Environ. Pollut. 228, 454–463 (2017).

39. Hidalgo-Ruz, V., Gutow, L., Tompson, R. C. & Tiel, M. Microplastics in the marine environment: A review of the methods used For identifcation and quantifcation. Environ. Sci. Technol. 46, 3060–3075 (2012).

40. Eriksen, M. et al. Plastic pollution in the South Pacifc subtropical gyre. Mar. Pollut. Bull. 68, 71–76 (2013).

41. Avio, C. G. et al. Pollutants bioavailability and toxicological risk from microplastics to marine mussels. Environ. Pollut. 198, 211–222 (2015).

42. de Miranda, D. A. & de Carvalho-Souza, G. F. Are we eating plastic-ingesting fsh?. Mar. Pollut. Bull. 103, 109–114 (2016).

43. Neves, D., Sobral, P., Ferreira, J. L. & Pereira, T. Ingestion of microplastics by commercial fsh of the Portuguese coast. Mar. Pollut. Bull. 101, 119–126 (2015).

44. Kaposi, K. L., Mos, B., Kelaher, B. P. & Dworjanyn, S. A. Ingestion of microplastic has limited impact on a marine larva. Environ. Sci. Technol. https://doi.org/10.1021/es404295e (2013).

45. Cole, M. & Galloway, T. S. Ingestion of nanoplastics and microplastics by pacifc oyster larvae. Environ. Sci. Technol. https://doi.Org/10.1021/acs.est.5b04099 (2015).

46. von Moos, N., Burkhardt-Holm, P. & Köhler, A. Uptake and efects of microplastics on cells and tissue of the blue mussel Mytilus Edulis L. afer an experimental exposure. Environ. Sci. Technol. 46, 11327–11335 (2012).

THE IMPACT OF ORAL HEALTH ON SALIVARY AND BLOOD BIOMARKERS IN ELITE SOCCER ATHLETES

Danilo Henrique Lattaro

University of São Paulo, Ribeirão Preto School of Dentistry, Department of Basic and Oral Biology, Ribeirão Preto, Brazil

ORCID NO: 0009-0002-2030-4274

Evandro Marianetti Fioco

University of São Paulo, Ribeirão Preto School of Dentistry, Department of Basic and Oral Biology, Ribeirão Preto, Brazil

ORCID NO: 0000-0002-8543-2296

Profa. Dra. Selma Siéssere

University of São Paulo, Ribeirão Preto School of Dentistry, Department of Basic and Oral Biology, Ribeirão Preto, Brazil

ORCID NO: 0000-0001-9756-3771

Profa. Dra. Neide Pena Coto

University of São Paulo, School of Dentistry, Department of Surgery, Prosthesis and Maxillofacial, São Paulo, Brazil

ORCID NO: 0000-0002-3235-0684

Profa. Dra. Simone Cecílio Hallak Regalo

University of São Paulo, Ribeirão Preto School of Dentistry, Department of Basic and Oral Biology, Ribeirão Preto, Brazil

ORCID NO: 0000-0003-4110-8299

ABSTRACT

Introduction and Purpose: To perform at the highest competitive level, athletes must maintain optimal physical condition, thorough preparation, and overall health. Oral health plays a vital role in supporting general health and well-being in athletes. A reduced salivary pH, particularly when acidic, can contribute to various oral health problems, including dental erosion, dentin hypersensitivity, and non-carious cervical lesions. Elevated salivary lactate levels following intense physical exertion may be associated with decreased salivary pH. Creatine phosphokinase (CPK) is a biochemical marker indicative of skeletal muscle damage, and its increased concentration during strenuous activity makes it a valuable predictor of muscle injury risk. Given these considerations, the aim of this study was to examine the association between oral health status, salivary pH and lactate levels, and blood CPK concentrations.

Materials and Methods: A total of 36 elite professional soccer players from Brazil were enrolled, with 18 demonstrating satisfactory oral health and 18 exhibiting poor oral health, as determined through clinical examination. Saliva samples were collected using disposable collectors at two time points: at rest prior to training sessions (pre-season) and immediately following official matches. Salivary pH was assessed using the MS Tecnopon® pH meter, and salivary lactate levels were measured using the Accu-Check Lactate® device. Blood samples were also obtained at two intervals—during the pre-season and 48 hours after official matches—for CPK level analysis using the SD-1 Kovalent® analyzer.

Results: Preliminary results showed that, on average, athletes with poor oral health had a salivary pH of 6,25, lactate levels below 0.7 mmol/L, and blood CPK levels of 309,8 U/L pre-training. Post-match, the results indicated a salivary pH of 5.16, lactate levels of 4.84 mmol/L, and blood CPK levels of 1038,1 U/L. Conversely, athletes with good oral health exhibited a salivary pH of 6.86, lactate levels below 0.7 mmol/L, and blood CPK levels of 224 U/L pre-training. Post-match, their salivary pH was 6,05, lactate levels remained below 0.7 mmol/L, and blood CPK levels were 426,4 U/L.

Discussion and Conclusion: These results demonstrate that when athletes' oral health is poor, their salivary pH is lower, which consequently leads to an increase in salivary lactate post-physical stress. Blood CPK levels increased in both groups; however, athletes with poor oral health experienced a 253,81% increase in the pre- to post-physical stress ratio, while those with good oral health had an increase of 90,3%. These findings suggest that oral health status may impact salivary pH and lactate concentrations both before and after physical exertion, in addition to influencing blood CPK levels. This relationship could represent a contributing factor to increased susceptibility to muscle injuries.

Keywords: salivary pH; athletes; soccer; salivary lactate; creatine phosphokinase.

NEURAL ACCUMULATION OF MICROPLASTICS: A NEW FRONTIER IN NEUROTOXICOLOGY RESEARCH

Arif Gull
Islamia University, Bahawalpur

Hafsa Naeem
University Of Agriculture Faisalabad

Ayesha Batool
University Of Agriculture Faisalabad

Chashman Ahmed
Quaid e Quaid-e-Azam Medical College

Rimsha Anwar
University of Agriculture Faisalabad

Abstract

Introduction and Purpose: Recent studies have confirmed the presence of microplastics in human brain tissue, raising significant concerns about their potential neuropathological effects. Microplastics, characterized as plastic particles smaller than 5 millimeters, are pervasive environmental pollutants that can enter the human body through ingestion, inhalation, and dermal absorption. Evidence suggests their capacity to cross the blood-brain barrier, accumulate in neural tissues, and play a role in neuroinflammation, oxidative stress, and neurodegenerative diseases, including dementia. This study aims to assess the current literature on exposure pathways, neurotoxic mechanisms, and the public health implications associated with microplastics.

Materials and Methodology: A comprehensive literature review was conducted using scientific databases such as PubMed, Scopus, and Web of Science. Keywords including "microplastics,"neurodegenerative "neurotoxicity," and "blood-brain barrier," were employed. Inclusion criteria focused on experimental, observational, and mechanistic studies investigating microplastic interaction with neural tissues and the central nervous system.

Results: Studies indicate that microplastics disrupt cellular homeostasis, trigger neuroinflammatory responses, and induce oxidative damage in brain tissue. Furthermore, chemical additives associated with plastics and adsorbed xenobiotics demonstrate synergistic toxicity, exacerbating neuronal dysfunction. Research indicates a mechanistic relationship between microplastic exposure and the worsening of neurological disorders.

Conclusion: The infiltration of microplastics into brain tissue presents a significant and emerging threat to neurological health. Despite growing evidence, critical gaps remain in our mechanistic understanding of microplastic-induced neurotoxicity. Interdisciplinary research is essential to clarify underlying pathways and inform effective public health and environmental interventions. Mitigating this risk is essential due to the increasing burden of plastic pollution and its possible long-term effects on global healthcare systems.

Keywords: Microplastics, Neurodegenerative, Neurotoxicity, and Blood-brain barrier.

ERGONOMIC SEATING FOR THE MASSES: A STUDY ON HEALTH OUTCOMES AND ECONOMIC FEASIBILITY IN OFFICE FURNITURE DESIGN

Dr. Nguyen Thi Bich Van

Faculty of Architecture Interior Design, University of Architecture Hochiminh City, Vietnam

Nguyen Tran Thien Phuc

Institute of International Education, University of Architecture Hochiminh City, Vietnam

Abstract

This study examines the design of an ergonomic office chair tailored to enhance the comfort and well-being of formal people in VietNam, particularly as they transition back to the Work from Office (WFO) model. According to the World Health Organization (WHO), the research identifies key ergonomic risks associated with non-ergonomic chairs currently in use, highlighting the prevalence of discomfort among employees due to inadequate support features. The proposed chair design incorporates adjustable features to cater to diverse user needs based on anthropometric data of Vietnamese workers. Materials were selected to balance durability and sustainability, with an aluminum star base for strength and a high-impact polystyrene frame to optimize cost and performance. The findings underscore the importance of ergonomic interventions in improving employee health and productivity while aligning with economic objectives.

Keywords: ergonomic chair design, economic efficiency, anthropometric data, durability and sustainability

Introduction

The resurgence of the Work from Home (WFH) model in Vietnam following the COVID-19 pandemic has once again underscored the critical importance of safeguarding employee health in evolving work environments. Among the many factors influencing both well-being and productivity, sitting posture remains one of the most significant. Prolonged periods of sitting—especially on non-ergonomic office chairs—have led to a growing incidence of back, neck, and shoulder pain among office workers. Such issues not only diminish daily comfort but also impair long-term occupational performance.

According to the World Health Organization (WHO), approximately 1.71 billion people worldwide are affected by musculoskeletal disorders (MSDs), with poorly designed workplace arrangements recognized as a major contributing factor. In Vietnam, the challenge is compounded by the widespread use of traditional office chairs that fail to provide adequate lumbar support, pressure distribution, or adaptability to individual body dimensions. This article examines the primary ergonomic risks posed by conventional office seating and highlights the urgent need for scientifically informed, culturally relevant ergonomic chair designs tailored to the specific physical, environmental, and economic realities of Vietnamese employees. By addressing these risks, organizations can not only enhance workplace health but also foster sustained productivity in the post-pandemic era.

The Importance of Ergonomics in Office Chairs

Common Risks from Non-Ergonomic Chairs

Traditional office chairs often lack adjustable features and fail to provide adequate lumbar support. Prolonged poor sitting posture can lead to muscle fatigue, spinal misalignment, and chronic back pain. According to WHO, 37% of lower back pain cases among office workers are related to poor ergonomic design.



Figure 1: Sitting posture.

Impact on Work Performance and Mental Health

Physical discomfort reduces productivity, increases absenteeism, and causes work-related stress. Many employees report taking sick leave for lower back pain at least three times a year. A healthy sitting posture improves focus, reduces fatigue, and enhances job satisfaction. Based on international data, in Vietnam, work-related musculoskeletal disorders (WMSDs) cost businesses an estimated USD 5–7 billion annually in lost productivity and healthcare expenses.

Understanding the Needs of Vietnamese Office Workers

Physical Characteristics and Work Habits

Vietnamese office workers are, on average, smaller in stature compared to Western anthropometric standards. According to Wikipedia's compilation of average heights by country, Vietnamese men have an average height of approximately 164.4 cm (5 feet 4.7 inches), while women average around 153.4 cm (5 feet 0.4 inches). This significant difference in body dimensions means that many imported office chairs—designed primarily to fit Western user, do not align well with the physical proportions of Vietnamese workers. Poor fit often forces users into awkward or unsupported positions, which, over time, can lead to incorrect sitting posture, discomfort, and even chronic musculoskeletal issues.

The problem is further compounded by the nature of modern office work. On average, Vietnamese employees spend more than six hours per day seated, whether in traditional offices or home-based work environments. Extended sitting without proper ergonomic support not only accelerates fatigue but also increases the risk of neck, shoulder, and lower back pain. This reality underscores the urgent need for office chairs that offer flexible adjustment capabilities such as adaptable seat height, depth, backrest tilt, and lumbar support so they can accommodate a wider range of body sizes and sitting habits. By tailoring these design features to the anthropometric characteristics of Vietnamese users, it becomes possible to significantly improve both comfort and long-term health outcomes in the workplace.

Employee Expectations for Office Chairs

Surveys and interviews show that employees prioritize comfort, adjustability, breathable materials, and lumbar support. They also expect chairs with modern designs that suit office aesthetics and the tropical climate.

Ergonomic Office Chair Design Criteria

Ergonomic Design Standards

An ideal chair should include the following features:

- Adjustable seat height and depth
- Adjustable lumbar and back support
- Headrest for neck support
- Flexible armrests for multiple postures
- High-quality foam or mesh for long-term comfort

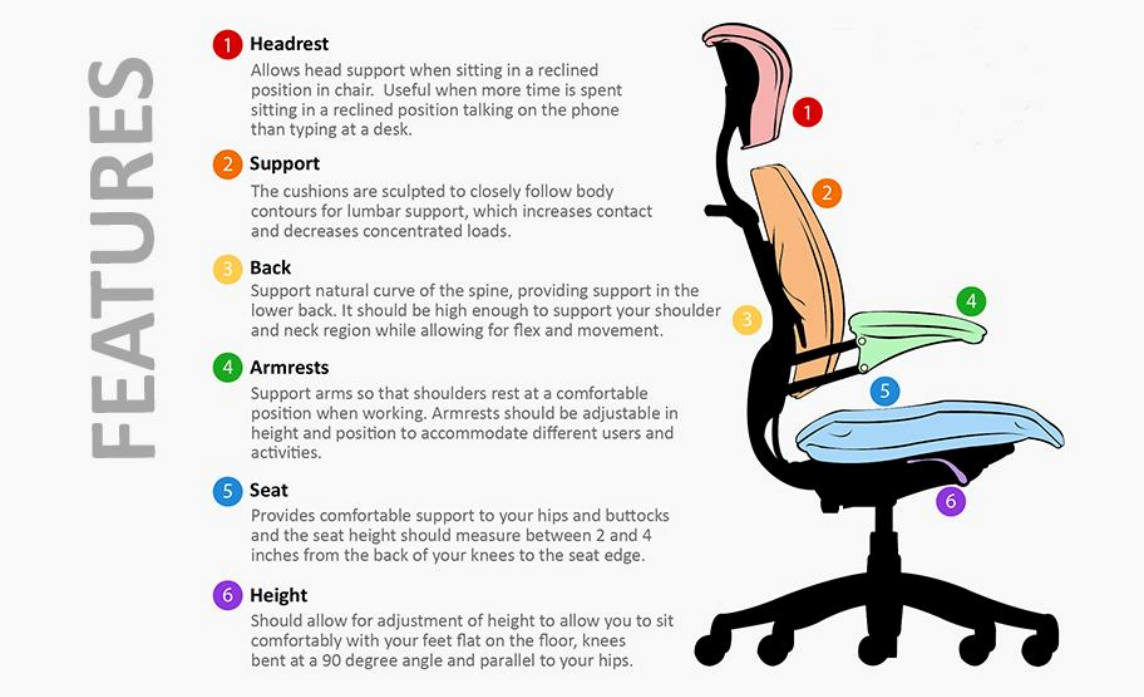


Figure 2: What to Look for in an Office Chair 2022.

Customization for Vietnamese Users: Chairs should be designed according to the average anthropometric measurements of Vietnamese people. Breathable mesh and sweat-resistant coatings are essential for Vietnam's hot and humid climate.

Application of Technology and AI in Ergonomic Chair Design

Smart Sensors for Posture Monitoring: Integrated pressure sensors and gyroscopes can track posture and sitting time in real time. The collected data helps analyze common poor postures and prolonged sitting habits.

AI-Based Smart Adjustment and User Feedback Machine learning algorithms can personalize chair adjustments based on user habits, alert users when poor posture is detected, and suggest appropriate corrections. Integration with virtual assistants (such as Google Assistant or Alexa) enables hands-free control.

Case Studies / Comparison with Existing Smart Chairs

High-end office chairs such as the Herman Miller Embody and Steelcase Gesture exemplify the potential of advanced ergonomic design, offering superior adjustability, pressure distribution, and long-term support for users. These models have been extensively praised for their ability to promote healthy posture, reduce musculoskeletal strain, and enhance work performance. However, their exceptionally high purchase prices, coupled with their large dimensions, make them impractical for widespread adoption in Vietnam—particularly in compact home offices or workplaces with limited budgets.

Given these constraints, there is a pressing need for a locally developed seating solution that balances ergonomic excellence with affordability and space efficiency. Such a product should integrate smart features—such as posture monitoring, adjustable lumbar support, and real-time usage feedback—while being tailored to the anthropometric dimensions, working habits, and environmental conditions of Vietnamese users. This approach would not only make ergonomic seating more accessible but also encourage broader adoption, ultimately improving both comfort and productivity across diverse work settings.

Design Proposal for WFH Employees in Vietnam

We propose a smart ergonomic chair designed to match Vietnamese anthropometry and integrated with AI-based feedback. Key features include:

- Real-time posture monitoring sensors
- AI-powered self-adjustment system
- Climate-adaptive materials
- Mobile app for tracking and control
- Modular design, cost-effective, and scalable for mass deployment

Conclusion

In the post-pandemic work environment, safeguarding employee health must be recognized as a top priority for both employers and policymakers. Prolonged sitting in poorly designed chairs remains one of the most common contributors to musculoskeletal disorders (MSDs), which not only compromise physical well-being but also lead to reduced work efficiency and increased absenteeism. A well-designed ergonomic office chair one that offers proper lumbar support, adjustable dimensions, and balanced pressure distribution can significantly enhance comfort, lower the risk of MSDs, and boost overall productivity.

The integration of artificial intelligence (AI) into office chair design offers a transformative opportunity. Smart seating systems equipped with sensors could monitor posture in real time, provide feedback to users, and automatically adjust settings to maintain optimal ergonomic alignment throughout the workday. However, for such innovations to succeed in Vietnam, the designs must be tailored to local anthropometric data, cultural work habits, and spatial constraints, ensuring accessibility and usability for the majority of the workforce.

By aligning technology with locally relevant ergonomic principles, Vietnam can position itself as a regional pioneer in developing smart, health-promoting workplace solutions. Achieving this vision will require multi-stakeholder collaboration among designers, engineers, healthcare professionals, government bodies, and businesses. With coordinated efforts, Vietnam has the potential not only to set a benchmark for workplace health in Southeast Asia but also to contribute innovative, export-ready solutions to the global market.

References

1. World Health Organization. (2021). *Promoting workplace health: Musculoskeletal disorders*. World Health Organization. https://www.who.int/news-room/fact-sheets/detail/musculoskeletal-conditions
2. Average human height by country (2019-2020). *Average height of Vietnamese people*. Wikipedia. https://en.wikipedia.org/wiki/Average_human_height_by_country
3. Szeto, G. P. Y., et al. (2017). Ergonomics and musculoskeletal disorders: Prevention strategies for office workers. *Journal of Occupational Rehabilitation*, 27(2), 336–345.
4. Nguyen, H. T., & Tran, M. Q. (2023). Ergonomic challenges in Vietnamese offices: Post-COVID-19 assessment. *Vietnam Journal of Occupational Health*, 12(3), 45–56.
5. Herman Miller. (2022). *Product guide: Embody chair*. Herman Miller, Inc.
6. Steelcase. (2022). *Gesture chair research*. Steelcase, Inc.
7. Ran, X., et al. (2021). Smart sitting posture monitoring system based on pressure sensors and AI. *Sensors*, 21(15), 5123. https://doi.org/10.3390/s21155123
8. Reza Anwary, A., et al. (2021). Real-time sitting posture monitoring with the Smart-Cover system. *IEEE Access*, 9, 123456–123465.
9. Pistolesi, F., et al. (2024). AI-based ergonomic monitoring system using LiDAR sensors and wearable devices. *Applied Ergonomics*, 110, 103957. https://doi.org/10.1016/j.apergo.2024.103957
10. Ashour, A. F., & Rashdan, W. (2024). Smart furniture: AI applications in posture-tracking furniture design. *Journal of Intelligent & Robotic Systems*, 108, 55–68. https://doi.org/10.1007/s10846-024-01832-3

RATE COEFFICIENTS FOR H_2^+ IONS IN Ar/H_2 MIXTURES

Željka Nikitović

Institute of Physics University of Belgrade, Pregrevica 118, 11080 Belgrade, Serbia

ORCID ID: https://orcid.org/0000-0002-0697-0927

ABSTRACT

An understanding of plasma distribution, characteristics and phenomena is necessary for the development and optimization of plasma equipment for the production of semiconductor devices, such as etching and deposition tools. For this reason, plasma simulation is currently used in every phase of equipment design, development and improvement.

It was found that the sets of cross sections obtained by applying the Denpoh-Nanbu theory to H_2^+ ions during Ar collisions are in general qualitative and partially quantitative agreement with the data from the literature. The Monte Carlo code was used to calculate the transport coefficients. The calculated cross-sections can be used to obtain transport coefficients, especially characteristic energy, reduced mobility, longitudinal diffusion coefficients and rate coefficients for low and moderately reduced electric fields *E/N* (E-electric field strength; N-gas density) and to calculate non-conservative collisions.

ACKNOWLEDGMENTS

The author acknowledges funding provided by the Institute of Physics University Belgrade, through the grant by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia.

OCCURENCE OF *STRONGYLUS EQUINUS* OF DOMESTIC MOUNTAIN HORSE IN SERBIA

Academician Dr Ivan PAVLOVIC

Scientific Institute of Veterinary Medicine of Serbia, Belgrade, Serbia

ORCID ID: https://orcid.org/0000-0003-4751-6760

Prof Dr Slavica ŽİVKOVIC

Agricultural School PKB, Belgrade, Serbia

ORCID ID: https://orcid.org/ 0009-0000-9905-062X

ABSTRACT

Introduction and Purpose: The domestic mountain horses are considered autochthonous species whose numbers are declining, so they are classified as endangered species. They live in small herds in nature reserves Stara planina Nature Park, Zasavica Special Nature Reserve and Krčedinska ada. Parasitic infections are a constant health problem in free-ranging animals. In our work, we present research on the presence of *Strongylus equinus* in animals that are kept in free breeding in nature reserves.

Materials and Methods: The research included 157 Domestic mountain horses. For fecal examination we use standard coprological methods. Determination of parasitrs eggs was based on their morphological characteristics.

Results: During our examinations infection with *Strongylus equinus* we established at 13, 33% horses.

Discussion and Conclusion: Endogenous development is direct, the eggs thrown out with feces into the external environment embryonate and from them emerge larvae of the first stage, which become infectious after two moults. After infection, its larvae pierce the mucous membrane of the cecum and colon and enter the subserosa, where they form nodules. After 10-12 days, they go from there to the peritoneal cavity, then to the liver, where they destroy liver cells, creating hemorrhagic foci and diffuse hepatitis. After a few months, they go to the pancreas, where they form dark cysts full of necrotic mass and larvae. Larvae lead to severe bleeding, necrosis and purulent inflammation, pancreatitis and organ enlargement. After leaving the pancreas, they return to the large intestine attach to the intestinal mucosa, feeding on blood and epithelium, which leads to hemorrhagic lesions and anemia. In acute cases, intestinal inflammation, anemia and weight loss occur. Diarrhea, colic and we find parasites in the excrement. During our research, the intensity of infections was low, so we had no recorded clinical cases of the disease.

Key Words: *Strongylus equinus*, domestic mountain horse, epidemiology, Serbia

DETERMINATION OF GENETIC DIVERSITY IN PEPPER SEEDS USING MOLECULAR METHODS

BİBER TOHUMLARINDAKİ GENETİK FARKLILIĞIN MOLEKÜLER YÖNTEMLERLE BELİRLENMESİ

Onur Ata ÇETİNKAYA

Ege Universitesi Tohum Bilimi ve Teknolojisi Anabilim Dalı, Bornova, İzmir, Turkiye

İsmail Can PAYLAN

Ege Universitesi Tohum Bilimi ve Teknolojisi Anabilim Dalı, Bornova, İzmir, Turkiye

ABSTRACT

Genetic diversity refers to the heritable variation observed both within and among populations of organisms, including plant species. The gene pool formed through mating in a population serves not just as a foundation for plant growth but besides as a crucial basis for natural selection. In recent times, awareness has increased regarding the necessity of a comprehensive approach to biodiversity—one that encompasses the protection and sustainable utilization of agricultural biodiversity and its incorporation into broader development policies.

This study aims to estimate the genetic variation in pepper seeds through the application of molecular methods. Within the scope of this research, Real-Time PCR was employed as the main method for determining genetic variation in peppers, a crop of significant global economic value. The use of this technique allowed for the optimization of parameters, enabling a comparative analysis with other molecular approaches. Real-Time PCR offers notable advantages in terms of sensitivity, specificity, and reproducibility, particularly in the rapid detection of target genes. The ability to monitor product formation during amplification enhances the trustworthiness of the information obtained.

In this study, DNA samples extracted from 20 different pepper (Capsicum) varieties were analyzed through DNA quality control and Real-Time PCR. The results, interpreted via melting curve analysis, revealed whether the genotypes were homozygous or heterozygous, thereby indicating the degree of genetic diversity among the varieties. This thesis highlights the effectiveness of Real-Time PCR techniques in identifying genetic variation in pepper plants. The findings contribute valuable insights to the field of genetic diversity research and may promote increased emphasis on genetic variability in agricultural production, encouraging further studies in this area.

Keywords: Pepper, genetic diversity, PCR, molecular marker

ÖZET

Genetik çeşitlilik, organizmaların popülasyonları içerisinde ve farklı bitki türleri arasında görülen kalıtsal varyasyonları ifade eder. Bir popülasyonda çiftleşme yoluyla oluşan bu genetik varyasyon havuzu, yalnızca bitkilerin ıslah edilmesinde değil, aynı zamanda doğal seçilimin işleyişinde de temel bir rol oynamaktadır. Bu nedenle bitkisel genetik çeşitliliğin korunması hem günümüz hem de gelecek kuşakların refahı açısından büyük bir önem taşımaktadır. Son dönemlerde, tarımsal biyoçeşitliliğin sürdürülebilir biçimde kullanımı ve korunması ile kalkınmaya entegre edilmesinin önemi konusunda toplumsal farkındalık giderek artmaktadır.

Bu tez çalışmasının temel amacı, biber tohumlarında bulunan genetik çeşitliliğin moleküler teknikler aracılığıyla analiz edilmesidir. Araştırma kapsamında dünya genelinde ekonomik değeri yüksek olan bitkilerden biri olan biberde genetik çeşitliliğin belirlenmesi amacıyla Real-Time PCR yöntemi tercih edilmiştir. Bu yöntem sayesinde optimize edilen parametreler belirlenmiş ve diğer moleküler analiz yöntemleriyle karşılaştırma yapma olanağı doğmuştur. Real-Time PCR teknolojisi, hedef genin hızlı bir şekilde tespit edilmesini sağlarken; duyarlılığı, özgünlüğü ve tekrarlanabilirliği açısından önemli avantajlar sunmaktadır. Amplifikasyon esnasında ürün oluşumunun anlık izlenebilmesi, elde edilen verilerin güvenilirliğini artıran başlıca faktörlerden biridir.

Çalışmada kullanılan 20 farklı biber çeşidinden elde edilen örnekler üzerinde DNA kontrolü gerçekleştirilmiş ve ardından Real-Time PCR analizleri uygulanmıştır. Elde edilen bulgular, melting eğrisi analizleri doğrultusunda örneklerin homozigot ya da heterozigot olup olmadığını ortaya koymuş; böylece çeşitler arasındaki genetik çeşitlilik düzeyi belirlenmiştir. Bu tez çalışması, biber bitkisindeki genetik çeşitliliğin saptanmasında Real-Time PCR yöntemlerinin verimliliğini ve kullanılabilirliğini ortaya koymaktadır. Elde edilen veriler, bu alandaki araştırmalara anlamlı katkılar sunarak, tarımsal üretimde genetik çeşitliliğe yönelik farkındalığın artmasına ve bu konuda yapılacak çalışmalara öncülük edebilir.

Anahtar kelimeler: Biber, genetik çeşitlilik, PCR, moleküler markör

PSYCHOLOGICAL FACTORS AFFECTING COGNITIVE HEARING: THE ROLE OF EMOTIONAL STATE AND MENTAL LOAD

Saliha KURT

Selçuk University, Vocational School of Health Services, Department of Medical Services and Techniques, Audiometry, Konya, Turkey

ORCID ID: https://orcid.org/0000-0002-6249-1162

Özlem ERDEM

Selçuk University, Vocational School of Health Services, Department of Medical Services and Techniques, Dialysis, Konya, Turkey

ORCID ID: https://orcid.org/ 0000-0003-3220-166X

Zuhal ŞEFLEK

Selçuk University, Vocational School of Health Services, Department of Medical Services and Techniques, Dialysis, Konya, Turkey

ORCID ID: https://orcid.org/ 0000-0002-1385-5310

Tuğçe DURAN

KTO Karatay University, Faculty of Medicine, Department of Medical Genetics, Konya, Turkey

Necmettin Erbakan University, Faculty of Medicine, Department of Pediatric Immunology and Allergy, Konya, Turkey

ORCID ID: https://orcid.org/0000-0002-7353-4527

ABSTRACT

Introduction: Cognitive hearing involves more than just the perception of sound—it includes the complex integration of auditory signals with attention, working memory, and executive functioning. Recent studies have shown that psychological factors such as anxiety, depression, and mental fatigue can significantly impair this process. These emotional states can alter attentional control and cognitive efficiency, which are critical for understanding speech in both quiet and noisy environments.

Materials and Methods: This study is a qualitative review of scientific research examining the effects of psychological factors on cognitive hearing. The literature review focused on studies investigating the relationship between variables such as anxiety, depression, stress, mental fatigue, and motivation with auditory-cognitive processes. The findings were analyzed and interpreted under thematic categories.

Results: The reviewed studies consistently indicate that psychological stress and anxiety reduce attentional capacity and increase listening effort. Depression is linked to slower cognitive processing and impaired working memory, resulting in decreased speech comprehension. Mental fatigue, especially in sustained listening conditions, was shown to compromise auditory

attention. Additionally, low motivation was found to correlate with reduced engagement in listening tasks.

Discussion and Conclusion: Cognitive hearing is highly susceptible to emotional and mental states. Psychological factors such as anxiety, depression, and fatigue diminish cognitive resources needed for effective auditory processing. Therefore, assessing and addressing these factors in clinical hearing assessments—especially for hearing aid and cochlear implant users—may enhance rehabilitation outcomes and listening satisfaction.

Keywords: Cognitive hearing, psychological factors, stress, anxiety, depression, mental fatigue, attention, motivation

GLOBAL UTILITY METHOD IN SOLVING THE LINEAR MULTI-CRITERIA OPTIMIZATION MODEL IN INTEGERS

Tkacenko Alexandra

Department of Mathematics, Moldova State University A. Mateevici str. 60, Chisinau, MD–2009, Moldova

Abstract

The multi-criteria optimization models are in increasing demand now. A wide range of practical optimization problems in various fields lead to the solution of multicriteria linear optimization models [1] in integers. In this paper we propose one method for solving the linear multi-criteria model in integers. This is interactive one, because the decision marker iteratively can change the utility of each criterion. According of these, he will obtain every time one set of efficient solution of multi-criteria model in integers. The proposed algorithm take into account the optimal and the worst values of the criteria for previously assigned utilities. The decisional problem with an infinite number of variants is described as follows:

$$\begin{cases} \begin{Bmatrix} \min \\ \max \end{Bmatrix} F_k(x) = \sum_{j=1}^{n} c_{kj} x_j, \quad k = \overline{1,r} \\ A \cdot x \le b \\ x \in Z^+ \end{cases} \tag{1}$$

where: $A = \|a_{ij}\|$ is an array of size $m \times n$ $(m < n)$, $C = \|c_{kj}\|$, is an array of size $r \times n$ $(r < n)$, x is a vector n-dimensional column, and *b* is a *m*-dimensional column vector.

According on the utilities assigned by the decision maker, the proposed algorithm generates sets of efficient solutions for the model, considering all possible combinations of the optimal or worst values of the criteria in R^+or in Z^+, which maximize the following objective function:

$$FU_j = \alpha_j F_j(X) + \beta_j, \ j = \overline{1,r} \tag{2}$$

The efficiency of the method can be assessed by concrete decision situations. The theoretical justifications of the methods as well as an example applying this are provided in the paper.

References

1. D.A.G Vieira, A.C. Lisbora, A cutting-plane method to non-smooth multi-objective optimization problems, European Journal of Operational Research, V.275, Issue, 3, June 2019, pp. 822-829.

2. A. Tkacenko, Method for solving the linear multicriteria optimization problem in integers Journal of Economic Computation and Economic Cybernetics Studies and Research, ISI Thomson Reuter Serv., ISSUE 1/2022, V.56, Bucuresti, Romania, pp. 159-174

FITNESS PRIORITIES AMONG GYM PARTICIPANTS IN TIRANA: A DEMOGRAPHIC AND GENDER-BASED ANALYSIS

PhD. Rando KUKELI

Sports University of Tirana, Faculty of Physical Activity and Recreation, Department of Sports Management and Tourism, Tirana, Albania

ORCID ID: https://orcid.org/0009-0000-4646-2671

Msc. Victoria KUKELI

Sports University of Tirana, Faculty of Movement Sciences, Department of Sports, Tirana, Albania

ORCID ID: https://orcid.org/0009-0008-3462-0052

ABSTRACT

Introduction and Purpose: Motivations for participating in gym-based physical activity vary widely and are influenced by demographic and gender factors. Understanding these priorities is essential for developing effective and inclusive fitness programs. This study aimed to identify the main fitness-related priorities among gym users in Tirana, Albania, and to examine differences based on gender and area of residence (urban vs. rural).

Materials and Methods: A cross-sectional study was conducted with 671 gym participants (330 men and 341 women) in Tirana. A structured questionnaire was used to assess participants' primary motivation for engaging in fitness activities: fitness, wellness, anti-stress, or food regime. Data were analyzed using descriptive statistics and chi-square tests to explore demographic and gender differences.

Results: The most frequently reported priority was fitness (45.6%), followed by anti-stress (19.0%), wellness (18.0%), and food regime (17.4%). Urban participants prioritized fitness (46.2%) and anti-stress (18.8%), while rural participants reported higher rates of wellness (30.1%). Men were more focused on fitness (50%), whereas women showed more balanced priorities, with greater emphasis on wellness (20%), food regime (19.4%), and anti-stress (19.1%).

Discussion and Conclusion: The findings highlight significant demographic and gender-based differences in fitness motivations. Tailored fitness interventions that consider these distinctions could enhance engagement and improve health outcomes in diverse populations.

Key Words: Fitness motivation, Gym participation, Gender differences, Urban-rural disparities, Wellness, Albania, Physical activity.

INTRODUCTION

Regular participation in physical activity has been widely recognized as essential for maintaining physical health, psychological well-being, and quality of life (World Health Organization [WHO], 2020). Gyms and fitness centers have become increasingly popular settings where individuals engage in structured exercise to achieve diverse personal goals. However, motivations for gym participation are not uniform and can vary considerably based

on gender, demographic background, and socio-cultural influences (Frederick & Ryan, 1993; Ingledew & Sullivan, 2002).

Previous research has identified a broad spectrum of fitness priorities among gym-goers, including goals related to body image and physical appearance (Duncan et al., 2005), mental health and stress reduction (Stults-Kolehmainen & Sinha, 2014), wellness and preventive health (Centers for Disease Control and Prevention [CDC], 2018), and weight management through diet and exercise (Jakicic & Rogers, 2016). These factors may differ across urban and rural populations due to unequal access to facilities, health services, and wellness education (Bennett et al., 2019), as well as between men and women, who often pursue exercise with differing expectations and values (Kilpatrick et al., 2005).

Understanding these motivations is important for designing tailored interventions, public health campaigns, and fitness programs that align with individuals' real needs and preferences. While several studies have examined exercise motivation globally, there is a lack of data regarding the Albanian context, particularly focusing on gym users in Tirana, the capital and urban hub of the country. The aim of this study is to explore the primary fitness priorities among individuals attending gyms in Tirana, Albania, and to examine how these priorities differ by gender and demographic location (urban vs. rural). This knowledge can contribute to the development of more inclusive and effective fitness promotion strategies in diverse populations.

METHODS

Study design and participants

This cross-sectional descriptive study was conducted in various fitness centers in Tirana, Albania, during the year 2025. The purpose of the study was to explore the main priorities and motivations for engaging in fitness activities among gym users, with a particular focus on demographic (urban vs. rural) and gender differences.

Participants were recruited using convenience sampling from multiple gyms. Inclusion criteria required that participants be at least 18 years old and have attended a gym regularly (at least once per week) during the last three months. A total of 671 individuals participated in the study: 597 from urban areas and 74 from rural areas; 330 men and 341 women. After accounting for missing responses, valid cases were used for statistical analysis.

Ethical Considerations

The study was conducted in accordance with ethical guidelines for research involving human subjects. Participants gave informed consent prior to completing the survey. No personal identifiers were collected. Approval was obtained from the institutional ethics committee of the coordinating university.

Instrument

Data were collected using a structured questionnaire developed by the research team. The questionnaire included items on: Demographic information (gender, place of residence), Main priority in attending the gym, with four response options: Fitness, Wellness, Anti-Stress, Food Regime

The questionnaire was administered on-site and took approximately 5–7 minutes to complete. Participation was voluntary and anonymous.

Statistical Analysis

Data were entered and analyzed using IBM SPSS Statistics Version 26. Descriptive statistics (frequencies and percentages) were used to summarize the priorities across gender and demographic groups.

To examine associations between demographic variables (urban/rural) and gender with fitness priorities, Chi-square (χ^2) tests of independence were conducted. Significance was set at $p < 0.05$. Results were displayed in tables showing frequency counts and valid percentages. Missing responses were excluded from inferential analysis but noted separately in the total counts.

RESULTS

Table 1 displays the demographic distribution of gym participants in Tirana based on their area of residence. Among the 655 valid responses, a significant majority (582 participants, or 88.9%) are from urban areas, while only 73 participants (11.1%) are from rural areas. Additionally, there were 12 missing responses in total. This urban dominance is expected, given the higher concentration of fitness centers, better access to facilities, and greater awareness of fitness culture in city environments.

Table 1. The priority of subjects in fitness: participants by demographic zone.

Urban	N	Valid	582
		Missing	11
Rural	N	Valid	73
		Missing	1

Table 2 summarizes participants' primary priorities when attending gyms in Tirana. Out of a total of 667 respondents, nearly half (45.6%) reported fitness as their main goal, emphasizing the traditional focus on improving physical appearance and performance. Anti-stress and wellness were reported by 19.0% and 18.0% of participants, respectively, underscoring the importance of mental health and general well-being as key motivators for gym participation. Meanwhile, 17.4% of respondents indicated a primary focus on food regime, suggesting that nutrition and weight control are also integral to their fitness journey.

Table 2. Percentage Distribution of Participant Preferences in Health and Lifestyle Domains.

Fitness	N	304	45.6 %
Wellness	N	120	18.0%
AntiStress	N	127	19.0 %
Food Regime	N	116	17.4%

Table 3 presents a breakdown of fitness priorities among urban and rural gym participants in Tirana. Among the urban population (N = 586 valid responses), the dominant priority is fitness with 46.2% of respondents, followed by anti-stress (18.8%), food regime (18.4%), and wellness (16.6%). This suggests that urban participants are primarily focused on physical performance and aesthetics, while a significant portion also values mental health and lifestyle management.

In contrast, among the rural participants (N = 73 valid responses), fitness still ranks highest at 39.7%, but the proportion is notably lower than in urban areas. Interestingly, wellness is reported by 30.1% of rural respondents, which is nearly double the urban rate. Anti-stress ranks third at 21.9%, while food regime is a much lower priority (8.2%) in rural settings compared to urban ones.

Table 2. Percentage Distribution of Health and Lifestyle Preferences by Residence (Urban vs. Rural).

Demographic			**Frequency**	**Percent**
Urban		Fitness	271	46.2
		Wellness	97	16.6
		AntiStress	110	18.8
		Food Regime	108	18.4
		Total	586	100
	Missing	System	11	
	Total		597	
Rural		Fitness	29	39.7
		Wellness	22	30.1
		AntiStress	16	21.9
		Food Regime	6	8.2
		Total	73	100
	Missing	System	1	
	Total		74	

Table 4 illustrates gender-based differences in fitness priorities among gym participants. Among men (N = 326 valid responses), the leading priority is fitness, reported by 50%, indicating a strong emphasis on physical performance, strength, and body image. Other notable motivations include anti-stress (18.7%), wellness (16%), and food regime (15.3%), showing a balanced but secondary interest in mental and nutritional aspects. Among women (N = 340 valid responses), the priority distribution is more evenly spread. Fitness still ranks highest at 41.5%, but to a lesser extent than among men. Interestingly, women report higher percentages for food regime (19.4%) and wellness (20%) compared to men, reflecting a broader focus on overall health, body composition, and well-being. The rate of those choosing anti-stress is nearly the same (19.1%), suggesting that mental health is a significant concern for both genders.

Table 4. Percentage Distribution of Health and Lifestyle Preferences by Gender.

Gender		Frequency	Valid Percent
Man	Fitness	163	50
	Wellness	52	16
	AntiStress	61	18.7
	Food Regime	50	15.3
	Total	326	100
Total		330	
Woman	Fitness	141	41.5
	Wellness	68	20
	AntiStress	65	19.1
	Food Regime	66	19.4
	Total	340	100
Total		348	

DİSCUSSİON

This study explored the primary fitness priorities among gym participants in Tirana, Albania, with a focus on demographic (urban vs. rural) and gender-based differences. The findings provide valuable insights into the motivational profiles of individuals engaging in physical activity in a rapidly urbanizing and transitional health context such as Albania. Overall, the most frequently reported priority was fitness (45.6%), followed by anti-stress (19.0%), wellness (18.0%), and food regime (17.4%). This aligns with global findings that physical fitness and appearance remain the most common reasons for gym attendance, especially in urban populations (Kilpatrick, Hebert, & Bartholomew, 2005; Ingledew & Sullivan, 2002). The high rate of stress-related motivation also reflects the increasing recognition of exercise as a coping mechanism for psychological stress (Stults-Kolehmainen & Sinha, 2014).

Urban participants (N = 586) showed a dominant preference for fitness (46.2%) and anti-stress (18.8%), whereas rural participants (N = 73) demonstrated a more balanced distribution of priorities, with fitness at 39.7% and wellness notably high at 30.1%. These results suggest that while urban populations prioritize body composition and stress relief, rural participants may associate exercise more strongly with general health and well-being. Similar trends have been observed in prior research, where urban residents tend to engage in physical activity for aesthetic and performance reasons, while rural individuals often emphasize health maintenance (Bennett et al., 2019).

Gender analysis revealed that men prioritized fitness (50%) significantly more than women (41.5%), while women reported higher rates for wellness (20%), anti-stress (19.1%), and food regime (19.4%) compared to men. These findings are consistent with the literature showing that men are often more focused on strength, body mass, and physical performance, whereas women are motivated by holistic goals such as weight management, mental well-being, and health improvement (Frederick & Ryan, 1993; Duncan et al., 2005).

The results further suggest that women's motivations are more multi-dimensional, reflecting growing societal awareness of wellness and lifestyle diseases. This shift may be influenced by cultural narratives, public health messaging, and gendered expectations regarding body image and self-care (Bratland-Sanda & Sundgot-Borgen, 2013).

CONCLUSION AND IMPLICATIONS

These findings carry practical implications for fitness center managers, physical education professionals, and public health authorities. Tailored programs that address the specific motivations of different demographic and gender groups may enhance participation and adherence. For example, urban male participants may benefit from strength-based programs and performance tracking tools, while women and rural users may be more responsive to holistic, stress-reducing, and health-oriented activities, including mind-body workouts and nutritional counseling.

Incorporating mental health benefits and nutritional education into fitness programs could improve outreach and satisfaction, particularly among women and rural populations. Furthermore, the low rural representation underscores the need for greater infrastructure and outreach in underserved areas to reduce health disparities.

LİMİTATİONS AND FUTURE RESEARCH

Despite its strengths, this study has some limitations. The use of convenience sampling may limit the generalizability of findings beyond the Tirana gym population. Self-reported data may also be influenced by social desirability bias. Future studies should use random sampling, include qualitative methods (e.g., interviews), and examine longitudinal trends in fitness motivation across age groups and regions.

REFERENCES

Bennett, G. G., Wolin, K. Y., Askew, S., Fletcher, R., & Emmons, K. M. (2019). Family health behaviors and socioeconomic status influence physical activity in overweight African American women. *Preventive Medicine*, *49*(5), 472–476. https://doi.org/10.1016/j.ypmed.2009.09.014

Bratland-Sanda, S., & Sundgot-Borgen, J. (2013). Eating disorders in athletes: Overview of prevalence, risk factors and recommendations for prevention and treatment. European Journal of Sport Science, 13(5), 499–508. https://doi.org/10.1080/17461391.2012.740504

Duncan, G. E., Anton, S. D., Newton, R. L., & Perri, M. G. (2005). Comparison of perceived health benefits of exercise and preferences for exercise mode in sedentary adults. Preventing Chronic Disease, 2(4), A13.

Frederick, C. M., & Ryan, R. M. (1993). Differences in motivation for sport and exercise and their relations with participation and mental health. Journal of Sport Behavior, 16(3), 124–146.Centers for Disease Control and Prevention. (2018). *Physical activity and health: A report of the Surgeon General*. U.S. Department of Health and Human Services.

Duncan, G. E., Anton, S. D., Newton, R. L., & Perri, M. G. (2005). Comparison of perceived health benefits of exercise and preferences for exercise mode in sedentary adults. *Preventing Chronic Disease*, *2*(4), A13.

Frederick, C. M., & Ryan, R. M. (1993). Differences in motivation for sport and exercise and their relations with participation and mental health. *Journal of Sport Behavior*, *16*(3), 124–146.

Ingledew, D. K., & Sullivan, G. (2002). Effects of body mass and body image on exercise motives in adolescence. *Psychology of Sport and Exercise*, *3*(4), 323–338. https://doi.org/10.1016/S1469-0292(01)00035-2

Jakicic, J. M., & Rogers, R. J. (2016). Exercise and weight control. In P. T. Katzmarzyk (Ed.), *Physical Activity and Public Health Practice* (pp. 47–63). Human Kinetics.

Kilpatrick, M., Hebert, E., & Bartholomew, J. (2005). College students' motivation for physical activity: Differentiating men's and women's motives for sport participation and exercise. Journal of American College Health, 54(2), 87–94. https://doi.org/10.3200/JACH.54.2.87-94

Stults-Kolehmainen, M. A., & Sinha, R. (2014). The effects of stress on physical activity and exercise. Sports Medicine, 44(1), 81–121. https://doi.org/10.1007/s40279-013-0090-5Kilpatrick, M., Hebert, E., & Bartholomew, J. (2005). College students' motivation for physical activity: Differentiating men's and women's motives for sport participation and exercise. *Journal of American College Health*, *54*(2), 87–94. https://doi.org/10.3200/JACH.54.2.87-94

Stults-Kolehmainen, M. A., & Sinha, R. (2014). The effects of stress on physical activity and exercise. *Sports Medicine*, *44*(1), 81–121. https://doi.org/10.1007/s40279-013-0090-5

World Health Organization. (2020). *Guidelines on physical activity and sedentary behaviour*. https://www.who.int/publications/i/item/9789240015128

USE OF HEART-TYPE FATTY ACID BINDING PROTEIN (H-FABP) AS A CARDIAC BIOMARKER IN EARLY DIAGNOSIS

Betul APAYDIN YILDIRIM

Ataturk University, Faculty of Veterinary Medicine, Department of Biochemistry, Erzurum, Turkey

ORCID ID: https://orcid.org/0000-0002-0361-6148

ABSTRACT

Small lipid-binding proteins known as fatty acid-binding proteins (FABPs) are found in cells with high fatty acid metabolism. In mammals, there are ten evolutionarily conserved types of FABPs that are expressed in specific organs and structures. Originally identified as intracellular fatty acid transporters, these proteins participate in various biological functions, including lipid metabolism, signal transduction, and gene expression regulation. There is also evidence that they can influence circulatory processes and be secreted outside cells. Increased levels of FABPs are observed in metabolic disorders, ischemia, myocardial infarction, inflammatory conditions, and certain viral diseases. They may also serve as potential tumor markers because they are overexpressed in some cancers, such as renal cell carcinomas, bladder, and prostate cancers. The heart-type fatty acid-binding protein (H-FABP), the cardiac isoform of this family, is a significant biomarker candidate for early detection of acute myocardial infarction due to its rapid release into the bloodstream during the initial stages of myocardial damage. Although traditional cardiac markers, including CK, CK-MB, and troponins, are commonly used in diagnosis, they can cause delays in diagnosis and treatment because their levels rise over time. H-FABP circumvents this issue and can be used for prognostic assessments, including estimating 30-day mortality risk in patients with acute coronary syndromes. Recent research suggests that H-FABP might be superior to other cardiac biomarkers in this regard. Therefore, further investigation into the diagnostic and prognostic applications of H-FABP will improve prompt and effective management of myocardial infarction, ultimately reducing the global health burden and mortality rate.

Key Words: CK-MB, fatty acid, FABP, myocardial infarction, troponins.

Introduction

Cardiovascular diseases are a major global public health problem, with a prevalence that is increasing in developing countries as well as being a leading cause of death in industrialized countries (Cho and Lee, 2012). Acute coronary syndrome is a clinical condition that utilizes electrocardiogram (ECG) findings and biomarkers, especially cardiac troponin (cTn), for diagnosis. The most effective approach to preventing major complications and mortality associated with ACS is early diagnosis (Thygesen et al., 2012a)

Currently, clinical and paraclinical findings are used to diagnose acute myocardial infarction (AMI). Patients typically seek emergency services for symptoms of normal chest discomfort, which is caused by ischemic alterations. The results of an electrocardiogram (ECG) may be normal or exhibit ST-elevation, depression, and/or abnormal Q-waves. The diagnosis is typically confirmed by a sharp increase in creatine kinase isoenzyme myocardial band (CK-MB) levels and a characteristic increase in cardiac troponin I or T levels. Although coronary angiography can be performed as a therapeutic technique and as a confirmatory test, many healthcare facilities do not have these units or trained teams for

interventional cardiology, which makes treating this potentially fatal condition even more challenging (Zeymer 2019)

Troponin is a commonly utilized cardiac biomarker for the diagnosis and risk assessment of coronary artery disease, a disorder compromises the myocardium's blood flow by narrowing or blocking the coronary arteries. A class of proteins called troponins is present in cardiac myocytes and is essential for controlling muscle contraction. Troponins are released into the bloodstream during myocardial damage brought on by diminished perfusion of the muscle wall, such as in myocardial infarction (MI, heart attack) or unstable angina, which raises the levels of this biomarker (Parikh et al., 2015).

Troponins have recently become very sensitive and specific biomarkers for identifying myocardial damage linked to coronary artery disease, especially cardiac troponin I (cTnI) and cardiac troponin T (cTnT). To determine the degree of myocardial damage and inform clinical judgment, troponin levels are measured both at the time of hospital admission and at later intervals (Morrow 2009).

For this purpose, numerous biomarkers for early diagnosis have been developed and introduced into clinical practice. However, today, not only early diagnosis but also the ability to predict patients' short- and long-term prognoses is of paramount importance. While highly sensitive biomarkers and ECGs offer high accuracy in making and excluding the disease, the need for new biomarkers for prognostic assessment continues.

The clinical value of H-FABP as a stand-alone marker for the diagnosis of MI is still being studied because high H-FABP levels can also occur in other illnesses that damage the heart muscle (myocarditis, congestive heart failure). The objective was to assess the potential use of H-FABP in the early detection of acute myocardial infarction in comparison to other cardiac markers.

Method

A review of the literature was conducted with PubMed Central. The authors searched through all available papers by title and, if appropriate, by abstract in order to choose potential research for inclusion.

H-FABP as a Cardiac Biomarker in Early Diagnosis

Heart-type fatty acid-binding protein (H-FABP) is recommended as a significant biomarker for the early diagnosis of myocardial damage. It is considered a potential prognostic indicator for predicting long-term mortality (Ye et al. 2018). H-FABP, located in the cytoplasm, is involved in the transport of long-chain fatty acids (Storch and Thumser 2000).

FABPs are cytosolic proteins that range in size from 12 to 15 kDa and are mostly present in tissues, including the liver, skeletal muscle, and heart, that have high levels of lipid metabolism. Additionally, they are present in cell types, including macrophages and adipocytes, that are specialized in lipid storage, transport, and signaling. Numerous metabolic and cardiovascular conditions, including atherosclerosis, obesity, and hyperglycemia, are impacted by FABPs. Every member of FABP has the same β-barrel hallmark, which includes a lipid ligand binding site and a water-filled cavity (Chmurzyńska 2006).

A class of cytoplasmic proteins known as fatty acid-binding proteins (FABPs) was initially described in 1972 and has since been studied by the scientific community (Bass 1988) (Figure 1). Numerous subtypes of FABPs have been identified to date, with varying amounts present in different organ systems. These low molecular weight proteins (about 15 kD) (Veerkamp et al., 1991) have been the subject of much discussion, particularly in light of the finding that H-FABP is a risk factor for cardiovascular and all-cause mortality (Otaki et al., 2014). The HUGO Gene Nomenclature Committee states that there are 16 members of the FABP family, each of

whom is encoded by a different gene. A- (adipocyte), B- (brain), E- (epidermal), H- (muscle/heart), I- (intestinal), Il- (ileal), L- (liver), M- (myelin), and T-FABP (testis) are presumably the most well-known members (HUGO 2019).

Because long-chain polyunsaturated fatty acids are reversibly bound by them and transported from cell membranes to the mitochondria, FABPs play a role in the metabolism of cellular fatty acids. They can also activate peroxisome proliferator-activated receptors (PPARs), which aid in the processes of cellular development and proliferation. As a result, they contribute to energy homeostasis and lipid metabolism (Chmurzy´nska et al. 2006; Hostetler et al. 2009).

For years, several publications have discussed the potential applicability of H-FABP as an early marker of myocardial damage about ischemic heart disease. H-FABP is a soluble protein found in the cytoplasm, as opposed to cardiac troponins, which are attached to the structural apparatus of the myocyte. Consequently, it may be possible to detect the release into the systemic circulation even after minor myocardial damage and more quickly (Iida et al. 2007).

According to Thygesen et al. (2012b), cTns are thought to be the most effective laboratory test for diagnosing acute MI. Within three hours of the start of chest pain in acute MI, troponin levels in the blood reach a detectable level. This prevents MI from being diagnosed earlier (Chacko et al. 2017).

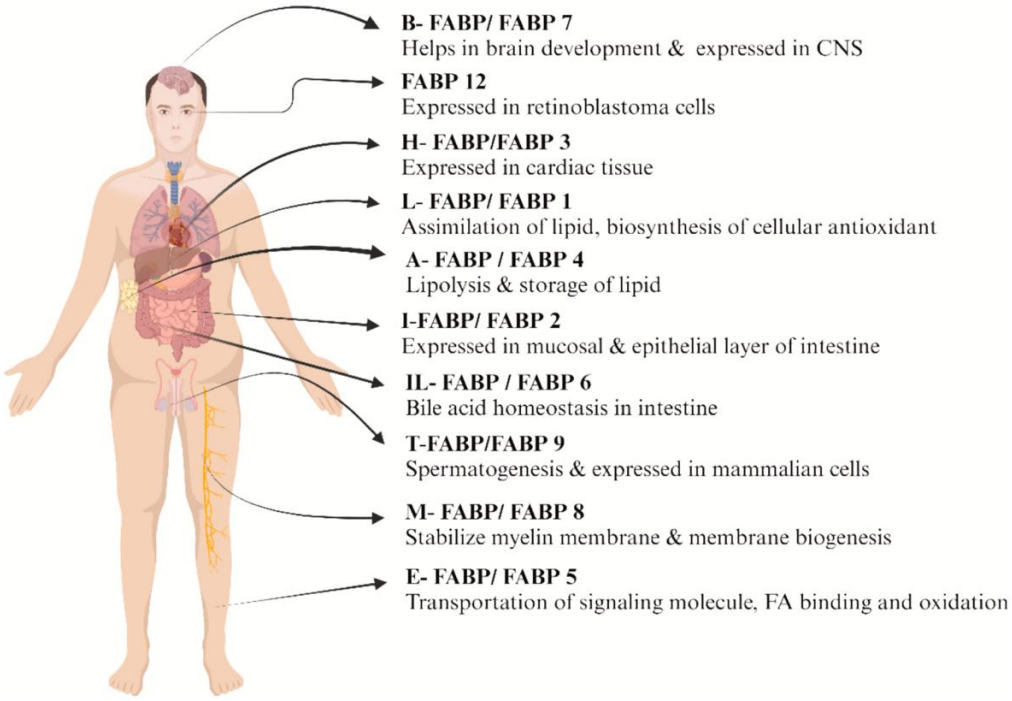


Figure 1. FABPs in different tissues (Shand et al. 2025).

Table 1. Time-course comparison of selected cardiac biomarkers after acute myocardial infarction

Cardiac Biomarker	Time to Detectability	Time to Peak Concentration	Time to Return to Baseline
Troponin I	4–6 hours	~12 hours	3–10 days
Troponin T	4–8 hours	12–48 hours	7–10 days
CK-MB	4–8 hours	12–24 hours	72–96 hours
LDH	2–5 days	—	~10 days

Diffusion of h-FABP from the interstitial spaces into the circulation occurs quickly when myocyte destruction occurs. Its smaller size allows it to enter the bloodstream more quickly than troponin (Colli et al. 2007). After chest pain starts, it can be tested in the blood 1-3 hours later. It reaches its peak levels 6-8 hours later and returns to normal levels 24-30 hours after the initial onset (Gururajan et al. 2010).

Discussion and Conclusion

Despite substantial expenditure for research, heart failure HF continues to rank among the top causes of death. Every year, a number of research studies are carried out to increase the precision of diagnosis and therapy monitoring. Research has been done on the tiny cytoplasmic heart-type fatty acid-binding protein (H-FABP) in a number of illnesses. In this article, we evaluate the body of research on H-FABP and its potential uses in heart failure.

The significance of utilizing a pair of biomarkers (h-FABP and hs-TnT) in conjunction for the first diagnosis of ACS was highlighted by Reddy et al. (2016). It has been suggested that the combination of troponin T and h-FABP together can enhance the identification of ACS in the emergency room following the start of chest discomfort. Additionally, these two indicators have a 100% negative predictive value when combined (Reddy et al. 2016). Early diagnosis was made easier in this study by adding h-FABP to regular cardiac biomarkers (cTnT, CK-MB) in individuals who presented with chest pain and ST-elevation ECG. By enabling the early hospital discharge of patients with chest discomfort but no MI, elevated h-FABP aids in the early diagnosis of MI. The inclusion of h-FABP to Hs-cTn makes it easier to identify patients as low-risk (up to 40%) when they arrive at the emergency room with chest discomfort but no ischemia ECG abnormalities (Young et al. 2016).

Setsuta et al. (2004) demonstrated that H-FABP plays a role in myocyte necrosis or apoptosis processes, contributing to the progression of heart failure. Hoffmann et al. (Hoffmann et al. 2015) reported that additional assessment of H-FABP levels in patients with decompensated heart failure could increase the diagnostic specificity and predictive value of NT-proBNP tests (Ho et al., 2018). In a study of patients undergoing cardiac surgery, Jo et al. (2019) demonstrated that H-FABP is a more practical biomarker for detecting myocyte damage compared to CK-MB and cardiac troponin T (cTnT). Furthermore, another study in the literature emphasized that persistently elevated H-FABP levels, despite clinical improvement and effective treatment, may be an indicator of progressive myocardial damage and, therefore, may have significant prognostic value (Kazimierczyk et al., 2018).

According to Liebetrau et al., transcoronary ablation of septal hypertrophy (TASH) causes iatrogenic myocardial infarction, and 15 minutes after the event, there is a markedly elevated blood level of H-FABP. in hypertrophic obstructive cardiomyopathy patients (Liebetrau et al. 2014). While some authors claim that combining H-FABP with high-sensitive troponins has extra benefits (Okomoto et al., 2000; Dupuy et al. 2015; Ho et al. 2018), others (Schoenenberger et al. 2016; Bivona et al 2018; Xu et al 2018) do not find that H-FABP adds any value to cardiac troponins in the diagnosis of acute myocardial infarction. Despite its quick and, in the case of CHF, prolonged release into the general circulation, H-FABP served as a marker of myocytal dyshomeostasis and, consequently, cellular damage as well as myocardial dysfunction.

Shirakabe et al. were able to link blood H-FABP levels to progressive renal failure as well as all-cause mortality in ADHF patients (Shirakabe et al. 2019). H-FABP may also be used as a biomarker in extremely specialized fields. In patients with coronary artery disease, Dalos et al. found that H-FABP levels increased exponentially while the left ventricular ejection fraction decreased, indicating chronic myocardial ischemia (Dalos et al. 2019).

According to Pavel et al. (2024), H-FABP is a valuable technique due to its precision and ability to detect myocardial damage in patients at an early stage. According to their findings, all patients who arrive at emergency rooms with a suspected acute myocardial infarction should have their H-FABP levels assessed in addition to their current test regimens and routine operational protocols. They contended that performing a single test, like H-FABP, to rule out myocardial infarction could lessen the anxiety that patients and their families experience in addition to the cost of doing several tests.

Large-scale investigations, including those carried out thus far, are still limited, and the use of H-FABPs in clinical settings has traditionally been experimental. Future applications of H-FABP as a more specialized diagnostic method in mid- to long-term treatment planning are thought to be promising. The development of a sensitive, rapid, and targeted FABP assay is recommended for future researchers to consider, as FABPs can be used as disease biomarkers in clinical practice.

Funding

This research received no external funding.

Conflicts of Interest

The authors declare no conflict of interest.

References

Cho CM, Lee YM. The relationship between cardiovascular disease risk factors and gender. *Health* 2012; 4: 309-15.

Thygesen K, Mair J, Giannitsis E, Mueller C, Lindahl B, Blankenberg S, et al. How to use high-sensitivity cardiac troponins in acute cardiac care. *Eur Heart J* 2012; 33: 2252–7.

Zeymer U. Diagnosis and initial management of acute myocardial infarction. *MMW Fortschr Med* 2019; 161(4): 34–6.

Parikh RH, Seliger SL, de Lemos J, et al. Prognostic significance of high-sensitivity cardiac troponin T concentrations between the limit of blank and limit of detection in community-dwelling adults: a metaanalysis. *Clin Chem* 2015; 61(12): 1524–31.

Morrow DA. Clinical application of sensitive troponin assays. *N Engl J Med* 2009; 361(9): 913–5.

Ye XD, He Y, Wang S, Wong GT, Irwin MG, Xia Z. Heart-type fatty acid binding protein (H-FABP) as a biomarker for acute myocardial injury and long-term post-ischemic prognosis. *Acta Pharmacol Sin* 2018; 39: 1155–63.

Storch J, Thumser AE. The fatty acid transport function of fatty acid-binding proteins. *Biochim Biophys Acta* 2000; 1486: 28–44.

Chmurzyńska A. The multigene family of fatty acid-binding proteins (FABPs): Function, structure and polymorphism. *J Appl Genet* 2006; 47: 39–48.

Bass NM. The cellular fatty acid binding proteins: Aspects of structure, regulation, and function. *Int Rev Cytol* 1988; 111: 143–84.

Veerkamp JH, Peeters RA, Maatman RG. Structural and functional features of different types of cytoplasmic fatty acid-binding proteins. *Biochim Biophys Acta* 1991; 1081: 1–24.

Otaki Y, Watanabe T, Takahashi H, Hirayama A, Narumi T, Kadowaki S, et al. Association of heart-type fatty acid-binding protein with cardiovascular risk factors and all-cause mortality in the general population: The Takahata Study. *PLoS One* 2014; 9: e94834.

Fatty acid binding protein family. HUGO Gene Nomenclature Committee. Available from: https://www.genenames.org/data/genegroup/#!/group/550 (Accessed 2 Jan 2019).

Hostetler HA, McIntosh AL, Atshaves BP, Storey SM, Payne HR, Kier AB, et al. L-FABP directly interacts with PPARalpha in cultured primary hepatocytes. *J Lipid Res* 2009; 50: 1663–73.

Iida M, Yamazaki M, Honjo H, Kodama I, Kamiya K. Predictive value of heart-type fatty acid-binding protein for left ventricular remodelling and clinical outcome of hypertensive patients with mild-to-moderate aortic valve diseases. *J Hum Hypertens* 2007; 21: 551–7.

Thygesen K, Alpert JS, Jaffe AS, Simoons ML, Chaitman BR, White HD, et al. Third universal definition of myocardial infarction. Circulation 2012; 126: 2020–35.

Chacko S, Haseeb S, Glover BM, Wallbridge D, Harper A. The role of biomarkers in the diagnosis and risk stratification of acute coronary syndrome. Future Sci OA 2017; 4: FSO251.

Colli A, Josa M, Pomar JL, Mestres CA, Gherli T. Heart fatty acid binding protein in the diagnosis of myocardial infarction: where do we stand today? Cardiology 2007; 108: 4–10.

Gururajan P, Gurumurthy P, Nayar P, Srinivasa Nageswara Rao G, Babu S, Cherian KM. Heart fatty acid binding protein (H-FABP) as a diagnostic biomarker in patients with acute coronary syndrome. Heart Lung Circ 2010; 19: 660–4.

Reddy LL, Shah SA, Dherai AJ, Ponde CK, Ashavaid TF. Troponin T and heart type fatty acid binding protein (H-FABP) as biomarkers in patients presenting with chest pain. Indian J Clin Biochem 2016; 31: 87–92.

Young JM, Pickering JW, George PM, Aldous SJ, Wallace J, Frampton CM, et al. Heart fatty acid binding protein and cardiac troponin: development of an optimal rule-out strategy for acute myocardial infarction. BMC Emerg Med 2016; 16: 34.

Setsuta K, Seino Y, Ogawa T, Ohtsuka T, Seimiya K, Takano T. Ongoing myocardial damage in chronic heart failure is related to activated tumor necrosis factor and Fas/Fas ligand system. Circ J 2004; 68: 747–50.

Hoffmann U, Espeter F, Weiß C, Ahmad-Nejad P, Lang S, Brueckmann M, et al. Ischemic biomarker heart-type fatty acid binding protein (H-FABP) in acute heart failure – diagnostic

and prognostic insights compared to NT-proBNP and troponin I. BMC Cardiovasc Disord 2015; 15: 50.

Ho SK, Wu YW, Tseng WK, Leu HB, Yin WH, Lin TH, et al. Author correction: The prognostic significance of heart-type fatty acid binding protein in patients with stable coronary heart disease. Sci Rep 2019; 9: 4838. Erratum for: Sci Rep 2018; 8: 14410.

Jo MS, Lee J, Kim SY, Kwon HJ, Lee HK, Park DJ, et al. Comparison between creatine kinase MB, heart-type fatty acid-binding protein, and cardiac troponin T for detecting myocardial ischemic injury after cardiac surgery. Clin Chim Acta 2019; 488: 174–8.

Kazimierczyk E, Kazimierczyk R, Harasim-Symbor E, Kaminski K, Sobkowicz B, Chabowski A, et al. Persistently elevated plasma heart-type fatty acid binding protein concentration is related with poor outcome in acute decompensated heart failure patients. Clin Chim Acta 2018; 487: 48–53.

Liebetrau C, Nef HM, Dörr O, Gaede L, Hoffmann J, Hahnel A, et al. Release kinetics of early ischaemic biomarkers in a clinical model of acute myocardial infarction. Heart 2014; 100: 652–7.

Okamoto F, Sohmiya K, Ohkaru Y, Kawamura K, Asayama K, Kimura H, et al. Human heart-type cytoplasmic fatty acid-binding protein (H-FABP) for the diagnosis of acute myocardial infarction. Clinical evaluation of H-FABP in comparison with myoglobin and creatine kinase isoenzyme MB. Clin Chem Lab Med 2000; 38: 231–8.

Dupuy AM, Cristol JP, Kuster N, Reynier R, Lefebvre S, Badiou S, et al. Performances of the heart fatty acid protein assay for the rapid diagnosis of acute myocardial infarction in ED patients. Am J Emerg Med 2015; 33: 326–30.

Schoenenberger AW, Stallone F, Walz B, Bergner M, Twerenbold R, Reichlin T, et al. Incremental value of heart-type fatty acid-binding protein in suspected acute myocardial infarction early after symptom onset. Eur Heart J Acute Cardiovasc Care 2016; 5: 185–92.

Bivona G, Agnello L, Bellia C, Lo Sasso B, Ciaccio M. Diagnostic and prognostic value of H-FABP in acute coronary syndrome: Still evidence to bring. Clin Biochem 2018; 58: 1–4.

Xu LQ, Yang YM, Tong H, Xu CF. Early diagnostic performance of heart-type fatty acid binding protein in suspected acute myocardial infarction: Evidence from a meta-analysis of contemporary studies. Heart Lung Circ 2018; 27: 503–12.

Shirakabe A, Hata N, Kobayashi N, Okazaki H, Matsushita M, Shibata Y, et al. Worsening renal failure in patients with acute heart failure: The importance of cardiac biomarkers. ESC Heart Fail 2019; 6: 416–27.

Dalos D, Spinka G, Schneider M, Wernly B, Paar V, Hoppe U, et al. New cardiovascular biomarkers in ischemic heart disease—GDF-15, a probable predictor for ejection fraction. J Clin Med 2019; 8: 924.

Pavel AL, Kundnani NR, Morariu SI, Tudor A, Man DE, Duda-Seiman DM, et al. Importance of H-FABP in early diagnosis of acute myocardial infarction. Int J Gen Med 2024; 17: 4335–46.

Shand, H., Patra, S., & Ghorai, S. (2025). Fatty acid binding protein as a new age biomarker. *Clinica Chimica Acta*, *565*, 120029.

VALORIZATION OF BREWERY BY PRODUCTS FOR SUSTAINABLE LIVESTOCK FEED: NUTRITIONAL ASSESSMENT OF ORGANIC WASTE IN ALBANIA

Msc. Polikseni DRAZHO

National Food Authority, Department of Risk Asesssment; PhD student at the University of Tirana

Prof. Dr Luljeta PINGULI

University of Tirana, Faculty of Natural Sciences, Department of Industrial Chemistry

Prof. Dr Ilirjan MALOLLARI

University of Tirana, Faculty of Natural Sciences, Department of Industrial Chemistry

ABSTRACT

This study focuses on the effective management and utilization of solid waste, particularly organic by-products, generated in breweries in Albania. The primary aim is to assess the nutritional potential of brewery spent grains (BSG), hot trub, cold trub, and spent yeast for use in animal feed. The project aims to explore sustainable practices that can reduce waste, lower feed costs, and contribute to environmental sustainability through the effective use of these by-products.

BSG, spent yeast, and trub are underutilized yet valuable by-products of the brewing process. These materials are rich in proteins, fibers, vitamins, and minerals, making them excellent sources of nutrition for animals. BSG, in particular, is a cost-effective and sustainable option for animal feed due to its high nutritional content and energy value. Furthermore, its incorporation into animal feed not only adds value to brewery waste but also reduces environmental impact by minimizing waste and contributing to a circular economy. The addition of spent yeast and hot and cold trub to animal feed formulation significantly enhances the nutritional profile, providing additional protein, amino acids, vitamins, minerals, and fiber. This adjustment allows for a reduction in traditional ingredients like soybean meals, fish meal, maize meal, and alfalfa. BSG can be used up to 25% especially if it is a fermented one. Spent Yeast rich in protein, amino acids, and B-vitamins, replacing part of the soybean meal and fish meal. Hot trub and cold trub provide protein, fiber, soluble sugars, and antioxidants, replacing some maize meal.

This modified feed formulation ensures a balanced, cost-effective diet, improving the nutritional quality of the feed while reducing reliance on traditional feed ingredients. It supports a sustainable and economical feeding strategy for livestock.

Keywords: Brewery spent grains (BSG), animal feed, organic waste management, nutritional value, spent yeast, hot trub, cold trub.

INTRODUCTION

Brewery operations generate several organic residues beyond spent grain that offer opportunities for reuse. In addition to spent grain—which accounts for about 85% of brewery waste and is rich in protein (15–25% on a dry matter basis) and fiber (35–60%), supporting animal nutrition and rumen health (Colby, 2023)—other by-products include hot trub, cold trub, and spent yeast.

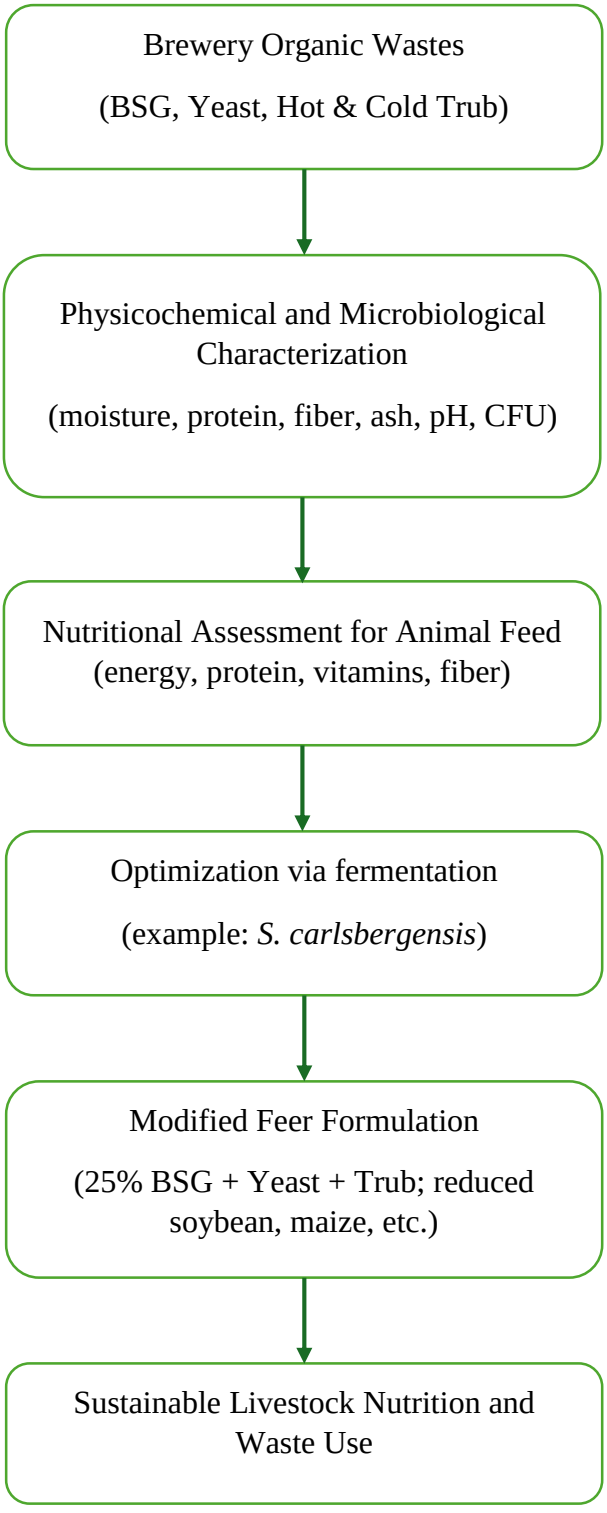
During the wort boiling stage, proteins and hop materials coagulate forming hot trub. This sediment is made of valuable organic compounds. If recovered or processed correctly, it might produce animal feed, biogas production, or fertilizer (Clarke, 2021).

After wort clarification, during the cooling phase, cold trub is formed. Being rich in protein and residual hop compounds, it might serve as a potential supplement for animal diets. Nevertheless, its its high moisture content and variable composition need further processing (Xhagolli et al., 2011) (Xhagolli et al., 2009) (Kamburi et al., 2017).

Spent yeast accumulates as a by-product during fermentation. It is a nutritious component in animal feed Sometimes spent yeast is transformed into dried yeast or yeast extracts, used in feed, or as flavouring agents or nutritional supplements for human consumption (Clarke, 2021).

The effective utilization of these organic residues, supports circular economy principles by converting waste into valuable input. These by-products can enhance the nutritional profile of animal feeds, contribute to soil fertility as organic fertilizers, and even be used in various food and industrial applications, if properly processed with methods such as drying, ensiling, or extraction (Terefe, 2022; Negash, 2021). Out of all the methods of BSG processing, fermentation is the most effective one. It has an ability to enhance its nutritional value, is low cost and requires minimal processing infrastructure. Fermentation requires less investment in expensive equipment and energy, compared to other methods like drying, pyrolysis, or protein extraction. For instance, drying processes can be costly and require high energy, fermentation requires only basic fermentation vessels and microorganisms (e.g., yeasts or bacteria), which are low-cost (Dahiya et al., 2018). By encouraging microbial growth, fermentation can also increase protein content (Pereira et al., 2016). This process helps to improve the overall digestibility and bioavailability of nutrients like amino acids and fatty acids (Santos et al., 2019). Fermented BSG has a longer shelf life compared to raw BSG. The fermentation process reduces spoilage by outcompeting harmful microorganisms, stabilizing the material for longer periods without requiring refrigeration or high-energy inputs (Vázquez et al., 2017). Fermentation often requires minimal additive quantities. Common additives include organic acids (such as lactic acid) or beneficial bacteria and yeasts, which are both cost-effective and enhance the fermentation process (Mendoza et al., 2021).

CONCEPTUAL FRAMEWORK



Scheme 1. Conceptual Framework Scheme

The conceptual framework of this study is based on the valorization of brewery-derived organic waste—namely brewer's spent grain (BSG), spent yeast, hot trub, and cold trub—as alternative, sustainable ingredients for livestock feed. At the core of this framework is the recognition that these by-products, often discarded or underutilized, contain significant nutritional value, including high levels of protein, fiber, vitamins, minerals, and metabolizable energy. The

process begins with the collection and physicochemical characterization of these waste streams, assessing parameters such as moisture content, protein levels, crude fiber, lipids, ash, pH, and microbiological load.

Their nutritional potential is then assessed, with particular emphasis on their ability to substitute conventional and expensive feed ingredients such as soybean meal, maize meal, fishmeal, and alfalfa. This framework means to enhance BSG through fermentation with beneficial yeasts such as *Saccharomyces carlsbergensis*. It improves protein bioavailability, breaks down complex fibers, increases digestible sugars, and energy content of the feed. The result is a more digestible and nutritionally balanced feed supplement, better suited for animal health and growth.

These findings are then integrated into modified feed formulations, which strategically incorporate these by-products—up to 25% BSG, 10% spent yeast, and small percentages of trub—thereby reducing reliance on traditional feed sources while maintaining or improving feed quality. Finally, the framework links this approach to broader goals of sustainability, such as reducing organic waste disposal, lowering feed production costs, and promoting a circular economy within the agricultural and brewing industries. This holistic approach ensures that brewery by-products are efficiently converted from waste into valuable nutritional resources for livestock.

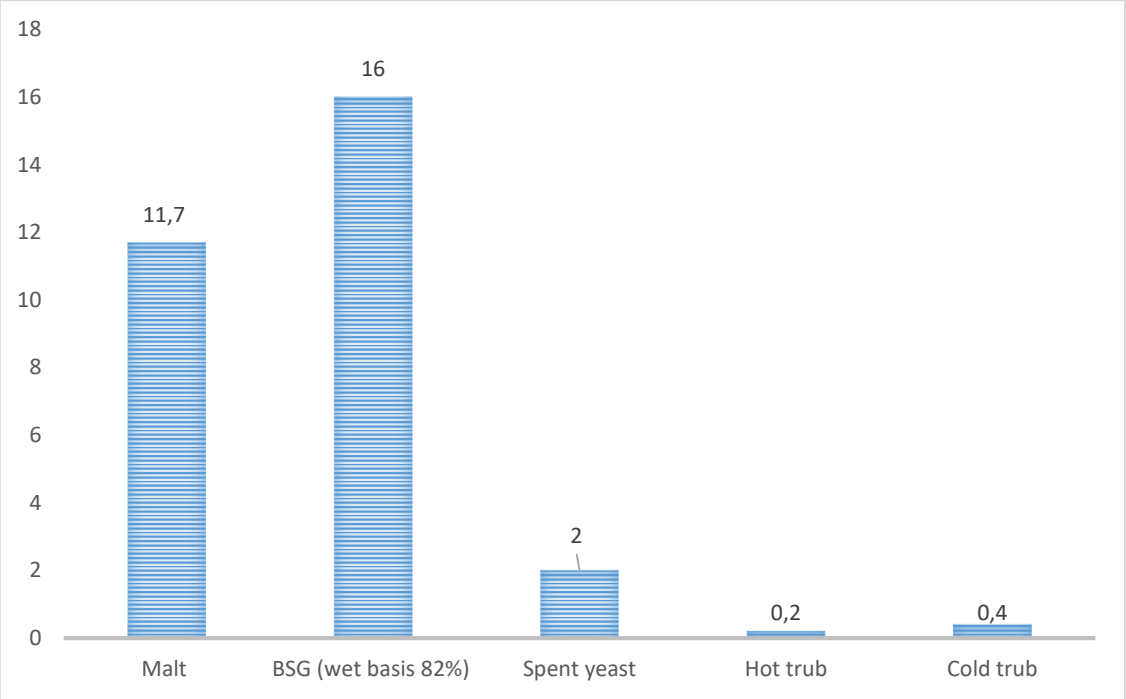
METHODOLOGY

Fresh BSG were collected at the “Stefani & Co” brewery after the brewing process. Depending on the initial moisture content of the Brewer's Spent Grain (BSG), the grains were either pressed to a moisture content of 60% or used fresh. Studying the brewing process waste streams identifies BSG as the primary solid organic waste, followed by spent yeast. Physicochemical characterization and microbiological analyses were conducted both on-site and at the Chemical Process Engineering Laboratory, Faculty of Natural Sciences, Department of Industrial Chemistry, University of Tirana. Each treatment was conducted in quintuplicate (n = 5). The treated samples were analyzed for physicochemical and microbiological parameters to evaluate the effectiveness of each stabilization method.

The following parameters were measured: moisture content, total protein (using the Kjeldahl method), total fiber content (via the acid-detergent fiber (ADF) method), fat extraction (using the Soxhlet method), ash content, and total carbohydrates, which were determined by subtracting the sum of protein, fat, fiber, and ash from 100%. A small quantity of prg

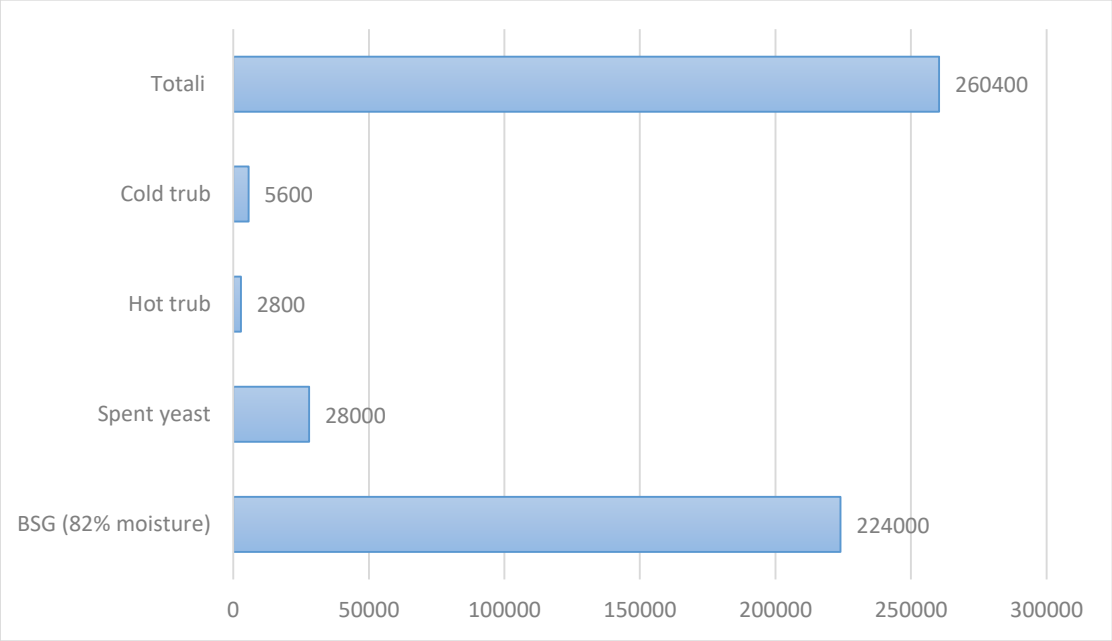
Beer yeast, hot trub and cold trub, represent a small quantity of organic waste compared to BSG but they are highly concentrated in proteins, polyphenols, and vitamins.

“Stefani & Co” brewery produces a lager beer. The wort production process is via infusion and the produced wort consists in an original extract of 11 degrees Plato. Filtration is performed using a Lauter Tun, and the wort is then transferred to a fermentation tank with a capacity of 14,000 hectoliters (Hl). The main products obtained in the form of organic wastes are Beer Spent Grains (BSG), col trub, hot trub and spent yeast. BSG make up for 85% of the solid wastes and derive from barley/mal. In order to produce 1 Hl of beer, the brewery uses 11.7 kg malt depending on the type of beer, from which they obtain 16 kg fresh BSG. Hot trub created from soluble proteins and polyphenols, precipitates during the rapid cooling of the wort. The yeast is separated at the end of the process. A portion of the yeast is retained for reuse, while the remainder is considered waste. The quantity of these wastes depends on the composition and the used technology, but the typical values for this brewery are as described in the graph 1 below.



Graph 1. Organic waste (kg) produced per Hl beer.

A fermentation tank with 14,000 Hl (1,400,000 liters) in the fabric generates wastes as described below in graph 2.



Graph 2. Quantity of organic wastes (kg) obtained in a fermentation tank (14,000 Hl) at the end of the fermenting process.

Beer Spent Grains are a by-product rich in proteins, fibers and energy that might serve as animal feed or for other products, due to their high nutritional values. Knowing their chemical composition and by analyzing the main constituents, we can calculate the nutritional values of BSG.

1. Dry matter (%)
2. Proteins (% PB – Unprocessed protein)
3. Lipids (% EE – Etheric extract)
4. Unprocessed fiber

(% CF – Crude Fiber)

5. Ash (% Minerals)
6. Metabolic Energy (EM, kcal/kg)

Table 1. Beer Spent Grains Parameters

Parameter	Value
Moisture (%)	82%
Dry matter (%)	18 %
Density (kg/m³)	500 - 650 kg/m³
pH	4.5 - 5.5
Colour	Yellow – Brown
Aroma	Malt like (very light), changes significantly with time, by taking the characteristics of a fermented product.
Total Proteins (%)	21% in dry matter
Total Lipids (%)	6% in dry matter
Total Carbohydrates (%)	10% in dry matter
Total Fibres (%)	50% in dry matter
Ash – total minerals (%)	5% in dry matter
Water Retention Capacity (WRC, g water/g dry matter)	3 – 4 g water /g dry matter
Metabolic Energy	210 kcal / 100 g

Determining the Metabolic Energy (EM)

Metabolic energy is the amount of energy utilized by microorganisms, calculated using the following formula:

$$EM = \left(4.0\ x\ PB^{2}\right) + \left(9.0\ x\ EE^{3}\right) + \left[4.0\ x\ \left(100 - PB - EE - CF^{4} - Ash^{5}\right)\right]$$

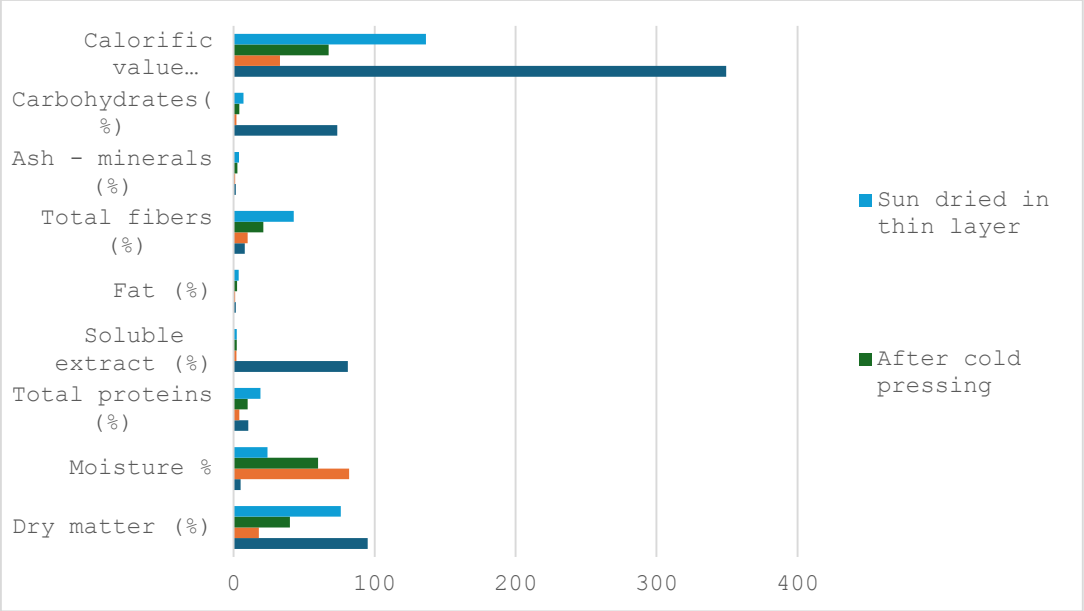
$$EM = 84 + 54 + 72 = \mathbf{210\ kcal/100g}$$ or **2100 kcal/kg for BSG dry matter**

The malt used in the “Stefani & Co” brewery, is lager the beer produced is lager with 4.5% v/v alcohol content. The sugar infusion graph differs depending on whether the sugar is derived directly from grains or produced through enzymatic action. Filtration is done with Lauter Tun and it does not produce wort with high sugar content “High Gravity”, but wort with 11-12° Plato.

[2] Total protein (%)
[3] Lipids (%)
[4] Fibers (%)
[5] ASh (%)

Table 2. Comparing physicochemical parameters of wort and the spent wort grains.

Parameter	Malt (%)	Beer Spent Grains in humid form	After cold pressing	Sun dried in thin layer
Dry matter (%)	95	18	40	76
Moisture %	5	82	60	24
Total Proteins (%)	10.5	4	10	19
Soluble extract (%)	81	2	2.2	2.2
Lipids (%)	1.5	1	2.4	3.6
Total Fibers (%)	8	10	21	42.6
Ash (minerals) (%)	1.5	1	2.6	3.8
Carbohydrates (%)	73.5	2	4	7
Calorific Power (kcal/kg)	**349.5**	**33**	**67.5**	**136.4**



Graph 3. Physicochemical properties of beer after undergoing various treatment method

Beer yeast is a by-product rich in proteins, aminoacids, vitamins and microorganisms. Below is a table that shows the physicochemical constitution and its microbiology.

Physicochemical constitution

Moisture Content (%): Determined by drying at 105 °C to constant weight. Critical for shelf-life and microbial stability. Bulk Density and Specific Weight: Evaluated to assess storage, transportation feasibility, and suitability for further processing (e.g., drying, fermentation). Dry Matter (%): Calculated post-drying as a basis for all compositional analysis. Total Protein (%): Determined using the Kjeldahl method. Soluble Protein (%): Measured spectrophotometrically via the Biuret method. Total Fat (%): Assessed using Soxhlet extraction to estimate caloric value. Total and Insoluble Fiber (%): Analyzed by the Van Soest method, relevant to feed formulation and functional foods. Total and Reducing Sugars (%): Measured spectrophotometrically; important for evaluating fermentability. Ash Content (%): Determined by incineration at 550 °C, representing total mineral content. pH and Total Acidity: Measured using a calibrated pH meter and titration,

respectively; relevant for spoilage risk and fermentation compatibility. Water-Holding Capacity (WHC): Evaluated by hydrating dried BSG and weighing retained water, indicating functional application potential in food matrices.

Table 3. Typical values for each BSG parameter

Parameter	Typical Value
Dry matter (%)	13 – 14 %
Total Protein (%)	45 % in dry matter
Lipids (%)	6 % in dry matter
Carbohydrates (%)	3 % in dry matter
Ash (Minerals) (%)	7 % in dry matter
pH	4.4 in dry matter
Calorific Power (kcal/kg)	**246**

Table 4. A comparison of physicochemical composition of hot breaks and cold break.

Parameter	Hot Break	Cold Break
Forming temperature	80 – 100 °C	0 – 15 °C
Formed Mass (g/L)	2.5	0.7 g/L
Protein (%)	42	60
Polyphenols (%)	10	17
Ash (minerals, %)	14	8
Lipids (fat, %)	8	4
Carbohydrates (%)	16	12
pH	5.2	5.2
Calorific Value (kcal/kg)	**304**	**324**

Hot break precipitates during wort boiling and consists mainly of proteins and oxidized polyphenols. Cold break forms during rapid cooling and contains a higher proportion of proteins and soluble polyphenols, which can contribute to beer stability and influence the quantity of by-products generated per liter of beer produced.

The nutritional value and physicochemical content of beer by-products—such as spent grains, spent yeast, hot trub, and cold trub—are notable. This mixture is rich in proteins, fibers, and minerals, making it valuable for use in animal feed or as a substrate for further fermentation.

Table 5. Physicochemical content of BSG, spent yeast, hot trub and cold trub mixture.

Parameter	Mixture of BSG, spent yeast, hot trub and cold trub
Dry matter (%)	20 – 25 (fresh), 85 – 90 (dry)
Moisture (%)	75 – 80 (fresh)
Total protein (%)	35 – 45
Total Fiber (%)	20 – 30
Lipids (fat, %)	5 – 10
Carbohydrates (%)	2 – 5
Ash (minerals, %)	5 – 12
pH	4.5 – 5.2
Calorific power (MJ/kg)	**193 – 315**

The nutritional value of this mixture is rich in proteins, aminoacids, vitamins like B1, B2, B6, B12, Niacin, folic acid and minerals.

Fermenting Beer Spent Grains (BSG) with *Saccharomyces carlsbergensis* can significantly alter its nutritional value. The process improves the digestibility and bioavailability of various nutrients by breaking down complex carbohydrates and increasing microbial protein content. Below is a table that outlines the potential changes in the nutritional composition of BSG before and after fermentation with *Saccharomyces carlsbergensis.*

Table 6. Comparison of physicochemical parameters in BSG prior to fermentation and after fermentation with *Saccharomyces carlsbergensis.*

Parameter	Prior to Fermentation (BSG)	After Fermentation with *Saccharomyces carlsbergensis*
Dry Matter (%)	18%	18%
Moisture (%)	82	80
Total Proteins (%)*[6]	21	25
Total Fats (EE, %) *	6	5
Crude Fiber (CF, %)*	50	46
Ash (Minerals, %)	5	5
Sugars (%)*	10	13
Metabolizable Energy (kcal/kg)*	**370**	**353**
Water Retention Capacity (WRC) g/g	3	4

Microbiological parameters

Fresh BSG samples were analyzed immediately after post-production in natural conditions to evaluate BSG shelf-life. Two serial dilutions were prepared for microbial analysis; 1:10 (10 g BSG + 90 mL sterile distilled water), 1:100 (10 g BSG + 190 mL sterile distilled water). After vigorous mixing and a 20-minute resting period to release microbial populations, two cultivation techniques were employed: **Pour Plate Technique** on Plate Count Agar (PCA) for total aerobic mesophilic bacteria. **Spread Plate Technique** on Wort Agar for yeast and mold enumeration. Plates were incubated under appropriate conditions over several consecutive days to track microbial dynamics and assess the stability of BSG under different treatments. This procedure was essential for estimating shelf life and microbial safety.

Table 7. Typical values (CFU/g) for each microorganism present in BSG.

Microorganism	Typical Number (CFU/g)
Saccharomyces cerevisiae (active beer yeast)	10^8–10^{10}
Lactobacilli (Lactobacillus spp.)	10^3–10^4
Acetic bacteria *(Acetobacter spp.)*	10^2–10^4
Mold and wild yeast	10^2–10^4

Spent Yeat can be used as a protein source in animal feed, pharmaceutical industry (food supplements), in the production of bioethanol or biogas, as yeast extract in the food industry, but also as a inoculate for the fermentation process of BSG.

[6] The parameters noted with * represent values analyzed and calculated in dry matter.

Physicochemical content of cold and hot breaks in the beer wort.

During wort production, we have two types of turbulences:

- **Hot Break** – precipitates during boiling.
- **Cold Break** – precipitates during rapid cooling.

Table 8. Overview of the organic wastes produced by the brewery, the amount that can be used as an additive to feedstock and its advantages.

Organic waste produced by the brewery	Amount that can be used as an additive to a feedstock (%)	Advantages
Brewery Spent Grains (BSG)	Up to 15%	Fiber and protein increase, contributes in metabolic energy (210 kcal/kg); can be used in diets as a source rich in fibers and proteins.
Spent Yeast	Up to 5%	Increases protein content (45% protein); offers essential aminoacids and vitamins B-complex (B1, B2, B6, B12); improves intestinal health and aids animal growth.
Hot Trub	Up to 3%	Rich in proteins and oxidized polyphenols; helps beer stabilization and increases antioxidant activity.
Cold Trub	Up to 2%	Rich in soluble proteins and polyphenols; contributes in the improvement of intestinal flora and diet stability.
BSG fermented with *Saccharomyces cerevisiae*	Up to 15%	Increases protein content and metabolic energy (220-240 kcal/kg); improves fiber solubility and increases protein Bioavailability.

Fermentation with *Saccharomyces cerevisiae* led to an increase in protein content due to the synthesis of microbial proteins. Fermentation is expected to break down some of the fibrous components, lowering the crude fiber content. During fermentation, complex carbohydrates will be broken down into simpler sugars, increasing the sugar content. The metabolizable energy of the fermented BSG is expected to increase as a result of the breakdown of complex carbohydrates and increased protein content.

Table 9. Inclusion Percentage of Dry Matter (DM) for Ingredients and their references.

Ingredient	Inclusion (% of DM)	Reference (APA Style)
Brewers' Spent Grain (BSG)	30	Belibasakis, N. G., & Tsirgogianni, D. (1996). *Effects of wet brewer's grains on milk yield, milk composition and blood components of dairy cows in hot weather*. Animal Feed Science and Technology, 62(3–4), 199–204.
Soybean Meal	20	National Research Council. (2001). *Nutrient Requirements of Dairy Cattle* (7th rev. ed.). National Academies Press.
Maize Meal (Corn)	25	National Research Council. (2001). *Nutrient Requirements of Dairy Cattle* (7th rev. ed.). National Academies Press.
Alfalfa (Roughage)	10	National Research Council. (2001). *Nutrient Requirements of Dairy Cattle* (7th rev. ed.). National Academies Press.
Fish Meal	5	National Research Council. (2007). *Nutrient Requirements of Small Ruminants: Sheep, Goats, Cervids, and New World Camelids*. National Academies Press.
Vitamin Premix	1	National Research Council. (1994). *Nutrient Requirements of Poultry* (9th rev. ed.). National Academies Press.
Mineral Premix (Ca, P, etc.)	4	National Research Council. (2001). *Nutrient Requirements of Dairy Cattle* (7th rev. ed.). National Academies Press.
Salt (NaCl)	1	National Research Council. (2001). *Nutrient Requirements of Dairy Cattle* (7th rev. ed.). National Academies Press.

Table 10. Proposed Modified Feed Formula with Spent Yeast and Hot & Cold Trub.

Ingredient	Percentage (%)	Comments
Brewer's Spent Grains (BSG)	25%	Slight reduction due to replacement with spent yeast and trub.
Spent Yeast	10%	Rich in proteins (45% protein), amino acids, and vitamins, replacing part of the soybean meal and fish meal.
Hot Trub	3%	Replaces some of the maize meal and alfalfa. Rich in protein and phenolic compounds.
Cold Trub	3%	Provides additional protein, soluble phenols, and carbohydrates, replacing part of the roughage (alfalfa) and maize meal.
Soybean Meal	15%	Slight reduction, as some protein content is now coming from spent yeast and trub.
Maize Meal (Corn)	18%	Reduced due to the contribution from the hot and cold trub.
Alfalfa (or other roughage)	7%	Slight reduction as some fiber is now contributed by the hot and cold trub.
Fish Meal	4%	Slight reduction as some amino acids and protein come from spent yeast.
Vitamin Premix	1%	Remains unchanged as no significant change in vitamin requirements.
Mineral Premix (Calcium, Phosphorus, etc.)	4%	Remains unchanged as mineral premixes are still needed for balanced nutrition.
Salt (NaCl)	1%	Remains unchanged.
Water	Adjust to 10-12% moisture content	Remains unchanged for optimal moisture levels in the feed.

RESULTS

The study shows that brewer's spent grain (BSG) constitutes the majority of solid organic waste generated during beer production, with around 16 kg of fresh BSG produced per hectoliter (Hl) beer. The remaining by-products include spent yeast, hot trub, and cold trub, which are produced in smaller quantities consist in high nutrient concentrations. The physicochemical analysis of fresh BSG revealed it has a moisture content of 82%, with dry matter composition rich in proteins (21%), crude fiber (50%), lipids (6%), ash (5%), and metabolizable energy of 2100 kcal/kg. When dried, BSG's nutrient density and caloric value increased significantly.

Spent yeast has a protein content of 45% on a dry matter basis, along with essential amino acids, B-complex vitamins (B1, B2, B6, B12), and a high population of viable yeast cells (10^8–10^{10} CFU/g). The presence of beneficial lactic acid bacteria and minimal amounts of spoilage microorganisms, was shown during microbiological analysis. Similarly, hot trub and cold trub consist in valuable nutritional profiles. Nutrient analysis reflected that Hot trub consists on lower protein and polyphenol values, 42% and 10% as opposed to 60% and 17% in cold trub. This results on a higher caloric value for cold trub 324 kcal/kg, contrary to the 304 kcal/kg in hot trub.

The nutritional profile of BSG was improved after being fermented with *Saccharomyces carlsbergensis*. The protein content increased to 25%, fiber decreased from 50% to 46%, sugars increased from 10% to 13%, and water retention capacity increased from 3 to 4 g/g dry matter. These changes enhanced digestibility and energy availability, by making fermented BSG a more suitable and effective feed ingredient. A modified animal feed formula was developed, consisting in 25% BSG, 10% spent yeast, and small percentages (3%) of hot and cold trub. This new formula successfully reduced the use of traditional feed components like soybean meal and maize without compromising nutritional quality.

DISCUSSIONS

The research shows how by-products of the brewing industry find application as alternative feed ingredients in livestock nutrition. BSG as the most abundant by-product demonstrated high levels of fiber and protein content, making it a suitable raw material for ruminant diets. High water retention capacity and caloric value contribute in both bulk and energy to feed formulations. However, the high moisture content in fresh BSG poses a limitation in terms of shelf life and handling, which can be improved by pressing or drying.

Adding spent yeast further enhanced the nutritional profile of feed, because the final product is rich in protein and B vitamins, which are essential for animal health. It also brings added value through its probiotic and immunostimulatory effects, which support gut health and overall productivity. Yeast also serves as a fermentation agent to improve the nutritional profile of BSG, increasing the bioavailability of key nutrients through the breakdown of complex fibers and the production of microbial proteins.

Although produced in smaller volumes, hot and cold trub proved to be valuable due to their high protein and polyphenol content. Their antioxidant and antimicrobial composition may support gut microflora and extend shelf life of feed. Included in small percentages (up to 3%) they have a positive contribution to the nutritional balance, without negatively affecting feed texture or palatability.

The high protein content and digestible sugars, with reduced fiber, made fermented BSG suitable to be included in higher proportions (up to 25%) on animal diets. This process also supports circular economy principles, by transforming waste into a high-value product.

CONCLUSIONS

Brewery by-products, particularly Brewer's Spent Grain (BSG), offer significant value as feed components due to their high protein and fiber content. While the optimal inclusion rate varies depending on animal type and dietary needs, BSG can typically make 6 to 15% of livestock rations. Higher percentages may be suitable for animals requiring increased fiber intake, though levels above 20% are generally avoided to maintain nutritional balance and prevent digestive issues.

The incorporation of other brewing residues enriches feed formulations. Spent yeast makes 2 to 5% of the feed mix and provides essential amino acids, B-complex vitamins (i.e., B1, B2, B6, B12), and minerals like iron and zinc. It enhances growth, supports gut health, and improves milk production. Additionally, spent yeast serves as an effective inoculant for BSG fermentation, improving its solubility and nutrient uptake.

Although used in small quantities (1–3%), hot trub contains protein and polyphenols that may offer antioxidant and gut-stabilizing benefits. Cold trub used at 1 to 2%, is richer in soluble proteins and polyphenols, further supporting diet stability and intestinal health.

Fermentation of BSG using *Saccharomyces carlsbergensis* enhances its nutritional profile in significant levels. Protein concentration is increased by microbial activity, also boosting metabolizable energy and improves fiber digestibility. Fermented BSG may account for 10 to 15% of the feed, depending on the livestock and their nutritional requirements.

The combination of BSG, spent yeast, hot and cold trub in animal feed provides a sustainable strategy that minimizes waste, by reducing the use of conventional feed ingredients, contributing in better livestock production systems. İt reduces the application of of traditional protein and forage sources, while contributing to economic and environmental sustainability. This approach based in circular bioeconomy principles, improves efficiency in both brewing and agricultural sectors.

REFERENCES

Colby, C. (2023, August 1). *Use spent grain for chicken and cattle feed*. Grit. https://www.grit.com/animals/livestock/spent-grain-for-livestock-feed-zm0z16soztri/

Clarke, C. (2021, October 18). *Brewery spent grains as animal feed*. First Key Consulting. https://firstkey.com/brewery-spent-grains-as-animal-feed/

Negash, D. (2021). *Use of brewery by-products as animal feeds*. Journal of Nutrition and Food Science, 4, 027. https://doi.org/10.11648/j.jnfs.20210404.11

Terefe, G. (2022). *Preservation techniques and their effect on nutritional values and microbial population of brewer's spent grain: A review*. CABI Agriculture and Bioscience, 3, Article 51. https://doi.org/10.1186/s43170-022-00120-8

Dahiya, S., Srivastava, A., & Kaur, A. (2018). Brewer's spent grain as a functional food ingredient: Nutritional, technological, and health benefits. *Food Science and Nutrition, 6*(6), 1491–1505. https://doi.org/10.1002/fsn3.722

Hassan, A. A., Khan, S. R., & Ali, M. (2019). Microbial fermentation of brewery spent grain: A review. *Journal of Food Science and Technology, 56*(6), 2639–2648. https://doi.org/10.1007/s11483-019-01728-4

Mendoza, E., Naranjo, J., & Hernandez, L. (2021). Use of fermentation in improving the nutritional properties of brewery waste. *Waste Management, 118*, 98–105. https://doi.org/10.1016/j.wasman.2020.11.027

Mo, S. J., Cheng, J. P., & Li, W. Q. (2020). Fermentation of brewery spent grain by mixed cultures: Improvement of nutritional composition for animal feed. *Bioresource Technology, 302*, 122825. https://doi.org/10.1016/j.biortech.2020.122825

Pereira, R. N., Rodrigues, P., & Bezerra, R. M. (2016). Brewer's spent grain in animal nutrition: A review. *Animal Feed Science and Technology, 211*, 19–29. https://doi.org/10.1016/j.anifeedsci.2015.11.009

Santos, J. M., Santiago, D., & Gomes, S. (2019). Fermentation of brewery spent grains by Lactobacillus plantarum: Effect on nutritional and microbiological properties. *Journal of the Science of Food and Agriculture, 99*(6), 2897–2903. https://doi.org/10.1002/jsfa.9539

Vázquez, M. M., Rodríguez, A., & Pérez, L. (2017). The fermentation of brewery spent grain as a strategy to improve its nutritional and functional properties for animal feed. *Animals, 7*(12), 101. https://doi.org/10.3390/ani7120101

Pereira, R. N., Rodrigues, P., & Bezerra, R. M. (2016). Brewer's spent grain in animal nutrition: A review. *Animal Feed Science and Technology, 211*, 19–29. https://doi.org/10.1016/j.anifeedsci.2015.11.009

Santos, J. M., Santiago, D., & Gomes, S. (2019). Fermentation of brewery spent grains by Lactobacillus plantarum: Effect on nutritional and microbiological properties. *Journal of the Science of Food and Agriculture, 99*(6), 2897–2903. https://doi.org/10.1002/jsfa.9539

Mo, S. J., Cheng, J. P., & Li, W. Q. (2020). Fermentation of brewery spent grain by mixed cultures: Improvement of nutritional composition for animal feed. *Bioresource Technology, 302*, 122825. https://doi.org/10.1016/j.biortech.2020.122825

Luljeta Xhagolli; Entela Pinguli; Gentian Hyka; Elibjonda Gjergjndreaj; “Development of waste management strategy in albanian breweries”; Journal of Environmental Protection and Ecology, Vol 4 A, No 4, 2011.

Tanja Kamburi; Luljeta Xhagolli, Lorena Lici. Ndikimi i parametrave proteinike te maltit ne optimizimin e rendimentit proteinik te mushtit te birres. Buletini i Shkencave te Natyres. Nr 23. 2017.

Tanja Kamburi; Luljeta Pinguli; Impact of malt protein parameters on brewing process optimization. Albanian Journal of Agricultural Science. Biotechnology in agriculture (special edition) 2017. eISSN 2218-2020, Vol 16.

Luljeta Xhagolli, Rozana Troja, Prof. Donika Prifti, Msc. Elibionda Gjergjndreaj; Ndikimi i parametrave fiziko-kimikë të maltit në teknologjinë dhe cilësinë e prodhimit të birrës”. (Impact of physical-chemical parameters of malt in technology and beer quality). International Conference Of Agriculture, Food And Environment (ICAFE); 27-28 May 2011, Korçë, Albania.

Luljeta Xhagolli; Entela Pinguli; Gentian Hyka; Elibjonda Gjergjndreaj; Development of waste management strategy in albanian breweries. The International Conference of BENA – Tiranë, 16-20 Shtator 2009.

NRC (National Research Council). (2000). *Nutrient Requirements of Beef Cattle* (7th ed.). National Academies Press.

FAO (Food and Agriculture Organization). (2012). *Animal Feed Resources Information System* (AFRIS).

O'Keefe, D. (2015). *Formulating Animal Rations*. Animal Nutrition Institute, UK.

Pereira, R. N., Rodrigues, P., & Bezerra, R. M. (2016). Brewer's spent grain in animal nutrition: A review. *Animal Feed Science and Technology, 211*, 19–29. https://doi.org/10.1016/j.anifeedsci.2015.11.009.

Belibasakis, N. G., & Tsirgogianni, D. (1996). *Effects of wet brewer's grains on milk yield, milk composition and blood components of dairy cows in hot weather*. Animal Feed Science and Technology, 62(3–4), 199–204.

National Research Council. (1994). *Nutrient Requirements of Poultry* (9th rev. ed.). National Academies Press.

National Research Council. (2001). *Nutrient Requirements of Dairy Cattle* (7th rev. ed.). National Academies Press.

National Research Council. (2007). *Nutrient Requirements of Small Ruminants: Sheep, Goats, Cervids, and New World Camelids*. National Academies Press.

5th INTERNATIONAL PARIS CONGRESS ON APPLIED SCIENCES

August 4-8, 2025 / Paris, FRANCE

25.08.2025

REF: Akademik Teşvik

İlgili makama;

5. Uluslararası Paris Uygulamalı Bilimler Kongresi, 4-8 Ağustos 2025, tarihleri arasında Paris, Fransa'da 21 farklı ülkenin (Türkiye 67 bildiri- Diğer ülkeler 83 bildiri) akademisyen/araştırmacılarının katılımıyla gerçekleşmiştir

Kongre 16 Ocak 2020 Akademik Teşvik Ödeneği Yönetmeliğine getirilen "Tebliğlerin sunulduğu yurt içinde veya yurt dışındaki etkinliğin uluslararası olarak nitelendirilebilmesi için Türkiye dışında en az beş farklı ülkeden sözlü tebliğ sunan konuşmacının katılım sağlaması ve tebliğlerin yarıdan fazlasının Türkiye dışından katılımcılar tarafından sunulması esastır." değişikliğine uygun düzenlenmiştir.

Bilgilerinize arz edilir,

Saygılarımla

Dr. Germán Martínez Prats
Committee Member

İKSAD ENSTİTÜSÜ
Çankaya – Ankara
06-146-071

Konu : Kongre Düzenlenmesi
Sayı : BSE-2

20 Ocak 2025

İLGİLİ KURUMA

İçişileri Bakanlığı tarafından tahsis edilen 06-146-071 tescil kodu ile Tüzel Kişiliğe sahip olan İKSAD Enstitüsü 5253 sayılı kanuna uygun olarak "Bilimsel araştırmalar ve akademik çalışmalar" alanında ulusal ve uluslararası düzeyde faaliyetlerini yürütmektedir.

Kurumumuzun Yönetim Kurulu 15 Ocak 2024 tarihinde saat 10.30'da "Bilimsel Diplomasi Projesi" görüşmeleri ile "Bilimsel Kongreler Düzenlenmesi" gündemleri ile toplanmış ve alınan (2 numaralı) karara istinaden aşağıda detayları yazılı olan bilimsel etkinliğin düzenlenmesine ve etkinliğe ilişkin resmi görevlendirme konusunda karar vermiştir.

Bilgi ve gereğini rica ederim

Dr. Mustafa Latif EMEK
Yönetim Kurulu Adına

Etkinlik Adı: 5. ULUSLARARASI PARİS UYGULAMALI BİLİMLER KONGRESİ

Etkinlik Tarihi ve Yeri: 4-8 Ağustos 2025 - Paris

DÜZENLEME KURULU

Prof. Dr. Anderi JEAN, Gas Petrolium University ROMANIA
Prof. Dr. German Prats, Universidad Autonoma Guadalajara
Assoc. Prof. Dr. Ethem İlhan ŞAHİN, Adana Alparslan Türkeş Science and Technology University TÜRKİYE
Dr. Elvan CAFEROV - ADPU AZERBAIJAN
Dr. Fouzia BENOUDJIT - M'hamed Bougara university ALGERIA

Etkinlik linki: https://tr.iksadparis.org/applied