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MeetCon conference

MEETCON-X
II. INTERNATIONAL SCIENTIFIC RESEARCH CONGRESS

-ANKARA-
TÜRKİYE

FEBRUARY 17-19 I 2026

EDITOR
PROF. DR. MİNE DEMİRTAŞ

ISBN: 979-8-89695-338-8

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PROCEEDINGS BOOK

MEETCON - X

II. INTERNATIONAL CONGRESS ON SCIENTIFIC RESEARCH

February 17-19, 2026/ Ankara, TÜRKİYE

Editor

Prof. Dr. Mine DEMİRTAŞ

ISBN - 979-8-89695-338-8

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CONGRESS ID

TITLE OF CONGRESS

MEETCON - X

II. INTERNATIONAL CONGRESS ON SCIENTIFIC RESEARCH

PARTICIPATION

Keynote & Invited

DATE - PLACE

February 17-19, 2026 / Ankara, Türkiye

ORGANIZATION

MEETCON CONFERENCE

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PARTICIPATING COUNTRIES (14)

Türkiye, Azerbaijan, TRNC, India, Morocco, Nigeria, Albania, Pakistan, Saudi Arabia, Malaysia, Mexico, Ukraine, Algeria, Poland

TOTAL PAPERS: 76

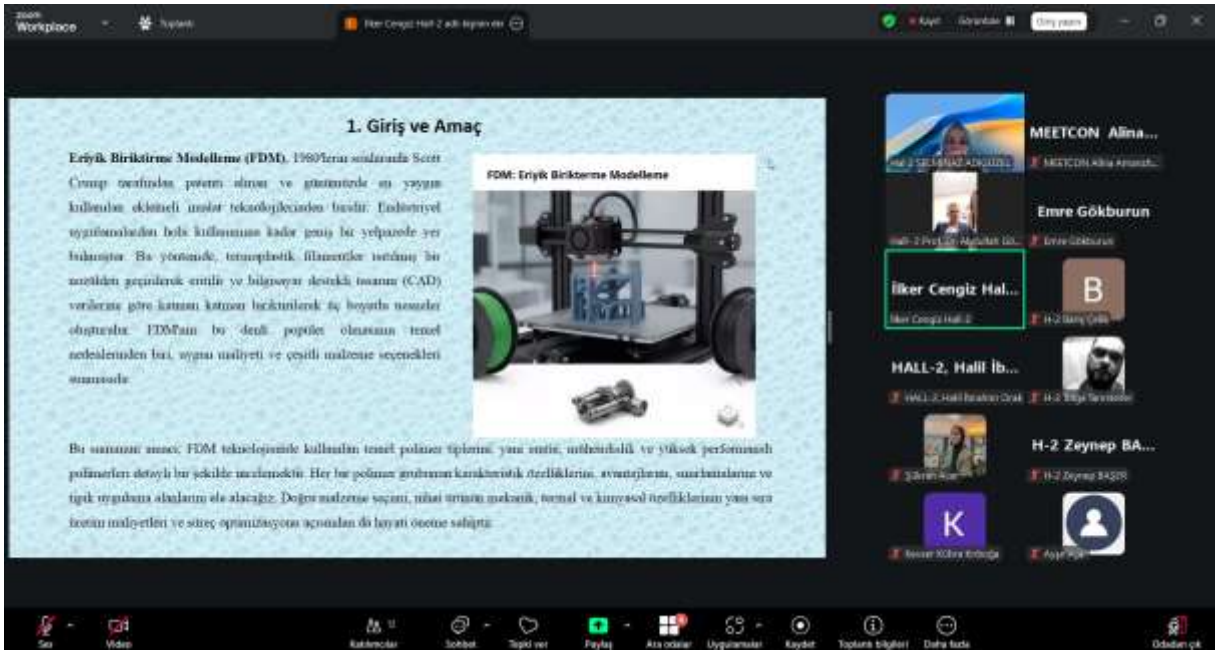
The number of papers from foreign countries: **41**

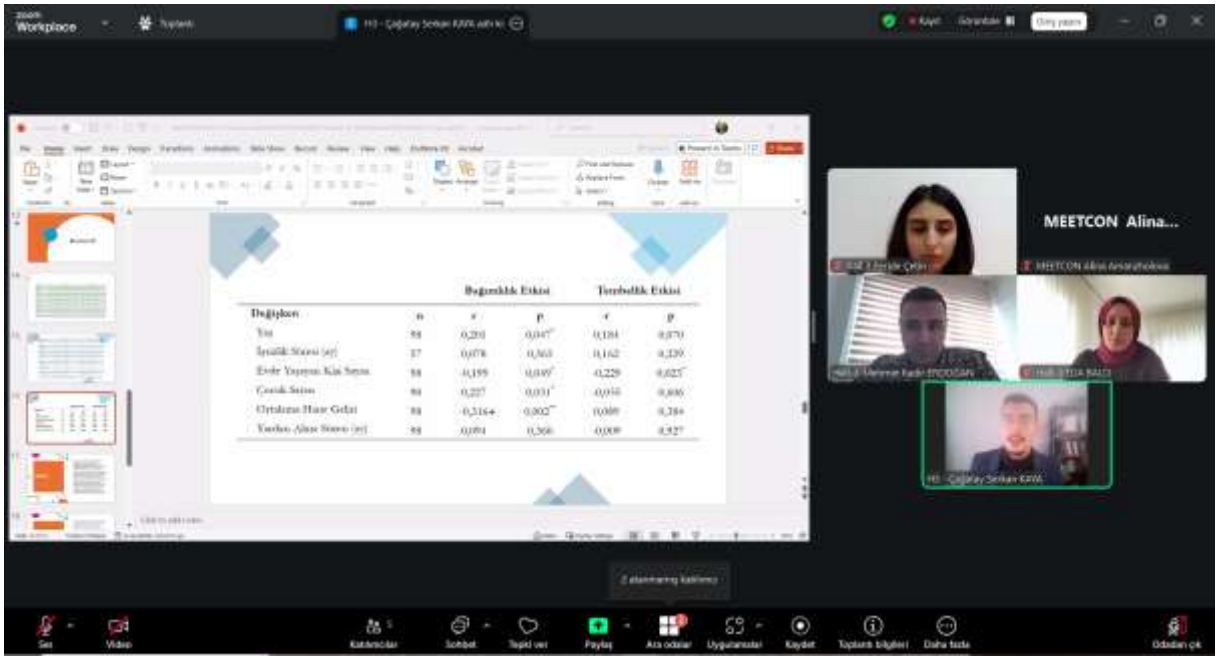
The number of papers from Türkiye: **35**

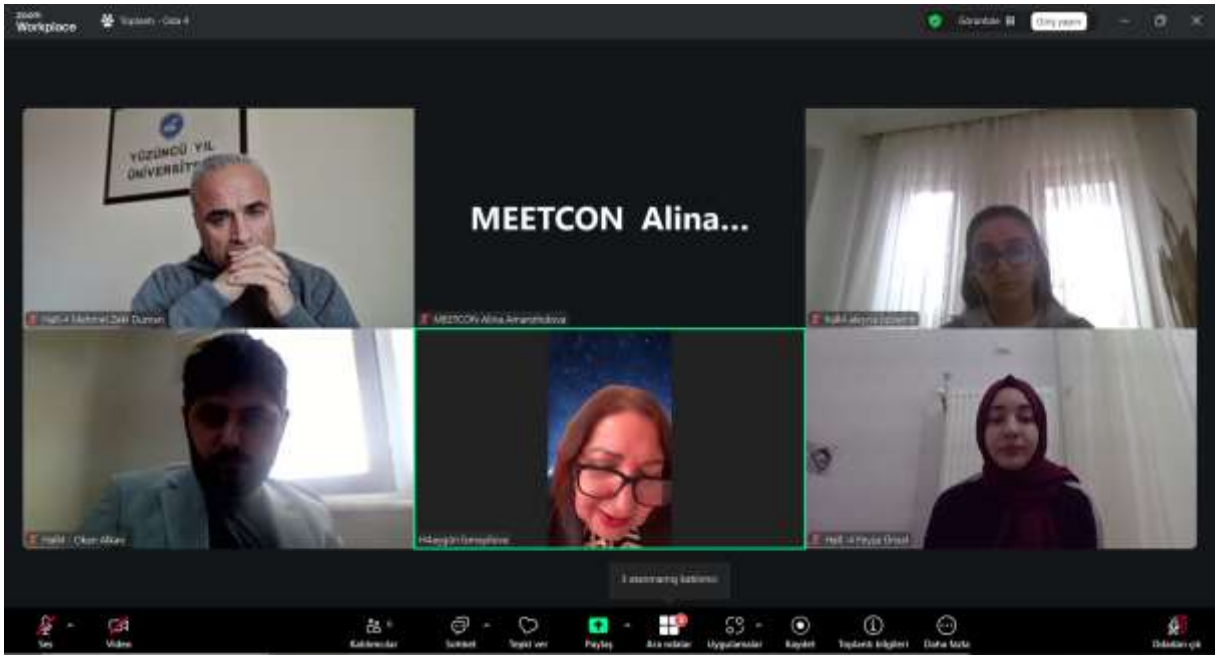
LANGUAGES

Turkish, English

PHOTO GALLERY



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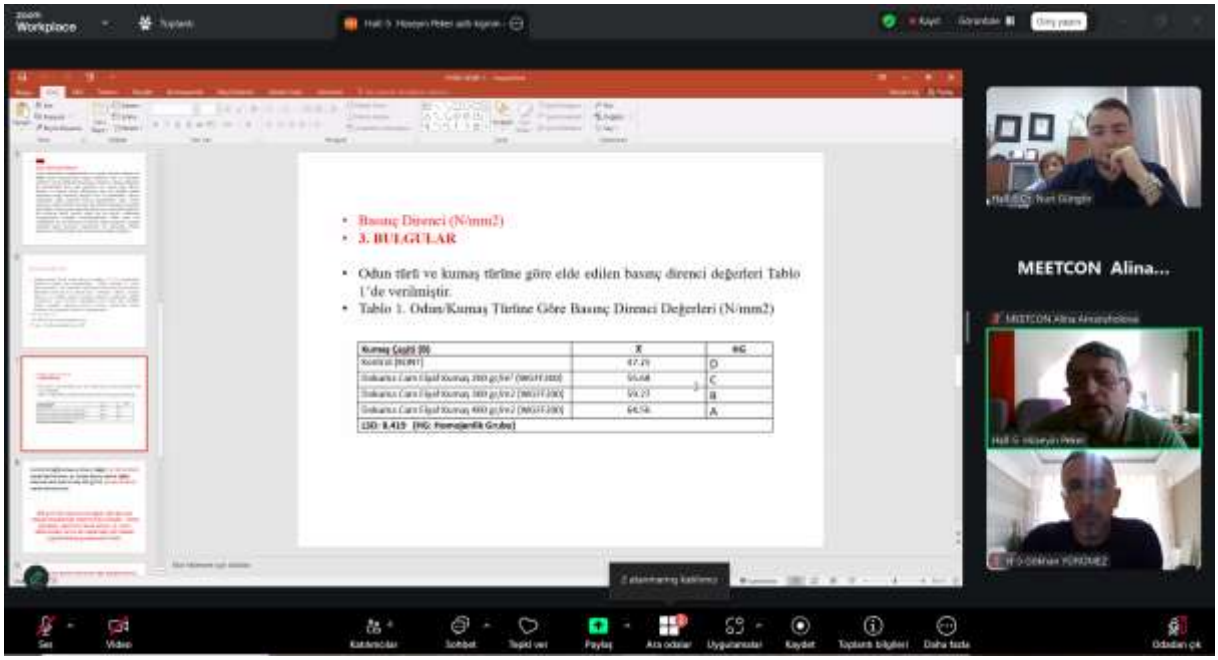
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3. BULGULAR
Odun türü ve kumaş türüne göre elde edilen basınç direnci değerleri Tablo 1'de verilmiştir.
Tablo 1. Odun/Kumaş Türüne Göre Basınç Direnci Değerleri (N/mm2)
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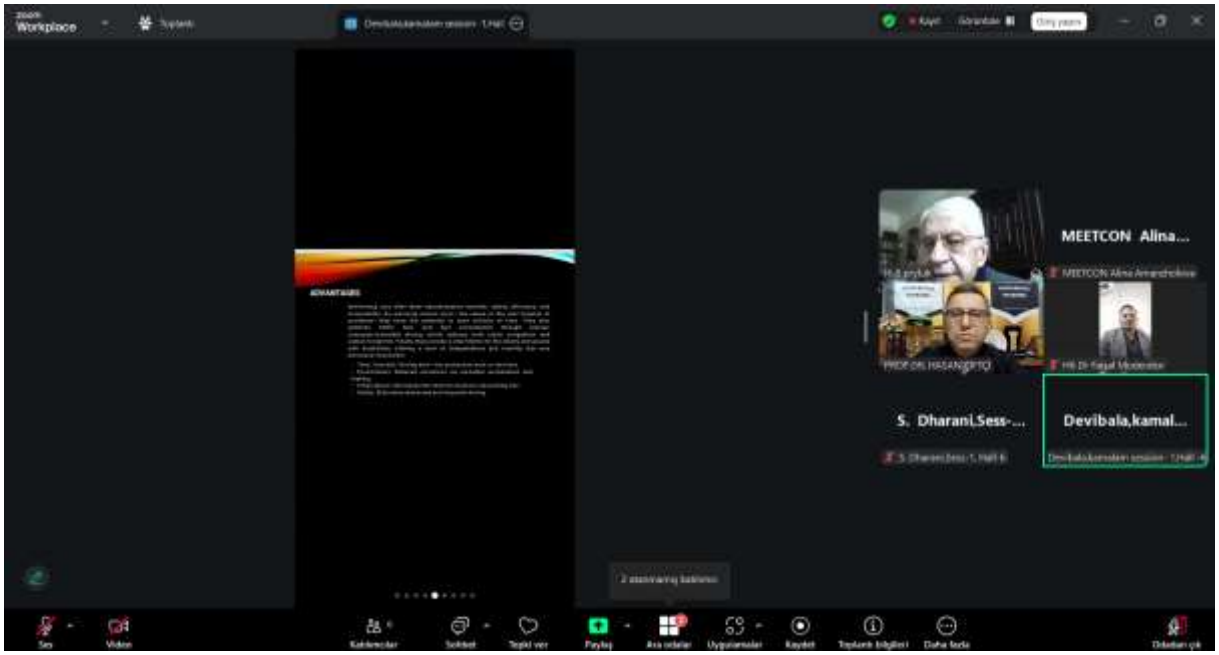
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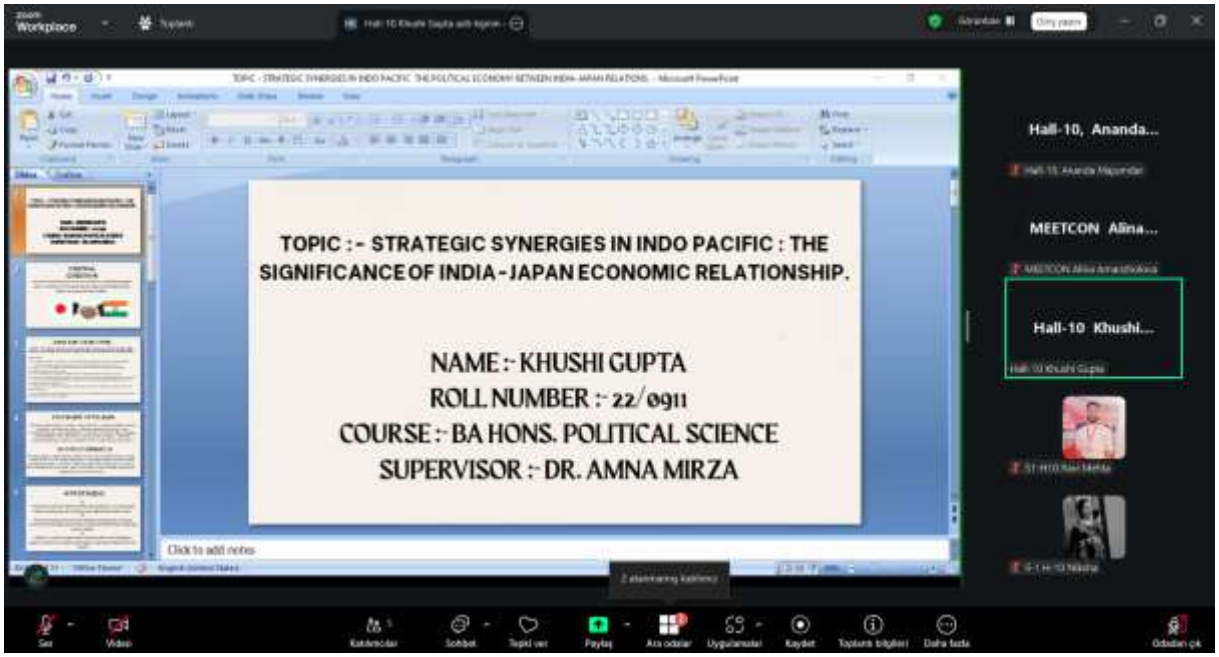
S. Dharani,Sess-...
Devibala,kamal...


TOPIC :- STRATEGIC SYNERGIES IN INDO PACIFIC : THE SIGNIFICANCE OF INDIA-JAPAN ECONOMIC RELATIONSHIP.
NAME :- KHUSHI GUPTA
ROLL NUMBER :- 22/0911
COURSE :- BA HONS. POLITICAL SCIENCE
SUPERVISOR :- DR. AMNA MIRZA
Hall-10, Ananda...
MEETCON Alina...
Hall-10 Khushi...

İLETİŞİMDE GÜNCEL ÇALIŞMALAR-5

EDİTÖRLER

Prof. Dr. Enderhan KARAKOÇ

Prof. Dr. Hasan ÇİFTÇİ

Son Başvuru Tarihi

13.03.2026

Yayınlanma Tarihi

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SOSYAL BİLİMLERDE GÜNCEL ÇALIŞMALAR -14

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Prof. Dr. Ahmet İLYAS

Prof. Dr. Sadettin PAKSOY

Prof. Dr. Hasan ÇİFTÇİ

Son Başvuru Tarihi

13.03.2026

Yayınlanma Tarihi

20.03.2026

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INTERNATIONAL CONFERENCE NETWORK

MEETCON - X
II. INTERNATIONAL CONGRESS ON SCIENTIFIC RESEARCH

February 17-19, 2026/ Ankara, TÜRKİYE

CONGRESS PROGRAM

zoom

Meeting ID: 325 629 5864
Passcode: meetcon

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- 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.

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- 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.

17.02.2026 / ONLINE / SESSION-1 / HALL-1

Ankara Local Time: 13:00-15:00 February 17, 2026

Zoom Meeting ID: **325 629 5864** / Zoom Passcode: **meetcon**

HEAD OF SESSION: Reha BAYANSAT

Authors	Affiliation	Presentation Title
Özden ŞENTÜRK	Dr.,Bağımsız Araştırmacı-CGAP	RESILIENCE OF FINANCIAL SYSTEMS IN THE AGE OF QUANTUM COMPUTING:THE ROLE OF INTERNAL AUDIT IN POST-QUANTUM CRYPTOGRAPHY TRANSITION PROCESSES
Reha BAYANSAT	Ankara Hacı Bayram Veli University, Türkiye	THE CONTRIBUTION OF DIGITAL TOOLS IN PUBLIC AUDITING TO TRANSPARENCY AND ACCOUNTABILITY
Muhammed Akif YENİKAYA Onur OKTAYSOY	Kafkas University, Türkiye	THE REBIRTH OF OCCUPATIONS IN THE AGE OF ARTIFICIAL INTELLIGENCE: DISAPPEARING JOBS, EVOLVING ROLES, AND EMERGING OPPORTUNITIES
Gökhan AYDIN Yunus KAYMAZ	Iskenderun Technical University, Türkiye	SELECTION CRITERIA OF LOGISTICS SERVICE PROVIDERS FOR PETROLEUM STORAGE OPERATIONS
Kadir KARAKUŞ Kurbani GEYİK	Yozgat Bozok University, Türkiye	WAR CORRESPONDENCE TRAINING AND JOURNALIST SAFETY IN TÜRKİYE
Esra Şafak ÇOKPARTAL Hilal UYGURTÜRK	Karabük University, Türkiye	THE ROLE OF CONSUMER TRUST IN MARKETING: A BIBLIOMETRIC MAPPING OF SCIENTIFIC PUBLICATIONS

(All speakers required to be connected to the session 10 min before the session starts)
Moderator is responsible for ensuring the smooth running of the presentation, managing the group discussion and dynamics.

17.02.2026 / ONLINE / SESSION-1 / HALL-2

Ankara Local Time: 13:00-15:00 February 17, 2026

Zoom Meeting ID: **325 629 5864** / Zoom Passcode: **meetcon**

HEAD OF SESSION: Prof. Dr. Abdullah GÖKTAŞ

Authors	Affiliation	Presentation Title
Berrin AKKUŞ İlker CENGİZ	Selcuk University, Türkiye Hacettepe University, Türkiye	INVESTIGATION ON POLYMERS USED IN FUSED DEPOSITION MODELING
Vakkas ULUÇAY İrfan DELİ Zeynep BAŞER	Kilis 7 Aralık University, Türkiye	A NEW INFERENCE SYSTEM BASED ON THE INTUITIONISTIC TAKAGI–SUGENO–KANG MODEL WITH SIMILARITY MEASURES
Vakkas ULUÇAY İrfan DELİ Zeynep BAŞER	Kilis 7 Aralık University, Türkiye	A NOVEL INFERENCE SYSTEM USING DICE SIMILARITY AND NEUTROSOPHIC TAKAGI-SUGENO-KANG MODEL
Yunis TORUN Tolga TANRISEVER Umur DEVECİ Emre GOKBURUN Barış ÇELİK	Cumhuriyet University, Türkiye Kapsam Elektromekanik Inc. R& D Department Boğaziçi Electric Distribution A. Ş. R& D Department	AUGMENTED REALITY–BASED RTK-SUPPORTED HIGH-PRECISION UNDERGROUND CABLE MAPPİNG SYSTEM
Halil İbrahim Orak Salah Hajismail	Ankara Yıldırım Beyazıt University, Türkiye	EVALUATING THE EFFECTIVENESS OF YES-TR CERTIFICATION IN ENHANCING BUILDING ENERGY EFFICIENCY: A COMPARATIVE STUDY WITH LEED, BREEAM AND EU DIRECTIVES
Abdullah GÖKTAŞ Hamida ALHUSSAIN	Harran University, Türkiye	STRUCTURAL OPTICAL AND PHOTOCATALYTIC PROPERTIES OF SNS THIN FILMS
Abdullah GÖKTAŞ	Harran University, Türkiye	PHOTOCATALYTIC PROPERTIES OF SNS THIN FILMS: ROLE OF OPERATIONAL PARAMETERS-A MINI REVIEW
Şükran ACAR Kevser Kübra KIRBOĞA	Bilecik Şeyh Edebali University, Türkiye	SYSTEMATIC EVALUATION OF KRAS-CENTERED PROTEIN–PROTEIN INTERACTION NETWORKS VIA BIOINFORMATICS APPROACHES
Ayşe AÇAR Kevser Kübra KIRBOĞA	Bilecik Şeyh Edebali University, Türkiye	COMPREHENSIVE PROTEIN–PROTEIN INTERACTION ANALYSIS OF FRATAXIN (FXN) IN FRIEDREICH'S ATAXIA

(All speakers required to be connected to the session 10 min before the session starts)
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17.02.2026 / ONLINE / SESSION-1 / HALL-3

Ankara Local Time: 13:00-15:00 February 17, 2026

Zoom Meeting ID: **325 629 5864** / Zoom Passcode: **meetcon**

HEAD OF SESSION: Assoc. Prof. Dr. Mehmet Kadir ERDOĞAN

Authors	Affiliation	Presentation Title
Doğa BAŞER Çağatay Serkan KAYA	Selçuk University, Faculty of Health Science, Department of Social Work *Afyon Kocatepe University, Sandıklı School of Applied Sciences, Department of Social Work*	INVESTIGATION OF SOCIAL ASSISTANCE DEPENDENCY LEVELS OF INDIVIDUALS RECEIVING SOCIAL ASSISTANCE
Eda BALCI	Istanbul Beykent University, Turkey	NEUROBIOLOGICAL EFFECTS OF PROBIOTICS ON THE GUT–BRAIN AXIS
Eda BALCI	Istanbul Beykent University, Turkey	NUTRITIONAL THERAPY AND CLINICAL IMPLICATIONS IN ACUTE KIDNEY INJURY
Yener ÖZEL Feride ÇETİN	Balıkesir University	EVALUATION OF THE ACTIVITY OF NISIN IN COMBINATION WITH ANTIBACTERIAL AND ANTIPARASITIC AGENTS AGAINST BACTERIA AND PARASITES
Seda BURGUCU Salih MOLLAHALİLOĞLU Derya ALTAY Murat KOÇ	Ankara Yıldırım Beyazıt University,Türkiye	EVALUATION OF THE PHENOLIC CONTENT AND ANTIOXIDANT ACTIVITY OF ULTRASONIC BATH-ASSISTED 70% ETHANOLIC EXTRACT OF Phlomis russeliana Lag. ex Benth.
Mehmet Kadir ERDOĞAN Ramazan GÜNDOĞDU	Bingöl University, Faculty of Arts and Sciences, Department of Molecular Biology and Genetics	HESPERIDIN MODULATES OLAPARIB-INDUCED APOPTOSIS IN U2OS CELLS
Fatma BOZKIR DİNLER Ramazan GÜNDOĞDU Mehmet Kadir ERDOĞAN	Bingöl University, Vocational School of Health Services, Department of Pharmacy Services	SYNERGISTIC INTERACTION BETWEEN GENISTEIN AND IRINOTECAN IN CACO-2 COLON CARCINOMA CELLS

(All speakers required to be connected to the session 10 min before the session starts)
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17.02.2026 / ONLINE / SESSION-1 / HALL-4

Ankara Local Time: 13:00-15:00 February 17, 2026

Zoom Meeting ID: **325 629 5864** / Zoom Passcode: **meetcon**

HEAD OF SESSION: Prof. Dr. Mehmet Zeki DUMAN

Authors	Affiliation	Presentation Title
Aleyna ÖZDEMİR Semra BENZER	Gazi University, Türkiye	THE EFFECT OF BIOLOGY INSTRUCTION INTEGRATED WITH ARTIFICIAL INTELLIGENCE–SUPPORTED PICTOBLOX APPLICATIONS ON PRE-SERVICE SCIENCE TEACHERS' ARTIFICIAL INTELLIGENCE ANXIETY
Feyza ÜNSAL Semra BENZER	Gazi University, Türkiye	THE EFFECT OF ENVIRONMENTAL EDUCATION INTEGRATED WITH ARTIFICIAL INTELLIGENCE–SUPPORTED PICTOBLOX APPLICATIONS ON PRE-SERVICE SCIENCE TEACHERS' ARTIFICIAL INTELLIGENCE ANXIETY
Yunus Emre ÖZENOĞLU Oğuz Emre BALKAR Okan ALKAN	Atatürk University, Türkiye Erzincan Binali Yıldırım University, Türkiye	DEVELOPING A SYSTEM FOR EVALUATING LEARNING OUTCOMES IN HIGHER EDUCATION WITHIN THE SCOPE OF EDUCATIONAL INNOVATION
Aygun Ismayilova	Azerbaijan State Pedagogical University, Azerbaijan	IN-CLASS INTERACTION AND INTERCULTURAL COMMUNICATION: IN THE CONTEXT OF TEACHING GERMAN AT UNIVERSITY
Mehmet Zeki DUMAN	Van Yüzüncü Yıl University, Türkiye	ALİ ŞERİATİ'S VIEWS ON ART
Mehmet Zeki DUMAN	Van Yüzüncü Yıl University, Türkiye	THE WORLDVIEW OF MODERNITY AS A WAY OF THINKING AND A PARADIGM
Seyfettin KAYA	Siirt University, Türkiye	A THEORIST IN ISLAMIC ASTRONOMY: SHAMS AL-DIN al-HAFRI AND PLANETARY MODELS
Seyfettin KAYA	Siirt University, Türkiye	THE VOICE OF ASTRONOMY IN THE MIDDLE AGES: ABU'S-SAKR AL-QABISI AND HIS WORKS

(All speakers required to be connected to the session 10 min before the session starts)
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17.02.2026 / ONLINE / SESSION-1 / HALL-5

Ankara Local Time: 13:00-15:00 February 17, 2026

Zoom Meeting ID: **325 629 5864** / Zoom Passcode: **meetcon**

HEAD OF SESSION: Asst. Prof. Dr. Gökhan YÜRÜMEZ

Authors	Affiliation	Presentation Title
Hüseyin PEKER	Artvin Çoruh University, Türkiye	WOOD MATERIAL ENGINEERING AND GLASS FIBER FABRIC USAGE SCALE
Hüseyin PEKER	Artvin Çoruh University, Türkiye	LOW-DENSITY WOOD MATERIAL AND VARIATION IN COMPRESSIVE STRENGTH
Nuri GÜNGÖR. Hatice YAZGAN	Cukurova University, Türkiye	EPIDEMIOLOGICAL AND ECONOMIC EVALUATION OF BRUCELLOSIS, TUBERCULOSIS, AND PARATUBERCULOSIS IN CATTLE SENT TO SLAUGHTER
Gökhan YÜRÜMEZ	Batman University, Türkiye	COMPARISON OF NUCLEOLAR ORGANIZER REGIONS OF THE NF=76 AND NF=74 CYTOTYPES OF THE 2n=52 CHROMOSOMAL FORM OF Nannospalax ehrenbergi (NEHRING, 1898) DISTRIBUTED IN TÜRKİYE

(All speakers required to be connected to the session 10 min before the session starts)
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17.02.2026 / ONLINE / SESSION-1 / HALL-6

Ankara Local Time: 13:00-15:00 February 17, 2026

Zoom Meeting ID: **325 629 5864** / Zoom Passcode: **meetcon**

HEAD OF SESSION: Prof. Dr. Muhammad Faisal

Authors	Affiliation	Presentation Title
Paul Oisamoje	Eastern Meditteranean University, Faculty of Education, Department of Computing annd Information Technology in Education, Famagusta, TRNC.	A FUSION-CENTRIC REVIEW OF DEEP LEARNING–BASED MULTIMODAL SYSTEMS (FOUNDATIONS, ARCHITECTURES, AND EMERGING DIRECTIONS)
S. DHARANI Dr. S.SELVAM	Nadar Mahajana Sangam S.Vellaichamy Nadar College	A COMPARATIVE STUDY OF BIOMETRIC AND TRADITIONAL AUTHENTICATION SYSTEMS
R.KAMALAM M.DEVIBALA Dr S.SELVAM	Nadar Mahajana Sangam S.Vellaichamy Nadar College	SELF-DRIVING CARS: THE FUTURE OF TRANSPORTATION
Muhammad Faisal	Allama Iqbal Open University	TRENDS IN PYTHON FOR DATA ENGINEERING
Muhammad Faisal	Allama Iqbal Open University	PYTHON'S EXPANDING ROLE IN GENERATIVE AI SYSTEMS
Muhammad Faisal	Allama Iqbal Open University	PYTHON AND EDGE COMPUTING CHALLENGES AND OPPORTUNITIES
Nilgün ULUTAŞDEMİR Hasan ÇİFTÇİ	Ordu University, Türkiye Harran University, Türkiye	THE ANATOMY OF ROLES: UNDERSTANDING JOB CONFUSION IN HEALTHCARE ORGANIZATIONS
Nilgün ULUTAŞDEMİR Hasan ÇİFTÇİ	Ordu University, Türkiye Harran University, Türkiye	THE INVISIBLE SHACKLES OF THE WHITE COAT: ROLE CONFUSION AND BURNOUT

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17.02.2026 / ONLINE / SESSION-1 / HALL-7

Ankara Local Time: 13:00-15:00 February 17, 2026

Zoom Meeting ID: **325 629 5864** / Zoom Passcode: **meetcon**

HEAD OF SESSION: K. A. Aly

Authors	Affiliation	Presentation Title
Amal Bassam, Rajaa Bassam, Marouane El Alouani, Mohammed Hafid, Hamid Saufi, Said Belaaouad, Younes Rachdi	Hassan II University of Casablanca, Casablanca, Morocco. Mohammed V University of Rabat, Morocco.	FABRICATION OF GREEN GEOPOLYMER/ALGINATE HYBRID SPHERES FOR EFFICIENT REMOVAL OF METHYL ORANGE DYE IN WATER: BATCH STUDIES
NITHISH V	R.M.K. ENGINEERING COLLEGE, KAVARIPETTAI, INDIA.	LAPLACE TRANSFORM AND ITS APPLICATION IN ENGINEERING
NITHISH V	R.M.K. ENGINEERING COLLEGE, KAVARIPETTAI, INDIA.	METHOED OF VARIATION OF PARAMETER AND ITS APPLICATION IN ENGINEERING
Rakshith Kumar, Raghul S.R, Nanjundeeswar S, Pranav P.R, Prodhosh L.K.M	R.M.K. Engineering College, Kavaraipettai , India	DIFFERENTIAL EQUATIONS AND THEIR APPLICATIONS IN ENGINEERING
Rakshith Kumar, Raghul S.R, Nanjundeeswar, Pranav P.R, Prodhosh	RMK Engineering College, Kavaraipettai, India	MULTIPLE INTEGRALS AND CHANGE OF ORDER OF INTEGRATION – AREA ENCLOSED BY CARTESIAN COORDINATES IN ENGINEERING APPLICATIONS
K. A. Aly	Jeddah University, Jeddah, Saudi Arabia	ENHANCING THE OPTICAL AND DIELECTRIC CONSTANTS OF CU-GE-S FILMS FOR SOLAR CELL WINDOWS
N Bharat Mohan Dyasani Advitha Banavath Sree Vidya Anugu Poojitha	MVSR Engineering College	PASSPORT VERIFICATION USING ZIGBEE TECHNOLOGY
Mohammed BELAHCEN, Siham EL HABIB, Najib TSOULI, Aya KHLIF	Mohammed I University, Oujda, Morocco	DISCRETE p(k)-Laplacian PROBLEMS WITH ROBIN BOUNDARY CONDITIONS

(All speakers required to be connected to the session 10 min before the session starts)
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17.02.2026 / ONLINE / SESSION-1 / HALL-8

Ankara Local Time: 13:00-15:00 February 17, 2026

Zoom Meeting ID: **325 629 5864** / Zoom Passcode: **meetcon**

HEAD OF SESSION: Prylyuk V.

Authors	Affiliation	Presentation Title
Azman bin Hashim, Masyanti binti Noor Rehan, Zirawina binti Zakaria	Kolej Komuniti Kepala Batas,13200 Kepala Batas, Pulau Pinang, Malaysia	AN ANALYSIS OF 12 PRINCIPLES OF ANIMATION AND EVALUATING THE EFFECTIVENESS AMONG 2D ANIMATION STUDENTS KEPALA BATAS COMMUNITY COLLEGE
Tanko Linus, Mohammed Sani Ibrahim, Audu Diggah, Emmanuel D. Sambe	Adult and Non-Formal Education Kaduna State College of Education, Gidan Waya, Kaduna State	HEALING THROUGH LEARNING: THE ROLE OF PRESCHOOL EDUCATION IN TRAUMA RECOVERY FOR CHILDREN IN SOUTHERN PART OF KADUNA STATE, NIGERIA
Karol Guadalupe López Soberanes Laura Cordova de los Santos Gloria Auristela Hernández Pérez	Universidad Juárez Autónoma de Tabasco.	COMPENSATORY PENSION HOW DOES IT WORK IN MEXICO?
Prylyuk V.	Taras Shevchenko National University of Kyiv, Kyiv, Ukraine	HOW TO END THE WAR IN UKRAINE AND CREATE A SECURITY ZONE FOR MANY YEARS
PhD(c) Murat Özay Taşkın PhD(c) Sümer Esin Şenyurt	University of Wroclaw University of Silesia in Katowice	MIGRATION DYNAMICS IN SUB-SAHARAN AFRICA: STRUCTURAL CAUSES, REGIONAL IMPACTS, AND INTERNATIONAL POLICIES
Dr. Naima Nawaz, Saeed Ahmad Zaman, Dr. Imran Ibrahim, Dr. Zain Nawaz, Dr. Ijaz Ashraf, Dr. Muhammad Idrees, Nadia Idrees, Lubna Anjum, Dr. Shahzad, Ayesha Riaz, Abdul Rahman, Muhammad Tariq	The University of Lahore, Pakistan University of Agriculture Faisalabad Government College University Faisalabad	SOCIAL PROTECTION OF OLDER PERSONS IN PUNJAB, PAKISTAN

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17.02.2026 / ONLINE / SESSION-1 / HALL-9

Ankara Local Time: 13:00-15:00 February 17, 2026

Zoom Meeting ID: **325 629 5864** / Zoom Passcode: **meetcon**

HEAD OF SESSION: Taskeen Fatima

Authors	Affiliation	Presentation Title
Fedwa BEGHDADI, El-Hadj DRICHE	Hassiba Benbouali University of Chlef, Hay Salem, 02000 Chlef, Algeria	ACTINOBACTERIA-MEDIATED INHIBITION OF ALTERNARIA SPP. AND ASSOCIATED MYCOTOXINS
Umar U. N., Olaleye R. S. Ajayi O. J., Ahmad I. I., Jibrin S	Federal University of Technology Minna, Niger State, Nigeria	EFFECTS OF E-AGRICULTURE EXTENSION SERVICE USAGE AMONG POULTRY FARMERS IN NIGER STATE, NIGERIA
Tabassum Ahmed Bushra	Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar-1207,Dhaka	EFFECT OF MANURE AND POTASSIUM ON GROWTH AND YIELD OF TOMATO
Onyekwelu Chinyere Nkemakonam	Federal Polytechnic, Oko, Anambra State, Nigeria	EVALUATION OF PROXIMATE COMPOSITION, FUNCTIONAL AND SENSORY PROPERTIES OF GARRI FROM BLENDS CASSAVA AND SWEET POTATO FORTIFIED WITH AFRICAN YAM BEAN
Emmanuel Tomisin Bello, Majekodunmi Rachael Adedayo	Newland Polytechnic and College of Health Technology, Ilorin. Kwara State University, Malete.	GOLD NANOPARTICLE–BASED LATERAL FLOW IMMUNOASSAYS FOR TUBERCULOSIS DIAGNOSIS: MECHANISTIC INSIGHTS, OPTIMIZATION STRATEGIES, AND TRANSLATIONAL PROSPECTS
Taskeen Fatima	Hajvery University	THE CLINICAL SIGNIFICANCE OF NORMAL PHYSIOLOGICAL BLOOD PARAMETERS IN HEALTH ASSESSMENT

(All speakers required to be connected to the session 10 min before the session starts)
Moderator is responsible for ensuring the smooth running of the presentation, managing the group discussion and dynamics.

17.02.2026 / ONLINE / SESSION-1 / HALL-10

Ankara Local Time: 13:00-15:00 February 17, 2026

Zoom Meeting ID: **325 629 5864** / Zoom Passcode: **meetcon**

HEAD OF SESSION: Ananda Majumdar

Authors	Affiliation	Presentation Title
Niksha, Ravi Mehta	Govt. College of Education, Canal Road, Jammu, Jammu & Kashmir, India	FROM ASANAS TO AWARENESS: YOGA'S INFLUENCE ON PSYCHOLOGICAL WELL-BEING
Dr. Amna Mirza Khushi Gupta	University of Delhi	STRATEGIC SYNERGIES IN THE INDO – PACIFIC: THE SIGNIFICANCE OF INDIA – JAPAN ECONOMIC RELATIONS
Enida Lutaj	'' Aleksander Moisiu '' University	QUESTIONS CHALLENGE IDEAS , DEEPEN UNDERSTANDING , AND TURN KNOWLEDGE INTO PROGRESS . KEEP QUESTIONING . THAT IS HOW LEARNING TRULY MOVES FORWARD
Ananda Majumdar	Harvard University	THE INFLUENCE OF FOOD CULTURE ON IDENTITY, HEALTH, AND COMMUNITY CONNECTIONS
Mtro. Miguel Alberto Romero Pérez Est. Héctor Jhovani De La Cruz Torres	Universidad Juárez Autónoma de Tabasco.	DETERMINANTS OF FINANCIAL GAPS IN THE HOUSEHOLD CAUSING DOMESTIC ECONOMIC VIOLENCE
Norziana bt Abdul Malim, Nur Mazlina binti Abdul Hadi, Norhasaliza binti Hassan	Kolej Komuniti Kepala Batas, Politeknik Metro Tasek Gelugor - Malaysia	EXPLORING FUNDAMENTAL DESIGN PRINCIPLES IN VISUAL LANGUAGE: INSIGHTS FROM ANIMATION STUDENTS

(All speakers required to be connected to the session 10 min before the session starts)
Moderator is responsible for ensuring the smooth running of the presentation, managing the group discussion and dynamics.

17.02.2026 / ONLINE / SESSION-1 / HALL-11

Ankara Local Time: 13:00-15:00 February 17, 2026

Zoom Meeting ID: **325 629 5864** / Zoom Passcode: **meetcon**

HEAD OF SESSION: Dr.R.Valarmathi

Authors	Affiliation	Presentation Title
Nejjari Amal Faiz Ahmed	FPN NADOR MAROC	AI-OPTIMIZED MINIATURIZED MICROSTRIP ANTENNA ON ROGERS RT5880 for Sub-6 GHz 5G/6G APPLICATIONS
Amina Aslam Bilal Aslam Muhammad Rehan Sajid Rimsha Ikram Ifraha Abbas Kashif Iqbal Faiza Hassan		ANTIHYPERLIPIDEMIC POTENTIAL OF ZINC OXIDE NANOPARTICLES FROM PUNICA GRANATUM
Simpa Abbas Abdulaziz, Abubakar D. Isah	Federal University of Technology Minna, Niger State Nigeria.	EXPLORING CRIME PREVENTION THROUGH ENVIRONMENTAL DESIGN (C.P.T.E.D) PRINCIPLES IN THE DESIGN PROPOSAL OF A BUS TERMINAL, NASARAWA STATE, NIGERIA
Dr.R.Valarmathi B.DINESH S.NANDHINI A.KEERTHANA S.MANOJ KUMAR S.SANTHOSH KUMAR	R.M.K. Engineering College, Chennai-601206	MODELING HONORS COURSE ENROLLMENT USING POISSON DISTRIBUTION FOR ACADEMIC RESOURCE PLANNING
Musa Isah, Baba Bamaiyi, Murtala Sa'adu, Farida Abubakar Tomo, Amina Muhammad, Bilyaminu Garba Jega, Baha'uddeen Salisu	Kebbi State University of Science and Technology, Nigeria Umaru Musa Yar'adua University, Katsina, Nigeria	PHYTOCHEMICAL CONSTITUENTS, ANTIBACTERIAL, AND ANTIOXIDANT PROPERTIES OF VITELLARIA PARADOXA ROOT EXTRACT
MD Moien	I.K. Gujral Punjab Technical University, Kapurthala	DEVELOPMENT AND EVALUATION OF CALCIUM-ENRICHED COOKIES FORTIFIED WITH EGGSHELL POWDER
Sani B.Y., Abdulmajid I., Muhammad B., Bashir S.B., Tukur Z.S.	State College of Basic and Advanced Studies, Sokoto	DETERMINATION OF MONOSODIUM GLUTAMATE (MSG) AND SODIUM ION CONCENTRATION IN SELECTED SEASONING SOLD IN SOKOTO METROPOLIS
Sani B.Y., Bawa H.Y., Muhammad B., Bashir S.B., Tukur Z.S.		DETERMINATION OF HEAVY METALS IN SELECTED COSMETIC PRODUCTS SOLD IN SOKOTO OLD MARKET, NIGERIA: CONCENTRATIONS AND HEALTH RISK ASSESSMENT
Ahalli Taoufik, Driss khatch, Nouayti Nordine, Cherif ELKHALIL, Ouassila RIOUCHI	Laboratory of Applied Sciences Université Mohammed 1er Cadi Ayyad University, Essaouira, Morocco	ISOTOPIC AND HYDROCHEMICAL ANALYSIS OF THE GHIS-NEKOR AQUIFER MOROCCO: ORIGIN OF SALINITY AND GROUNDWATER QUALITY

(All speakers required to be connected to the session 10 min before the session starts)
Moderator is responsible for ensuring the smooth running of the presentation, managing the group discussion and dynamics.

CONTENT

PROCEEDINGS BOOK

A COMPARATIVE STUDY OF BIOMETRIC AND TRADITIONAL AUTHENTICATION SYSTEMS

S. DHARANI

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ABSTARACT

This analysis delves into the evolving landscape of identity verification by contrasting biometric technologies—which draw upon immutable human attributes such as retinal scans, palm prints, facial geometry, vocal inflections, or even typing rhythms—with longstanding traditional techniques centered on knowledge-based elements like passphrases, numeric codes, or possession factors including keycards and temporary passcodes sent through digital channels. Biometrics stand out for their inherent resistance to duplication or transfer, delivering rapid, context-aware confirmation that ties access directly to the person's presence, thereby curbing widespread issues like credential reuse across platforms that fuel over 80% of known security incidents; however, they demand careful handling of sensitive data to avoid permanence risks if compromised. Traditional approaches maintain appeal through straightforward integration and recovery mechanisms but expose users to frequent pitfalls such as memory lapses, social manipulation tactics, or bulk database exposures. By evaluating real-world deployments in areas like financial services, healthcare records, and physical entry points, this study advocates for integrated strategies that merge biometric precision with traditional flexibility to achieve peak reliability, usability, and adaptability in today's threat-intensive digital environment.

Keywords: Identity verification, biometric modalities, physiological traits, behavioral patterns, password vulnerabilities, multi-layered security, user convenience, false acceptance rates, data privacy protocols, hybrid verification frameworks.

[1] INTRODUCTION

The proliferation of online and physical access points has intensified the need for dependable authentication that balances ironclad defense with effortless interaction, spotlighting the shortcomings of conventional systems predicated on external or recallable proofs that users routinely mishandle—resulting in forgotten details prompting helpdesk overloads or stolen items enabling unauthorized entry. Biometrics pivot this model toward intrinsic verification, harnessing traits forged by genetics or habit that defy forgery or delegation, thus enabling seamless transitions from cumbersome logins to glance-based or touch-free approvals prevalent in consumer gadgets, enterprise networks, and public infrastructure. This foundational shift not only accelerates processes by factors of three to five but also diminishes fraud vectors tied to shared secrets, as evidenced by industry shifts toward contactless borders and instant banking validations, setting the stage for a deeper probe into technical underpinnings, operational strengths, and synergistic potentials amid regulatory pressures for consent-driven data stewardship.

[2] ARCHITECTURE

Biometric frameworks unfold through a layered sequence starting with signal acquisition from dedicated hardware that converts biological inputs into digital streams, followed by sophisticated processing to distill invariant descriptors—employing techniques like edge detection for ridge patterns or neural embeddings for structural likenesses—yielding compact, non-reversible representations stored securely in isolated vaults or device-local memory. Subsequent phases involve live resampling, algorithmic alignment via distance metrics such as Euclidean norms or correlation coefficients, and binary rulings informed by calibrated boundaries that minimize erroneous grants while incorporating vitality assessments like heartbeat sensing or texture anomalies to neutralize synthetic forgeries. Traditional architectures, by comparison, streamline to input normalization, cryptographic transformation using salting and one-way functions, and direct equivalence checks against centralized ledgers, potentially extended by challenge-response protocols for added transience but inherently reliant on vault integrity without embodied uniqueness or temporal proofs.

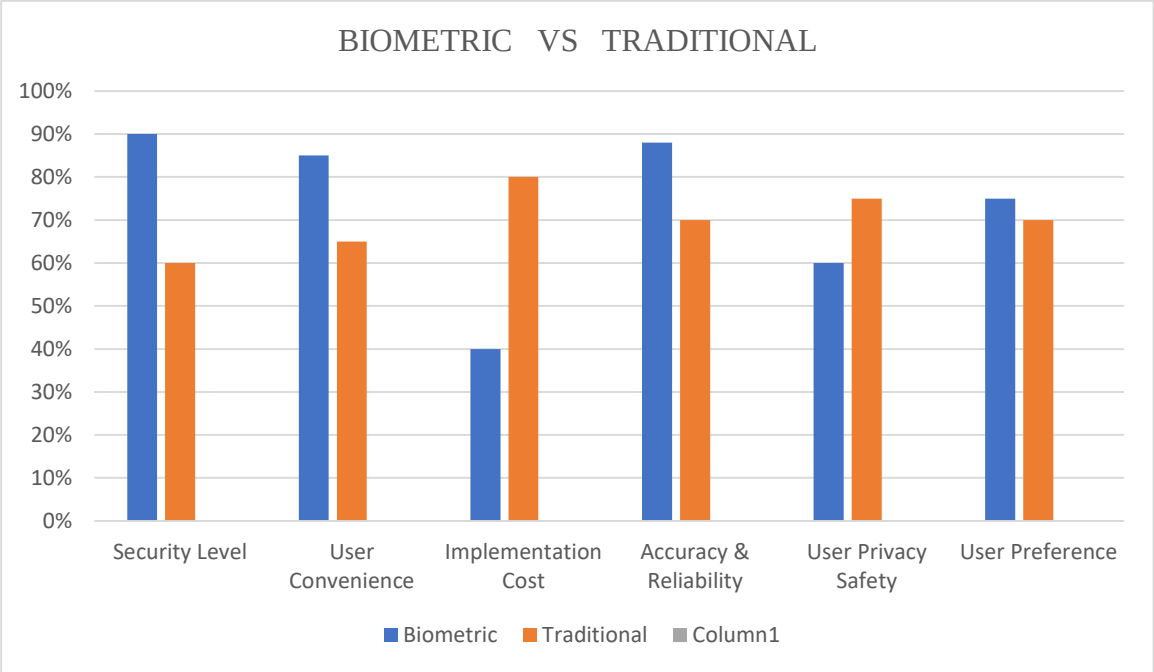
[3] ADVANTAGES

Biometrics empower unmatched linkage between user and privilege through traits impossible to lend or fabricate at scale, fostering accountability in shared settings while streamlining interactions to mere physiological actions that bypass mnemonic demands and cut verification durations to fractions of a second—ideal for high-traffic venues from transit hubs to corporate lobbies. They further bolster resilience via adaptive learning that refines thresholds over time and multimodal redundancy, yielding acceptance rates above 98% and slashing operational disruptions like reset requests that plague legacy setups. Traditional methods counter with negligible upfront demands, leveraging ubiquitous software for broad interoperability and swift revocation via simple regenerations, proving resilient in bandwidth-scarce or budget-limited domains despite propensities for human-error amplification and exposure to pervasive interception schemes.

[4] TABLE

Feature	**Biometric**	**Traditional**
Security	High, harder to forge	Moderate, prone to hacking
Convenience	Easy, no password to remember	Needs memory, can be forgotten
Cost	High	Low, software-only
Accuracy	High	Depends on password strength
Privacy	Sensitive, permanent data	Changeable if compromised
Examples	Fingerprint, face, iris	Password, PIN, OTP
Uses	High-security systems	Low-risk or backup systems

[5] BARCHART



[6] CONCLUSION

Biometrics redefine access paradigms with their unyielding personalization and velocity, eclipsing traditional susceptibilities in an assault-laden era by delivering exponential efficiency boosts, fraud curtailments nearing 60%, and economic offsets through averted incidents, yet their indelible essence calls for fortified anonymization, fallback layers, and ethical governance to sidestep overreach pitfalls. Pure legacy reliance fades as untenable for critical paths, but judicious pairings—infusing biometric cores with selective traditional adjuncts—forge versatile shields attuned to variance in risk profiles, regulatory mandates, and tech maturations, paving toward inclusive, impenetrable verification landscapes.

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SELF-DRIVING CARS: THE FUTURE OF TRANSPORTATION

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ABSTRACT

Self-driving cars, also known as autonomous vehicles, are revolutionizing transportation with AI-powered technology. The convergence of advanced sensors, computer vision, and machine learning algorithms has enabled vehicles to perceive their surroundings, make informed decisions, and navigate complex environments. This technology has the potential to enhance safety, increase mobility for the elderly and disabled, and reduce traffic congestion. However, despite the progress made, significant challenges remain, including the development of regulatory frameworks, ensuring cybersecurity, and addressing public acceptance. As the industry continues to evolve, self-driving cars are poised to transform transportation, reshaping urban landscapes and redefining mobility. With major players like Waymo, Tesla, and traditional automakers investing heavily in autonomous technology, the future of transportation is likely to be shaped by these innovations, promising a safer, more efficient, and connected transportation ecosystem.

Keywords: Autonomous Vehicles, Artificial Intelligence (AI), Computer Vision, Sensor Fusion, LiDAR (Light Detection and Ranging), Radar Technology, Machine Learning, Navigation Systems, Advanced Driver Assistance Systems (ADAS), V2X Communication (Vehicle-to-Everything).

[1] INTRODUCTION

The advent of self-driving cars is revolutionizing the way we think about transportation, marking a seismic shift in the automotive industry and our daily lives. Imagine a future where vehicles navigate roads without human intervention, reducing accidents, and making mobility accessible to everyone, regardless of age or ability. Self-driving cars, powered by Artificial Intelligence (AI), are no longer a distant dream but a rapidly approaching reality, with prototypes already logging millions of miles on public roads. With cutting-edge technologies like LiDAR, computer vision, and sensor fusion, these vehicles can perceive their surroundings, make informed decisions, and navigate complex environments, from bustling city streets to rural highways. The potential benefits are substantial, ranging from enhanced safety and reduced congestion to increased mobility for the elderly and disabled, and even

new business models like Mobility-as-a-Service (MaaS). As pioneers like Waymo, Tesla, and traditional automakers push the boundaries, self-driving cars are poised to transform transportation, reshaping urban landscapes, redefining what it means to travel, and unlocking new possibilities for smart cities and sustainable transportation ecosystems.

[2] ARCHITECTURE

The architecture of self-driving cars is a complex system comprising multiple layers and components that work in tandem to enable autonomous driving. At the core is the sensing layer, which includes an array of sensors like LiDAR, radar, cameras, and ultrasonic sensors that capture data about the vehicle's surroundings, detecting obstacles, lanes, and other vehicles. This data is then processed by the perception layer, which uses computer vision and machine learning algorithms to interpret the environment, identifying objects, predicting trajectories, and creating a semantic understanding of the scene. The decision-making layer, often powered by AI and deep learning models, analyzes the perceived environment and makes informed decisions about steering, acceleration, and braking. The control layer executes these decisions, sending commands to the vehicle's actuators, while the mapping and localization layer provides high-definition maps and precise location information, enabling the vehicle to navigate and understand its position in the world. Finally, the connectivity layer enables Vehicle-to-Everything (V2X) communication, allowing the vehicle to interact with other vehicles, infrastructure, and the cloud, enhancing safety and efficiency. This modular architecture enables self-driving cars to navigate complex environments, making transportation safer, more efficient, and accessible.

Sensing Layer:

LiDAR (Light Detection and Ranging)

Radar

Cameras (monocular, stereo, and 360°)

Ultrasonic sensors

GPS and IMU (Inertial Measurement Unit)

Perception Layer:

Computer Vision (object detection, segmentation, and tracking)

Machine Learning (predictive modeling and decision-making)

Sensor Fusion (integrating data from multiple sensors)

Decision-Making Layer:

AI-powered decision-making (rule-based, model-based, and learning-based)

Path planning and motion planning

Behavioral decision-making (e.g., lane changing, merging)

Control Layer:

Actuator control (steering, acceleration, and braking)

Feedback control (PID, model predictive control)

Mapping and Localization Layer:

High-definition maps (HD maps)

SLAM (Simultaneous Localization and Mapping)

GPS and inertial navigation

Connectivity Layer:

V2X communication (Vehicle-to-Vehicle, Vehicle-to-Infrastructure, Vehicle-to-Pedestrian)

Cellular connectivity (4G, 5G, and beyond)

Cloud connectivity (data storage, processing, and analytics)

[3] ADVANTAGES

The advent of self-driving cars is poised to revolutionize transportation, offering a plethora of advantages that can transform the way we travel. For one, safety is significantly enhanced as autonomous vehicles can detect and respond to hazards far more quickly and accurately than human drivers, reducing accidents and saving lives. Additionally, self-driving cars can increase mobility for the elderly, disabled, and those unable to drive, promoting independence and access to opportunities. Traffic congestion is also likely to decrease as autonomous vehicles can optimize traffic flow, reduce stop-and-go driving, and even enable new modes of transportation like shared mobility services. Furthermore, self-driving cars can boost productivity by freeing up time spent driving, allowing commuters to work, relax, or focus on other tasks. Environmentally, autonomous vehicles can be optimized for fuel efficiency and reduced emissions, contributing to cleaner air and a more sustainable future. With the potential to redefine transportation, self-driving cars can reshape urban landscapes, reduce parking needs, and create new economic opportunities, making transportation more efficient, accessible, and enjoyable for all.

Enhanced Safety:

Reduced accidents and fatalities

Faster reaction times to hazards

Improved visibility and detection of obstacles

Increased Mobility:

Independence for elderly and disabled individuals

Access to transportation for those unable to drive

Expanded transportation options for rural areas

Improved Traffic Flow:

Reduced congestion and optimized traffic routing

Smoother acceleration and braking

Potential for increased road capacity

Productivity and Convenience:

Free time for commuters to work, relax, or focus on other tasks

Reduced driver fatigue on long trips

Simplified parking and vehicle management

Environmental Benefits:

Optimized fuel efficiency and reduced emissions

Potential for electric or hybrid autonomous vehicles

Reduced urban pollution and improved air quality

Economic Opportunities:

New business models like Mobility-as-a-Service (MaaS)

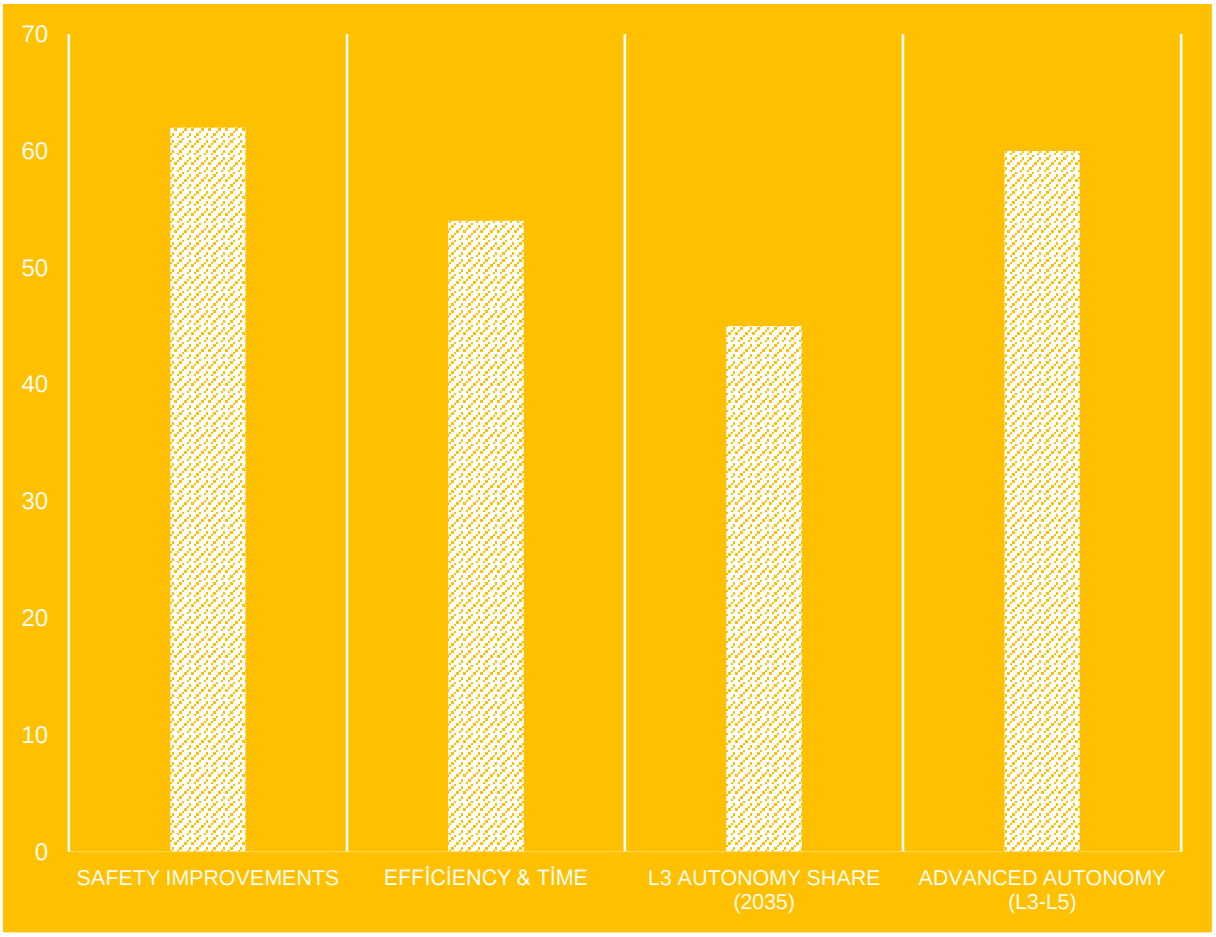
Reduced healthcare costs due to improved safety

Increased productivity and economic growth

[4] TABLE

Aspect	Description
Technology	AI, Computer Vision, LiDAR, Radar, Sensors, Machine Learning
Benefits	Enhanced Safety, Increased Mobility, Improved Traffic Flow, Productivity, Environmental Benefits
Components	Sensing Layer, Perception Layer, Decision-Making Layer, Control Layer, Mapping and Localization Layer
Levels of Autonomy	Level 0 (No Automation) to Level 5 (Full Autonomy)
Challenges	Regulatory Frameworks, Cybersecurity, Public Acceptance, Liability Issues
Potential Impact	Reshaped Urban Landscapes, New Business Models, Improved Accessibility, Reduced Emissions

[5] BARCHART



Self-Driving Cars: Survey In Future

[6] CONCLUSION

The emergence of self-driving vehicles marks a profound departure from over a century of human-centric driving, signaling a future where transportation is defined by algorithmic precision rather than human intuition. This evolution is not merely a technological upgrade but a societal transformation that promises to decouple mobility from the risks of human error. By shifting the responsibility of navigation to sophisticated sensor suites and artificial intelligence, we are moving toward a reality where the "driver's seat" may become an obsolete concept, replaced by mobile living spaces that prioritize passenger productivity and safety. As autonomous systems continue to mature through billions of miles of real-world and simulated testing, the focus of the automotive industry is pivoting from mechanical engineering to software-defined mobility.

The long-term success of this transition, however, depends on more than just code and hardware; it requires the development of a cohesive ecosystem involving smart city infrastructure, updated legal frameworks, and widespread public confidence. While the transition period will involve complex challenges—such as the "mixed-traffic" era where AI must interact with unpredictable human drivers—the eventual goal is a seamless, interconnected network that optimizes traffic flow and reduces carbon emissions. Ultimately, the future of transportation lies in a model where mobility is accessible to everyone, including those currently sidelined by age or disability, creating a more equitable world where the journey is as safe and effortless as the destination itself.

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A FUSION-CENTRIC REVIEW OF DEEP LEARNING–BASED MULTIMODAL SYSTEMS (FOUNDATIONS, ARCHITECTURES, AND EMERGING DIRECTIONS)

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ABSTRACT

The growing popularity of disparate data types (images, text, signals, behavioral logs, and sensor streams) has made it possible for multi-modal deep learning to become a foundation for real-world artificial intelligence systems. While a lot of research has been conducted, reviews keep providing more insights on the application domains and model families to the exclusion of foundational design principles that are used to seamlessly integrate multiple modes. This paper reviews the deep learning of multi-modal systems with a focus on the specific combination of modalities and how they are blended in the configuration of the systems. We integrate the basic principles of different strategies of multi-modal fusion and architecture and detail how they are instantiated in a limited range of application domains like healthcare, education, intelligent monitoring, and human AI. The reviews also analyze the design of the systems in terms of the data sets used, providing a glimpse into the most common design system failures; especially, in the systems with low data set balance, misalignment, poor fusion, internal robustness, low system interpretability, and no scalability. Having used data distributed across various domains, the document is able to identify common architectural patterns and system design trade-offs that are not driven by specific tasks. In view of the challenges, the paper proposes a set of focus areas for future research; multi-modal models using transformers, fusion of different systems where one is more robust, and socially and ethically responsible multi-modal AI. Overall, the document attempts to provide a framework to guide authoritative design and evaluation of the multi-modal deep learning systems that are made to serve specific purposes.

FABRICATION OF GREEN GEOPOLYMER/ALGINATE HYBRID SPHERES FOR EFFICIENT REMOVAL OF METHYL ORANGE DYE IN WATER: BATCH STUDIES

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ABSTRACT

Discharges of various micropollutants (organic and inorganic) into the environment are on the increase. These pollutants are generally toxic, poorly biodegradable, and cause numerous adverse health effects. In this context, this work focuses on the development of a geopolymer based on red clay waste, with a view to its application as an adsorbent in the treatment of an aqueous medium contaminated by Methyl Orange. The synthesized geopolymer was characterized by various analytical techniques. The raw material and the synthesized geopolymers were characterized by various physico-chemical methods. The results of XRF, XRD, and FTIR confirmed the successful synthesis of geopolymer beads, while the SEM/EDX findings revealed the homogeneous surface of the adsorbents. Adsorption tests were carried out by varying various parameters likely to affect adsorption performance, including adsorbent dose, solution pH, contact time, initial Methyl Orange concentration, and solution temperature. The kinetic study revealed that the geopolymer eliminates Methyl Orange relatively quickly. The pseudo-second-order model is the most suitable for presenting the adsorption mechanism. The isotherm for Methyl Orange retention on geopolymer is in perfect agreement with the Langmuir model. Evaluation of the thermodynamic quantities showed that the Methyl Orange adsorption process is favorable, spontaneous, and endothermic. The results we have found allow us to predict that the use of these new generations of geopolymers offers great potential for the retention of cationic textile dyes.

Key words: Adsorption; red clay waste; Geopolymer Beads; Methyl Orange; Characterization.

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KUANTUM BİLİŞİM ÇAĞINDA FİNANSAL SİSTEMLERİN DAYANIKLILIĞI: POST-KUANTUM KRİPTOGRAFİ GEÇİŞ SÜREÇLERİNDE İÇ DENETİMİN ROLÜ

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ÖZET

Kuantum bilişim, finansal sistemlerin temelini oluşturan kriptografik güvenlik altyapısı için varoluşsal bir tehdit oluşturmaktadır. Bu tehdidin en acil boyutu, şifreli verilerin bugün toplanıp gelecekte kuantum bilgisayarlar ile çözülmesini hedefleyen "Şimdi Topla, Sonra Çöz" (Harvest Now, Decrypt Later - HNDL) saldırı modelidir. Mevcut literatür, Post-Kuantum Kriptografi (PQC- Post-Quantum Cryptography) standartlarını ve teknik geçiş yol haritalarını kapsamlı bir şekilde ele alırken, bu karmaşık ve uzun soluklu dönüşüm sürecinde iç denetim fonksiyonunun stratejik rolünü önemli ölçüde göz ardı etmektedir. Bu çalışma, söz konusu boşluğu doldurmayı ve kurumların PQC geçiş sürecinde iç denetimin yönetişim ve güvence sağlama rolünü tanımlayan stratejik bir çerçeve sunmayı amaçlamaktadır. Yöntem olarak, akademik yayınlar, sektör raporları ve düzenleyici kurum kılavuzları gibi çeşitli kaynakların yapılandırılmış bir sentezinden yararlanılmıştır. Çalışmanın temel katkısı, iç denetim fonksiyonunu finans sektöründe kuantum dayanıklılığının kritik bir etkinleştiricisi olarak konumlandıran, altı aşamalı, eyleme dönük bir denetim çerçevesi sunmasıdır.

ABSTRACT

Quantum computing poses an existential threat to the cryptographic security infrastructure that underpins financial systems. The most urgent dimension of this threat is the “Harvest Now, Decrypt Later” (HNDL) attack model, which involves collecting encrypted data today with the intention of decrypting it in the future using quantum computers. While the existing literature extensively examines Post-Quantum Cryptography (PQC) standards and technical migration roadmaps, it largely overlooks the strategic role of the internal audit function in managing this complex and long-term transformation process. This study aims to address this gap by proposing a strategic framework that defines the governance and assurance role of internal audit during the PQC transition in financial institutions. Methodologically, the study draws on a structured synthesis of academic literature, industry reports, and guidance issued by regulatory and standard-setting bodies. The primary contribution of the study is the development of an action-oriented, six-stage internal audit framework that positions the internal audit function as a critical enabler of quantum resilience in the financial sector.

Keywords: Post-Quantum Cryptography; Quantum Computing; Internal Audit

GİRİŞ

Kuantum bilişim, finansal hizmetler sektörü için ikili bir doğa taşımaktadır. Bir yanda, portföy optimizasyonu, risk modellemesi ve dolandırıcılık tespiti gibi karmaşık problemleri çözme konusunda dönüştürücü bir potansiyel sunarken (Dixit, 2022; McKinsey, 2025), diğer yanda Shor algoritması gibi yetenekleriyle dijital ekonominin kriptografik temellerine yönelik varoluşsal bir tehdit oluşturmaktadır (Campbell, 2025). Bu tehdidin aciliyeti, "Şimdi Topla, Sonra Çöz" (HNDL) olarak bilinen saldırı modeliyle somutlaşmaktadır. Bu modelde, saldırganlar bugün şifrelenmiş verileri toplamakta ve gelecekte yeterli güce sahip bir kuantum bilgisayarla bu şifreleri kırmayı hedeflemektedir (Bobier vd., 2025; Post-Quantum Financial Infrastructure Framework, 2025). Kuantum bilişimle ilgili en acil risk, saldırganların bugün kuantum bilgisayarları olmasa bile şifreli verileri toplamaya başlamasıdır. "Harvest Now, Decrypt Later" (HNDL) olarak bilinen bu strateji, özellikle gizlilik süresi uzun olan veriler (sağlık kayıtları, 20 yıllık mortgage dosyaları, devlet sırları) için devasa bir tehdit oluşturmaktadır (Grant

Thornton, 2025). Bir veri varlığının gizlilik ömrü, kuantum güvenliğe geçiş süresiyle birleştiğinde, kuantum bilgisayarların ortaya çıkış tarihinden sonraya sarkıyorsa, o veri bugün itibarıyla tehlike altındadır (ISACA, 2025). Bu durum, on yıllarca gizli kalması gereken finansal verilerin şimdiden risk altında olduğu anlamına gelmektedir.

Bu bağlamda merkezi problem, kuantum sonrası kriptografiye (PQC- *Post-Quantum Cryptography*) geçişin basit bir teknik güncelleme değil, on yıldan fazla sürebilecek, geleneksel BT proje yönetimini aşan, benzeri görülmemiş bir kurumlar arası koordinasyon ve sağlam bir yönetişim gerektiren karmaşık bir sosyo-teknik geçiş olmasıdır (Campbell, 2025). Mevcut literatür incelendiğinde, bu alandaki çalışmaların ezici bir çoğunlukla teknik nitelikte olduğu, algoritmik performans ve protokol tasarımına odaklandığı, böylece bu makalenin doldurmayı amaçladığı kritik bir yönetişim boşluğu yarattığı görülmektedir (Grant Thornton, 2025; Wolters Kluwer, 2025). Teknik ekiplerin tek başına yönetemeyeceği kadar karmaşık olan bu geçiş, kurumsal yönetişimin tüm katmanlarını ilgilendiren stratejik bir risk yönetimi sorunudur.

Çalışmanın amacı, söz konusu araştırma boşluğunu doldurarak, finansal kurumların PQC geçiş sürecinde iç denetimin rolünü ve sorumluluklarını tanımlayan kapsamlı bir stratejik çerçeve sunmaktır. Bu çerçeve, kuantum tehdidine karşı kurumsal dayanıklılığın sağlanmasında iç denetimin nasıl proaktif ve yol gösterici bir rol üstlenebileceğini ortaya koymayı hedeflemektedir.

LİTERATÜR TARAMASI

Bu bölüm, çalışmanın akademik temelini oluşturan literatürü karşılaştırmalı ve eleştirel bir yaklaşımla sentezlemektedir.

Kuantum Bilişimin İkili Doğası: Fırsatlar ve Tehditler

Kuantum bilişim, finans sektörü için hem önemli fırsatlar hem de temel tehditler barındıran ikili bir yapıya sahiptir. Fırsatlar tarafında, kuantum algoritmaları, türev fiyatlandırması ve piyasa çöküşü tahmini gibi klasik bilgisayarların yetersiz kaldığı karmaşık optimizasyon problemlerini çözme potansiyeli taşımaktadır (Booz Allen, 2025b; Taylor Wessing, 2025). Ayrıca, Kuantum Makine Öğrenmesi (QML- Quantum Machine Learning) teknikleri, dolandırıcılık tespiti gibi anomali belirleme süreçlerini önemli ölçüde geliştirme vaadi sunmaktadır (Micheal, 2024; Sopra Steria, 2026).

Bu fırsatların karşısında ise, Kriptografik Olarak Anlamlı bir Kuantum Bilgisayarın (CRQC- Cryptographically Relevant Quantum Computer) ortaya çıkmasıyla oluşacak temel tehdit yer almaktadır. Böyle bir bilgisayar, günümüzde yaygın olarak kullanılan RSA(*Rivest–Shamir–Adleman*-Asimetrik açık anahtarlı kriptografi algoritması) ve ECC (*Elliptic Curve Cryptography*-Eliptik Eğri Kriptografisi) gibi asimetrik şifreleme algoritmalarını Shor algoritması aracılığıyla kırarak dijital güvenliğin temelini ortadan kaldırabilir (Gordon, Loeb, & Zhou, 2020; SISA, 2025).

Post-Kuantum Kriptografi (PQC) ve Kripto-Çeviklik Stratejisi

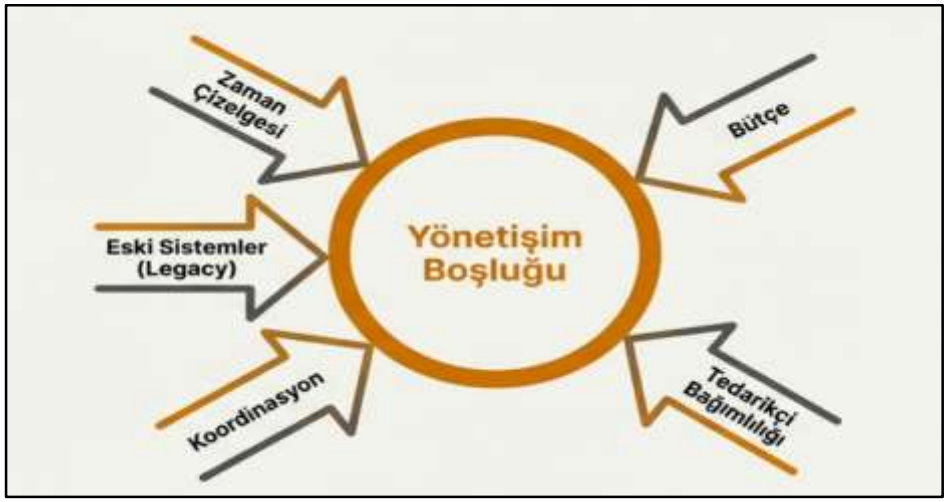
Kuantum tehdidine karşı küresel yanıt, NIST'in (National Institute of Standards and Technology- ABD Ulusal Standartlar ve Teknoloji Enstitüsü) öncülüğünde yürütülen standartlaşma süreciyle şekillenmiştir. Bu süreç, ML-KEM ((Modül-kafes tabanlı anahtar kapsülleme mekanizması – CRYSTALS-Kyber) ve ML-DSA (CRYSTALS-Dilithium) gibi kafes tabanlı algoritmaların standart olarak belirlenmesiyle sonuçlanmıştır (Bobier vd., 2025). Ancak bu yeni standartların operasyonel etkileri oldukça önemlidir. PQC algoritmaları, %15-20 oranında ek bant genişliği yükü getirmekte ve anahtar ile imza boyutlarını klasik algoritmalara kıyasla önemli ölçüde artırmaktadır. PQC standartlarının getirdiği bu önemli performans ve depolama cezaları, statik ve kod içine gömülü kriptografik uygulamaları operasyonel olarak savunulamaz kılmakta, bu da kripto-çevikliği yalnızca bir en iyi uygulama değil, başarılı bir geçiş için temel bir ön koşul haline getirmektedir. Bu bağlamda, literatürde ve sektörde uzlaşılan stratejik zorunluluk, "kripto-çeviklik" yani kriptografik algoritmaları hızlı ve kesintisiz bir şekilde değiştirebilme yeteneğidir (Post-Quantum Financial Infrastructure Framework, 2025).

Kurumsal PQC Geçiş Süreçleri ve Yönetişim Boşluğu

Kurumsal çapta PQC geçişinin pratik zorlukları, literatürde kapsamlı bir şekilde ele alınmıştır. Büyük ölçekli kurumlar için geçiş sürelerinin 12-15 yılı aşabileceği tahmin edilmektedir. Bu uzun zaman

çizelgesi, CRQC'lerin ortaya çıkış tahminleriyle karşılaştırıldığında potansiyel bir "risk açığı" yaratmaktadır. Geçiş sürecinin temel zorlukları; eski (legacy) sistemlerdeki teknik borç, kurumlar arası karmaşık koordinasyon gereksinimleri, tedarikçi hazırlık düzeyine olan bağımlılıklar ve önemli bütçe kısıtlamaları olarak kategorize edilebilir (Taylor Wessing, 2025).

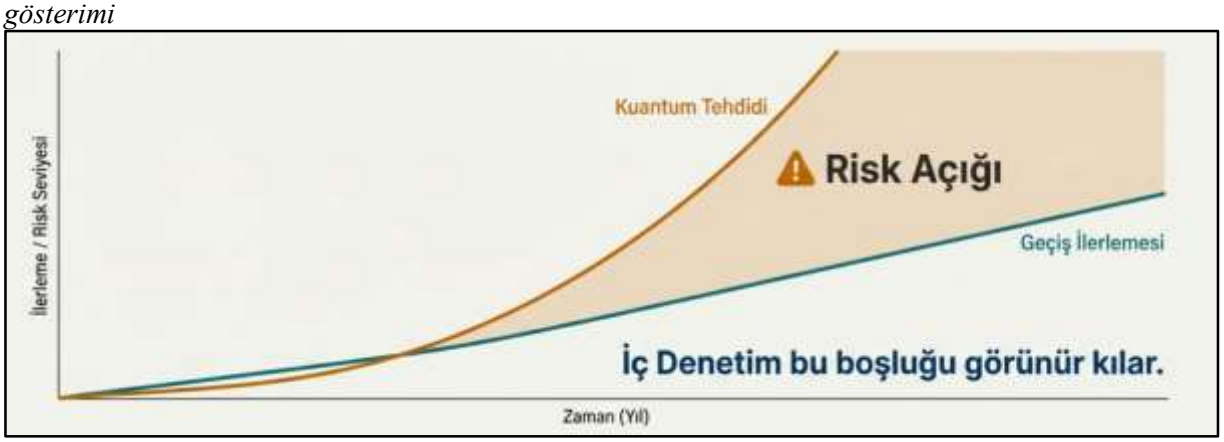
Şekil 1. *Post-kuantum kriptografi geçişinde yönetişim boşluğunu oluşturan temel kurumsal faktörler*



Bu çok yönlü ve karmaşık zorluklar, sadece teknik ekiplerin yönetebileceği bir süreç olmaktan öte, stratejik düzeyde ele alınması gereken önemli bir yönetişim boşluğu yaratmaktadır. Bahse konu katmanlı zorluklar, PQC geçişini salt teknik bir dönüşüm olmaktan çıkararak kurumsal düzeyde bir yönetişim boşluğuna dönüştürmektedir (Şekil 1). Geçiş sürecinin uzun zaman çizelgesine yayılması, bütçe planlamalarının kısa vadeli önceliklerle şekillenmesi, eski (legacy) sistemlere gömülü teknik borçların yüksekliği, kurum içi ve kurumlar arası koordinasyon gereksinimleri ile üçüncü taraf tedarikçilerin hazırlık düzeyine olan bağımlılık, karar alma sorumluluğunun tek bir fonksiyon veya teknik ekip tarafından üstlenilmesini fiilen imkansız kılmaktadır. Bu durum, kriptografik riskin teknik katmanlarda tanımlanmasına rağmen, riskin sahipliğinin stratejik düzeyde netleşmemesine ve hesap verebilirliğin dağılmasına yol açmaktadır. Sonuç olarak PQC geçişi, teknolojik bir uyum sürecinden ziyade, kurumsal yönetişim mekanizmalarının sınandığı, rol ve sorumlulukların yeniden tanımlanmasını gerektiren bütüncül bir risk yönetimi problemi olarak ortaya çıkmaktadır.

PQC geçiş sürecinin kurumsal açıdan en kritik boyutlarından biri, teknolojik dönüşümün doğası gereği uzun vadeye yayılması ile kuantum bilişim alanındaki gelişmelerin öngörülemez hızının yarattığı zamansal uyumsuzluktur. Büyük ölçekli finansal kurumlarda kriptografik altyapının envanterlenmesi, yeniden tasarlanması, test edilmesi ve tedarikçi ekosistemiyle uyumlu hâle getirilmesi on yılı aşabilen zaman çizelgeleri gerektirmektedir.

Şekil 2. *Post-kuantum kriptografi geçiş hızı ile kuantum tehdidi arasındaki risk açığının zamansal gösterimi*



Şekil 2'de görselleştirilen bu risk açığı, yalnızca teknik bir güvenlik zafiyeti olarak değil, kurumsal risk yönetimi açısından birikimli ve geri döndürülemez sonuçlar doğuran yapısal bir kırılma alanı olarak değerlendirilmelidir.

Özellikle "Şimdi Topla, Sonra Çöz" (HNDL) saldırı modeli bağlamında, bugün şifrelenen ancak uzun yıllar gizli kalması gereken veriler, geçiş tamamlanmadan önce kalıcı olarak risk altına girebilmektedir. Bu durum, riskin gelecekte değil, fiilen bugünde oluştuğunu göstermektedir. Dolayısıyla risk açığı, yalnızca olasılıksal bir tehdit değil; zaman ilerledikçe genişleyen, kurumsal risk iştahını ve yatırım önceliklerini yeniden tanımlamayı zorunlu kılan stratejik bir yönetişim sorunudur.

Teknolojik Kırılımlar Karşısında Denetimin Gelişen Rolü

Büyük teknolojik kırılımlar, iç denetim fonksiyonunun rolünün evrimini zorunlu kılmaktadır (Wolters Kluwer, 2025). Geleneksel reaktif (tepkisel) güvence modelinden, riskleri öngören ve önleyici tedbirleri değerlendiren proaktif (ön alıcı) bir modele geçiş kaçınılmazdır (Grant Thornton, 2025). Bu dönüşüm, denetçiler için yeni yetkinlikler gerektirmektedir. Dijital okuryazarlık ve karmaşık ortamlarda yol bulmayı sağlayan duygusal zeka gibi beceriler, modern denetçiler için bir zorunluluk haline gelmiştir (Developing Auditor Competencies, 2025; Vinsys, 2025).

Yapay zeka okuryazarlığı üzerine yapılan bir çalışmada tanımlanan dört boyutlu yetkinlik çerçevesi (farkındalık, etik, değerlendirme, kullanım), modern denetçilerin ihtiyaç duyacağı "kuantum okuryazarlığı" için güçlü bir analoji sunmaktadır (Al-Abdullatif, 2024).

Yine yapay zeka okuryazarlığı analojisi özellikle yerindedir, çünkü hem kuantum bilişim hem de yapay zeka, deterministik sistemlerden birer paradigma kaymasını temsil etmektedir. Denetçiler artık geleneksel uyum kontrol listelerinin ötesinde yeni değerlendirme çerçeveleri gerektiren, olasılıksal, karmaşık ve genellikle şeffaf olmayan sistemler üzerinde güvence sağlamak zorundadır. PQC geçişi, tam da bu evrilmiş ve proaktif denetim yaklaşımını gerektiren en önemli teknolojik kırılımlardan biridir.

METODOLOJİ

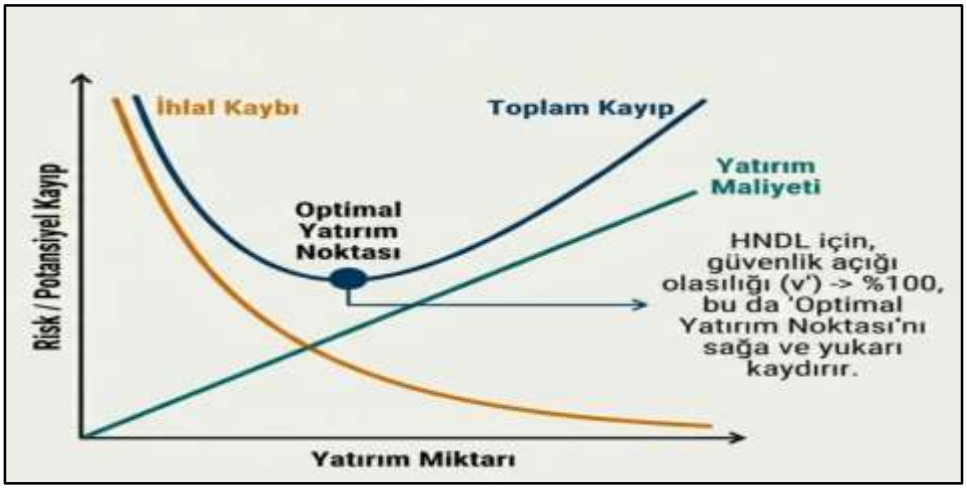
Bu çalışmada kullanılan metodoloji, literatür taraması ekseninde kavramsal çerçeve geliştirme yaklaşımıdır. Araştırma süreci; hakemli akademik makaleler, önde gelen teknoloji ve danışmanlık firmalarının teknik raporları ve düzenleyici kurumların kılavuz belgeleri dahil olmak üzere çeşitli kaynakların sistematik olarak toplanmasını ve analiz edilmesini içermektedir. Analiz, dağınık bilgileri belirli bir profesyoneller (iç denetçiler) için tutarlı ve eyleme geçirilebilir bir çerçevede sentezlemeye odaklanmıştır.

TEORİK ÇERÇEVE

Gordon-Loeb Siber Güvenlik Yatırım Modeli

Gordon-Loeb modeli, siber güvenlik yatırımlarını analiz etmek için temel bir çerçeve sunar (Gordon, Loeb, & Zhou, 2020). Modelin temel ilkesi, bir ihlalin olasılığı ile potansiyel kaybı dengeleyerek optimal harcama seviyesini belirlemektir. Bu model kuantum tehdidine uyarlandığında, HNDL (Şimdi Topla, Sonra Çöz saldırı modeli) tehdidi altındaki uzun ömürlü veriler için, güvenlik açığı olasılığının (v) onlarca yıllık bir zaman diliminde etkin bir şekilde %100'e yaklaştığı varsayılabilir. Bu durum, PQC önlemlerine yönelik önemli ve proaktif yatırımların rasyonel ve gerekli olduğunu teorik olarak doğrulamaktadır.

Şekil 3. *HNDL tehdidinin Gordon–Loeb siber güvenlik yatırım modeline etkisi*



Şekil 3'de gösterilen bu kayma, kuantum tehdidi bağlamında siber güvenlik yatırımlarının klasik marjinal fayda–maliyet dengesiyle ele alınamayacağını ortaya koymaktadır. HNDL tehdidi altında güvenlik açığı olasılığının zamana yayılı olarak neredeyse kesin hâle gelmesi, beklenen kaybın doğrusal olmayan biçimde artmasına neden olmakta ve böylece daha erken, daha yüksek ve daha kapsamlı güvenlik yatırımlarını ekonomik açıdan rasyonel kılmaktadır. Bu durum, siber güvenlik harcamalarının isteğe bağlı veya ertelenebilir bir maliyet unsuru değil, uzun vadeli veri gizliliğini ve kurumsal itibarı korumaya yönelik zorunlu bir risk azaltma yatırımı olarak değerlendirilmesini gerektirmektedir. Dolayısıyla Gordon–Loeb modeli, kuantum çağında yalnızca yatırım seviyesini değil, aynı zamanda yatırım zamanlamasını da yeniden tanımlayan bir analitik çerçeve sunmakta; proaktif PQC yatırımlarını ekonomik açıdan gerekçelendirmektedir.

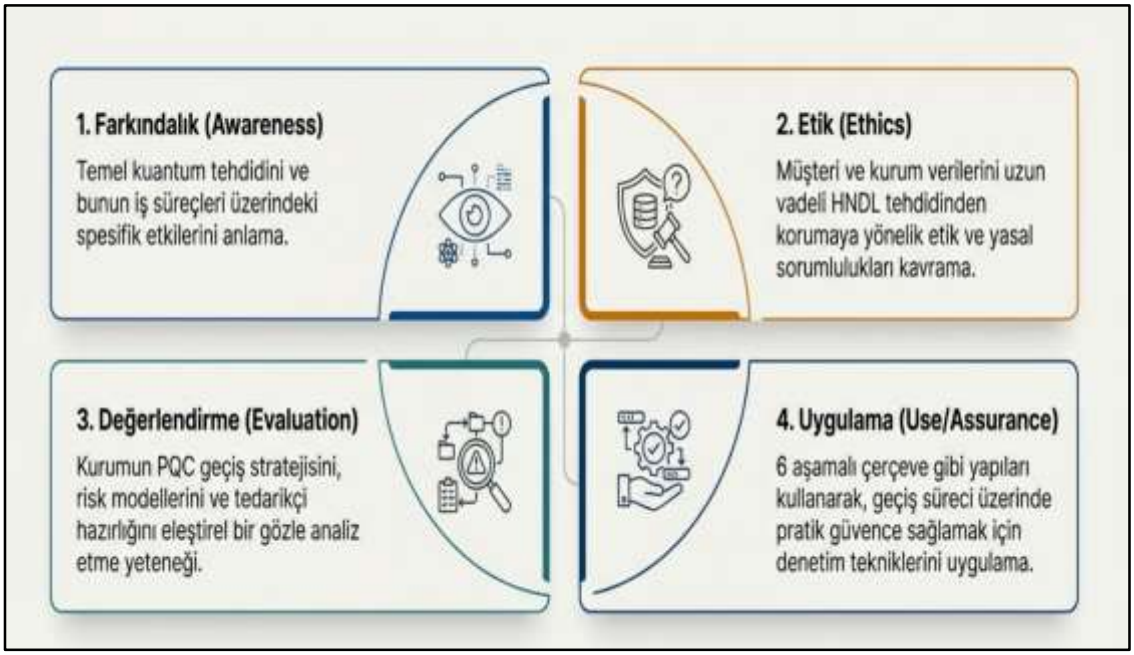
Bütünleşik Risk Yönetimi ve Uygunluk Çerçeveleri

PQC geçişi, mevcut risk yönetimi çerçeveleri içinde konumlandırılmalıdır. Bu süreç, NIST Siber Güvenlik Çerçevesi 2.0'ın temel fonksiyonları olan Tanımla, Koru, Tespit Et, Müdahale Et ve İyileştir ile doğrudan uyumludur (Post-Quantum Financial Infrastructure Framework, 2025). Türkiye perspektifinden bakıldığında, T.C. Cumhurbaşkanlığı Dijital Dönüşüm Ofisi tarafından yayınlanan "Bilgi ve İletişim Güvenliği Rehberi", kamu kurumları ve kritik altyapılar için standartlaştırılmış güvenlik tedbirlerinin kritik önemini vurgulamaktadır. Bu rehber, PQC geçişi gibi sistemik riskleri yönetmek için gereken kapsamlı, devlet düzeyinde güvenlik yönetişimi için kritik bir ulusal emsal oluşturmakta ve kritik altyapıyı güvence altına almaya yönelik yukarıdan aşağıya bir yaklaşımı göstermektedir (T.C. Cumhurbaşkanlığı Dijital Dönüşüm Ofisi, 2019).

Denetçi Yetkinliği için Kuantum Okuryazarlığı Modeli

Bu çalışma, denetçiler için bir "Kuantum Okuryazarlığı" kavramsal modelini, yapay zeka okuryazarlığı çalışmasındaki dört boyutlu çerçeveyi uyarlayarak önermektedir(Al-Abdullatif, 2024).

Şekil 4. *İç denetçiler için önerilen kuantum okuryazarlığı yetkinlik modeli*



Bu modelin PQC denetimi bağlamındaki boyutları şu şekilde tanımlanmıştır:

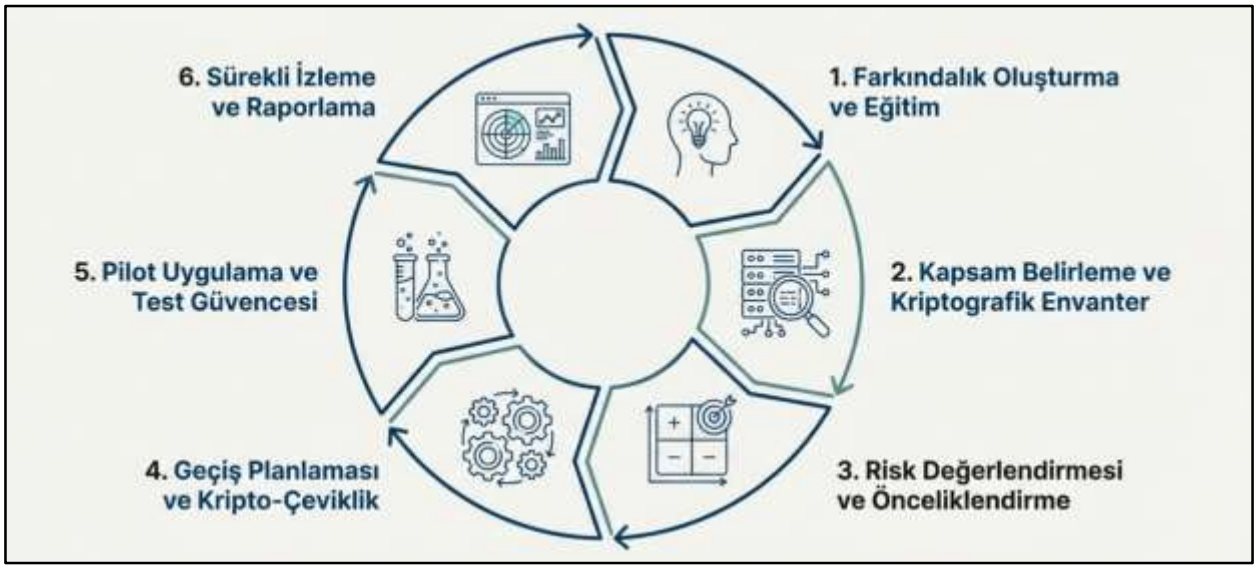
- Farkındalık (Awareness): Temel kuantum tehdidini ve bunun iş üzerindeki etkilerini anlama.
- Etik (Ethics): Uzun ömürlü hassas verileri HNDL tehdidinden korumaya yönelik etik sorumlulukları kavrama.
- Değerlendirme (Evaluation): Kurumun PQC geçiş stratejisini, risk değerlendirmelerini ve tedarikçi hazırlığını eleştirel bir gözle değerlendirme yeteneği.
- Uygulama (Use/Assurance): Geçiş süreci üzerinde güvence sağlamak için denetim tekniklerini pratik olarak uygulama.

BULGULAR

Bu çalışmanın temel bulgusu, iç denetim fonksiyonu için tasarlanmış çok aşamalı stratejik bir çerçevedir. Her aşama için net bir başlık, amacın kısa bir açıklaması ve kaynaklara dayandırılmış spesifik, eyleme dönük denetim adımları sunulmaktadır.

Aşağıda sunulan altı aşamalı çerçeve, post-kuantum kriptografi geçiş sürecinde iç denetimin güvence ve yönetişim rolünü sistematik ve uygulamaya dönük bir biçimde ortaya koymaktadır

Şekil 5. *Post-kuantum kriptografi geçişi için iç denetime yönelik altı aşamalı stratejik güvence çerçevesi*



Bu çerçeve, iç denetimin PQC geçiş sürecine tek seferlik bir uyum faaliyeti olarak değil, aşamalar arasında geri besleme üreten sürekli bir güvence ve yönetişim döngüsü olarak yaklaşmasını esas almaktadır.

Aşama 1: Farkındalık Oluşturma ve Eğitim

Denetimin ilk rolü, yönetim kurulunun ve üst yönetimin kuantum tehdidi ve stratejik sonuçları hakkında yeterince eğitildiğine dair güvence sağlamaktır.

Denetim Eylemleri;

1. Yönetici Eğitimlerini Değerlendirme: Liderlik için kuantum riskleri konusunda mevcut eğitim programlarının varlığını ve yeterliliğini değerlendirmek (Grant Thornton, 2025; The Institute of Internal Auditors, 2025).

2. Risk İletişimini Doğrulama: Kuantum tehdidinin sadece teknik bir sorun olarak değil, aynı zamanda risk komitesi tüzüklerinde ve yönetim kurulu materyallerinde stratejik bir iş riski olarak ifade edildiğini doğrulamak (Wolters Kluwer, 2025).

Aşama 2: Kapsam Belirleme ve Kriptografik Envanter

Bu aşamada amaç, sonraki tüm geçiş faaliyetlerinin vazgeçilmez temelini oluşturan kriptografik envanterin eksiksizliği ve doğruluğu üzerinde bağımsız güvence sağlamak.

Denetim Eylemleri;

1. Keşif Sürecini Gözden Geçirme: Kriptografik keşif süreci için kullanılan metodolojiyi değerlendirmek ve bu sürecin yazılım, donanım, bulut hizmetleri ve eski sistemler dahil tüm ortamları kapsadığından emin olmak (Booz Allen, 2025a; Palo Alto Networks, 2025).

2. Envanter Doğruluğunu Test Etme: Kriptografik varlık envanterinin eksiksizliğini ve iş süreçleriyle eşleştirilmesini doğrulamak için örneklem bazlı testler yapmak.

Aşama 3: Risk Değerlendirmesi ve Önceliklendirme

Kurumun, geçiş yapılacak sistemleri riske göre önceliklendirmek için kullandığı çerçeveyi değerlendirmek amaçlanmaktadır.

Denetim Eylemleri;

1. Risk Modelini Değerlendirme: Risk puanlaması için kullanılan kriterleri değerlendirmek ve bu kriterlerin veri hassasiyeti, HNDL tehdidi, yasal gereklilikler ve operasyonel

kritikliğe uygun ağırlık verdiğinden emin olmak (Post-Quantum Financial Infrastructure Framework, 2025).

2. Önceliklendirme Yol Haritasını Gözden Geçirme: Geçiş yol haritasını inceleyerek en yüksek riskli varlıkların (örneğin, kritik ödeme sistemleri, uzun ömürlü hassas veri depoları) en erken eylem için önceliklendirildiğinden emin olmak (Post-Quantum Financial Infrastructure Framework, 2025).

Aşama 4: Geçiş Planlaması ve Kripto-Çeviklik Değerlendirmesi

Geçiş planının sağlamlığını ve kurumun kripto-çeviklik sağlama stratejisini değerlendirmek bu aşamada kritiktir.

Denetim Eylemleri;

1. Tedarikçi Durum Tespitini Değerlendirme: Kritik üçüncü taraf tedarikçilerin, bulut sağlayıcıların ve yazılım üreticilerinin PQC hazırlık düzeyini değerlendirme sürecini gözden geçirmek (The Institute of Internal Auditors, 2025).

2. Hibrit Stratejiyi Değerlendirme: Geçiş önlemi olarak hibrit kriptografik şemaların uygulanmasına yönelik teknik ve operasyonel planları değerlendirmek (Post-Quantum Financial Infrastructure Framework, 2025).

3. Kripto-Çeviklik Mimarisi Denetimi: Sistem tasarımlarını ve geliştirme pratiklerini, kod içine gömülü algoritmalar yerine soyutlanmış, yapılandırılabilir kripto hizmetlerini destekleyerek kripto-çevikliği sağlayıp sağlamadığını belirlemek için değerlendirmek.

Aşama 5: Pilot Uygulama ve Test Güvencesi

PQC'nin gerçek dünya performans etkilerinin ölçüldüğü test ve prototipleme aşaması üzerinde güvence sağlamak gerekmektedir.

Denetim Eylemleri;

1. Test Planlarını Gözden Geçirme: PQC prototip projelerinin kapsamını ve metodolojisini değerlendirmek ve gecikme, bant genişliği kullanımı ve hesaplama yükü gibi temel performans göstergelerini ölçtüğünden emin olmak (Booz Allen, 2025a).

2. Test Sonuçlarını Analiz Etme: Pilot testlerin sonuçlarını gözden geçirerek, geniş ölçekli dağıtımdan önce performans etkilerinin kabul edilebilir operasyonel eşikler içinde olup olmadığına dair bağımsız bir değerlendirme sunmak. Uygulanabilir olduğu durumlarda özel kuantum yazılım test tekniklerinin önemine atıfta bulunmak (Özdemir & Öztürk, 2025).

Aşama 6: Sürekli İzleme ve Raporlama

Hem dış tehditleri hem de iç geçiş ilerlemesini izlemede denetimin devam eden güvence rolünü detaylandırmak 6. aşamanın amacıdır.

Denetim Eylemleri;

1. Tehdit İstihbarat Yeteneğini Değerlendirme: Kurumun kuantum bilişim ve kriptanalizdeki gelişmeleri izleme sürecini değerlendirmek ve bu istihbaratın geçiş planını bilgilendirdiğinden emin olmak (Post-Quantum Financial Infrastructure Framework, 2025).

2. Program Yönetişimi ve Raporlama Denetimi: PQC programının yönetişim yapısını gözden geçirmek ve denetim komitesine ve yönetim kuruluna sunulan ilerleme raporlarının doğru ve şeffaf olduğundan emin olmak için denetlemek (Grant Thornton, 2025).

SONUÇ VE TARTIŞMA

Bulgularda sunulan çerçeve, önemli teorik ve pratik sonuçlar doğurmaktadır. İlk olarak, önerilen denetim çerçevesi, Gordon-Loeb modeli tarafından oluşturulan ekonomik rasyoneli operasyonel hale getirmektedir. Model, neredeyse kesin olan gelecekteki kayıpları göstererek proaktif yatırım için teorik bir gerekçe sunarken, çerçevemiz bu yatırımın etkin, şeffaf ve stratejik risk iştahına uygun bir şekilde yönetildiğine dair güvence sağlamak için iç denetime pratik bir yönetişim mekanizması sunmaktadır.

İkinci olarak, bu çerçeve iç denetim mesleğinin kendisi için önemli zorluklar ortaya koymaktadır. Denetçiler, dik bir öğrenme eğrisiyle ve acil yeni yetkinlik ihtiyaçlarıyla karşı karşıyadır. Bu durum, önerilen "Kuantum Okuryazarlığı Modeli"nin önemini bir kez daha vurgulamaktadır. Olasılıksal kuantum sistemleri ve hibrit mimariler üzerinde güvence sağlamanın getirdiği benzersiz zorluklar, denetim metodolojilerinde köklü bir değişim gerektirecektir (Vinsys, 2025).

Üçüncü olarak, PQC geçişi, artan bir BT riskinden ziyade paradigma değiştiren bir kırılım olarak ele alınmalıdır. Bu durum, daha proaktif ve stratejik bir iç denetim fonksiyonu çağrısını doğrulamaktadır (Wolters Kluwer, 2025).Son olarak, geçiş zaman çizelgelerinin tehdidin ortaya çıkma zaman çizelgesini aşabileceği "risk açığı" kavramı kritik bir öneme sahiptir. İç denetim, bu noktada "kurumun vicdanı" olarak işlev görmeli, bu uzun vadeli ve sistemik riskin daha acil üç aylık baskılar tarafından gölgede bırakılmamasını ve potansiyel etkisinin yönetim kuruluna ve denetim komitesine belirsizlik olmaksızın iletilmesini sağlamalıdır.

Bu çalışma, kuantum çağında iç denetimin reaktif bir uyum fonksiyonundan, kurumsal dayanıklılık inşa etmede proaktif ve stratejik bir ortağa dönüşmesi gerektiğini savunmaktadır. Önerilen altı aşamalı stratejik çerçeve, bu dönüşüm için net bir yol haritası sunarak, denetçilere farkındalık oluşturmaktan sürekli izlemeye kadar uzanan bir rehberlik sağlamaktadır.

çalışmada, PQC algoritmaları üzerine yazılmış son derece teknik literatür ile stratejik denetim ve yönetişim teorisinin ayrık alanı arasındaki önemli uçurumu kapatmakta ve denetimin bu kritik geçişteki güvence rolünü operasyonelleştirmek için kapsamlı bir çerçeve sunulmaktadır

Sunulan çerçeve, iç denetim yöneticilerine ve ekiplerine, güvence faaliyetlerini yapılandırmak için anında, eyleme geçirilebilir bir oyun kitabı sunmakta ve ürkütücü, soyut bir tehdidi yönetilebilir, aşamalı bir yönetişim programına dönüştürmektedir.Bu çalışmanın, mevcut kaynakların sentezine dayalı kavramsal bir çerçeve olduğu ve gelecekte ampirik doğrulamaya ihtiyaç duyduğu kabul edilmelidir.

Gelecekteki araştırmalar şu konulara odaklanabilir: (1) bu çerçeveyi uygulayan finans kurumlarındaki denetim fonksiyonlarına ilişkin vaka çalışmaları, (2) PQC hazırlığı için özel ve ayrıntılı denetim çalışma programlarının geliştirilmesi ve (3) kuantum destekli yapay zeka ve QML sistemlerini denetlemek için gereken yöntem ve beceriler üzerine daha fazla araştırma yapılması.

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MIGRATION DYNAMICS IN SUB-SAHARAN AFRICA: STRUCTURAL CAUSES, REGIONAL IMPACTS, AND INTERNATIONAL POLICIES

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ABSTRACT

Migration in Africa is a multidimensional phenomenon shaped by structural inequalities, political fragility, and the asymmetries of the global system. Migration movements across the continent are not limited to economic factors; they are also driven by armed conflicts, weak state capacity, ethnic and sectarian tensions, and environmental threats caused by climate change. In particular, increasing drought, food insecurity, and the unsustainability of livelihoods in Sub-Saharan Africa have intensified forced migration and internal displacement.

This study examines the root causes of migration in Africa from a structural and regional perspective. First, intra-African migration dynamics and their effects on regional stability are analyzed. Subsequently, irregular migration from Africa to Europe is discussed with reference to its security and humanitarian dimensions. In addition, the European Union's externalized migration policies, cooperation mechanisms with African countries, and readmission agreements are evaluated. The study aims to address migration in Africa through a holistic framework that integrates development, security, and human rights perspectives. In this context, the study also highlights the role of international organizations, regional institutions, and non-state actors in migration governance across Africa. Particular attention is paid to the implications of migration for state sovereignty, border management, and social cohesion in both origin and destination countries. By combining theoretical discussions with policy-oriented analysis, the study seeks to contribute to the academic literature on African migration and to offer insights for more sustainable and rights-based migration policies.

Key Words: Africa, migration, forced migration, irregular migration, Sub-Saharan Africa

INVESTIGATION ON POLYMERS USED IN FUSED DEPOSITION MODELING

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ABSTRACT

3D printing is one of the most important technologies used today. This method, which allows for the production of complex-shaped parts at lower costs and shorter production times than traditional manufacturing methods, is used in many sectors such as aerospace, automotive, medical, and bioengineering. Three-dimensional models designed using Computer-Aided Design programs, or additive manufacturing, are built into an object by stacking thin layers of different materials. Many additive manufacturing methods are available with 3D printing. FDM (fused deposition modeling) is one of the most widely used methods due to its low cost, ease of use, high part quality, and high printing speed. In this method, thermoplastic materials are built layer by layer according to a specific pattern. Thermoplastic materials such as PLA, ABS, and PEEK are used in FDM. This review provides information about the properties of these thermoplastic materials used in FDM. In addition, the mechanical, thermal, and chemical properties of FDM-printed parts are highly dependent on material selection and printing parameters. Understanding the advantages and limitations of commonly used thermoplastics is essential for optimizing part performance in different applications. Factors such as layer adhesion, anisotropy, surface quality, and environmental resistance play a significant role in the final product quality. This review also discusses current challenges in FDM technology and highlights recent developments aimed at improving material performance and expanding the application potential of FDM-based additive manufacturing.

Keywords: 3D printer, FDM (fused deposition modeling), PLA, ABS.

FROM ASANAS TO AWARENESS: YOGA'S INFLUENCE ON PSYCHOLOGICAL WELL-BEING

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ABSTRACT

With its origins in ancient Indian philosophy, yoga is gaining recognition in contemporary society as an additional tactic for promoting psychological well-being. This study explores how yoga practices, such as physical postures (asanas), breath control (pranayama), and meditation mindfulness, affect several facets of mental health. The study explores how regular yoga practice enhances self-awareness, lowers stress, controls emotions, and boosts life satisfaction. It is based on interdisciplinary research from the domains of psychology, neuroscience, and integrative health sciences. The study highlights how yoga serves as both a physical workout and a comprehensive mind-body discipline that fosters inner harmony and cognitive clarity. Yoga can help people become more resilient to the symptoms of anxiety and depression by improving attentional control, lowering cortisol levels, and having a good effect on the autonomic nervous system, according to research. Moreover, yoga's development of attentive awareness makes people better capable of managing life's challenges with composure and adaptability. According to the study, yoga is accessible and flexible for a variety of groups because it is inexpensive and low-risk. Yoga promotes holistic health promotion, long-term behavioral change, and the development of regular practice, which enhances standard mental health interventions in a society where stress is on the rise. This study emphasizes the usefulness of yoga in both preventive and therapeutic mental health settings by fusing contemporary psychological frameworks with traditional yogic knowledge. The findings back up the cautious application of yoga-based treatments to enhance mental health in clinical, educational, and community settings. In the end, the study portrays yoga as a life-changing experience that greatly improves mental health in modern culture, from increased awareness to physical discipline.

Keywords: Yoga, Psychological Well-Being, Mind–Body Integration, Mindfulness, Stress Reduction

Introduction

Since stress, anxiety, depression, and emotional instability are on the rise worldwide, mental health has become a major topic in public health debate in recent decades. Both industrialized and developing civilizations have experienced psychological strain as a result of social isolation, competitive lifestyles, rapid urbanization, and technological dependence. Although there are many evidence-based interventions available in contemporary psychotherapy to address these issues, the benefits of integrative and complementary approaches that prioritize holistic well-being are becoming increasingly acknowledged. Of these, yoga has drawn a lot of interest as a mind-body activity that can promote mental well-being. Yoga, which has its roots in ancient India, is a holistic discipline that combines physical postures (asanas), breathing exercises (pranayama), meditation (dhyana), and moral precepts with the goal of fostering inner peace and self-awareness. Yoga has historically been thought of as a means of achieving self-realization and leading a balanced life. But more and more recent studies are emphasizing its therapeutic value in fostering mental health. Yoga provides a systematic way to control stress reactions and improve emotional stability by activating both physiological and cognitive processes. According to scientific studies, yoga practices enhance attentional control, lower physiological indicators of stress, and have a good impact on the autonomic nervous system. Breathing and movement synchrony promotes present-moment awareness, which is strongly linked to better mood control and less rumination. Additionally, the meditation techniques incorporated into yoga foster reflective awareness, which enables people to notice their thoughts and feelings without reacting right away. A key component of psychological resilience is the transition from reactive to mindful response. A larger trend toward holistic mental health care is reflected in the increasing use of yoga in clinical and

therapeutic settings. To supplement traditional treatment approaches, psychotherapists are increasingly using mindfulness-based practices, breathing exercises, and relaxation techniques inspired by yogic traditions. In addition to improving therapeutic results, this kind of integration equips people with self-regulation abilities that they may use outside of the clinical setting. In light of this, the current study investigates the impact of yoga on psychological health, looking at how the shift from physical discipline to increased awareness promotes mental clarity and emotional equilibrium. This study aims to provide light on yoga's function as a transforming route to comprehensive mental wellness by fusing traditional wisdom with modern psychology knowledge.

Objectives of the Study:

1. To examine the impact of yogic practices on psychological well-being.
2. To analyse the role of yoga in enhancing emotional regulation and stress management.
3. To explore the integration of yoga-based techniques within modern psychotherapeutic approaches.

Research Questions:

1. How do regular yogic practices influence overall psychological well-being?
2. In what ways does yoga contribute to emotional regulation and stress reduction?
3. How can yoga-based techniques be effectively integrated into modern psychotherapeutic practice?

Review of Literature

According to **Domingues (2023)**, a recent systematic review that looked at yoga therapies in both clinical and non-clinical populations consistently concluded that yoga reduces stress, anxiety, and depressive symptoms. The review supported yoga's inclusion in preventative mental health care by highlighting its benefits for self-awareness and emotional control.

In their experimental investigation, **Tolahunase, Sagar, and Faiq (2020)** showed that sustained yoga practice improved subjective well-being while dramatically lowering stress biomarkers, such as cortisol levels. According to the research, yoga improves resilience by regulating both the body and the mind.

Cramer et al. (2018) concluded that yoga had moderately beneficial benefits on depression when compared to conventional treatment in a thorough meta-analysis of randomized controlled studies. Yoga was emphasized by the authors as a potentially effective supplemental intervention for mental health care.

In their research of yoga's effects on stress and mood disorders, **Pascoe & Bauer (2015)** came to the conclusion that yoga improves emotional stability by lowering hypothalamic-pituitary-adrenal (HPA) axis activation and promoting parasympathetic nervous system functioning.

According to Goyal et al. (2014), a comprehensive meta-analysis of meditation programs that incorporate yoga-based techniques revealed modest improvements in pain, anxiety, and sadness. Yoga's mindfulness elements were very successful in lowering psychological distress.

A neurophysiological model was put up by **Streeter et al. (2012)** to explain how yoga affects the brain's levels of gamma-aminobutyric acid (GABA). Improved mood and decreased anxiety were linked to increased GABA activity, providing a scientific explanation for the psychological advantages of yoga.

According to Khalsa's (2010) research, individuals who used systematic yogic breathing and meditation practices reported significantly lower levels of anxiety and better emotional regulation.

In a randomized controlled trial, **Smith et al. (2009)** found that yoga practitioners reported higher levels of stress and anxiety reductions than those in relaxation-only groups, suggesting the unique therapeutic benefits of yoga.

According to **Brown & Gerbarg (2005),** breath management is essential to psychological balance, and the authors emphasized the therapeutic potential of yogic breathing (pranayama) in treating anxiety, depression, and post-traumatic stress disorder (PTSD).

A preliminary clinical investigation by **Shapiro et al. (1998)** revealed that mindfulness meditation techniques with yogic roots enhanced mood and decreased stress in medical professionals, pointing to potential wider uses in populations that are prone to stress.

Kabat-Zinn (1990) This seminal work draws substantially from yogic meditation traditions, although being focused on Mindfulness-Based Stress Reduction (MBSR). Results showed improved psychological well-being and notable decreases in chronic stress.

Benson (1975) established early scientific support for mind-body practices in stress reduction with his groundbreaking work on the "relaxation response," which found physiological mechanisms that resemble meditative characteristics of yoga, such as decreased heart rate and oxygen consumption.

Methodology

The current study uses a qualitative research approach to investigate the impact of yoga on mental health and its applicability in modern psychotherapy settings. A qualitative approach is suitable for comprehending the breadth, significance, and subjective aspects of psychological transformation connected to yogic practices because yoga is a mind-body discipline that is conceptual and experiential in character. The study's main foundation is a thorough evaluation and interpretive analysis of the body of existing academic literature, which includes theoretical papers, systematic reviews, peer-reviewed journal articles, and meta-analyses produced between 1975 and 2023. These resources were chosen because they offer both historical underpinnings and up-to-date scientific viewpoints on the psychological effects of yoga. Keywords such as "yoga and mental health," "yoga and stress reduction," "yoga and emotional regulation," "mind–body interventions," and "yoga in psychotherapy" were used to search databases including PubMed, Google Scholar, APA PsycINFO, and other academic repositories. To maintain consistency and credibility, only research written in English and published in respectable journals was included. The results from the studied literature were combined using a theme analysis approach. Recurring themes pertaining to psychological well-being, such as stress reduction, emotional regulation, self-awareness, resilience, neurobiological mechanisms, and integration into therapeutic settings, were found by closely examining the chosen studies. In order to comprehend how yoga practices affect mental health outcomes, these themes were grouped and analyzed within a more comprehensive psychological framework. A conceptual-analytical method was also employed in the study to investigate theoretical hypotheses that explain the efficacy of yoga, including autonomic nervous system modulation, mindfulness-based awareness, and neurochemical alterations (e.g., GABA activity). The study places more emphasis on interpretative knowledge of how physical postures, breathing exercises, and meditation together promote psychological equilibrium than it does on quantitative effect sizes. Ethical considerations were maintained by accurately representing the findings of previous researchers and avoiding misinterpretation of results. Since the study is based entirely on secondary data, no direct human participants were involved. Through this qualitative synthesis, the methodology aims to provide a comprehensive and integrative understanding of yoga as a holistic intervention that bridges ancient traditions with modern psychological science.

Theoretical Framework

This study's theoretical underpinnings are based on an integrative mind-body viewpoint that links modern psychological theories with traditional yogic philosophy. According to the ancient Indian classic Patanjali's Yoga Sutras, yoga views mental health as a condition of equilibrium attained by controlling one's thoughts, emotions, and physical functions. A philosophical foundation for comprehending how yoga practices foster psychological stability is provided by the core idea of "Chitta Vritti Nirodha," which is the calming of mental fluctuations. According to this paradigm, the mind and body are interdependent systems, and cognitive and emotional functioning are influenced by physical discipline and breath control. The study's psychological foundation is the biopsychosocial model, which highlights how social, psychological, and biological variables interact to shape mental health. Asanas and pranayama are examples of yoga practices that are known to control physiological reactions, especially the autonomic nervous system. By promoting relaxation and lowering stress reactivity, deep breathing and mindful movement activate the parasympathetic nervous system, which supports emotional control and resilience. The mindfulness theory, which emphasizes nonjudgmental awareness of the present moment, also informs the framework. Yoga meditation techniques help people develop attentional

control and meta-awareness, which enables them to notice their thoughts and feelings without reacting right away. This procedure is consistent with cognitive-behavioral viewpoints, which place an emphasis on reorganizing unhelpful thought processes and enhancing self-control. Yoga helps people develop better coping mechanisms and experience less psychological distress by increasing awareness and decreasing automatic reactions. Neuropsychological theories also offer additional support for explanation. According to research, yoga affects neurotransmitter activity, such as elevated levels of gamma-aminobutyric acid (GABA), which are linked to mood enhancement and decreased anxiety. The psychological advantages seen in both clinical and non-clinical individuals can be explained by these neurobiological alterations. These theoretical stances combine to create a thorough framework that presents yoga as a multifaceted intervention that affects the body, mind, and emotions. The study's main hypothesis that yoga helps people move from physical practice to heightened awareness and ultimately promote psychological well-being in modern therapeutic contexts is supported by this framework, which combines traditional yogic philosophy with contemporary psychological and neuroscientific models.

Analysis and Discussion

By combining physical, physiological, and cognitive processes, yoga has a multifaceted impact on psychological well-being, according to the analysis of the reviewed research. Yoga serves as a comprehensive intervention that addresses the connection between the mind and body, in contrast to discrete therapeutic approaches that mainly concentrate on either behavior or cognition. Regular yoga practice has been consistently linked to lower stress, better mood, better emotional regulation, and more self-awareness, according to the research. The effect of yoga on stress reduction is a major issue that emerges from the literature. The parasympathetic nervous system is activated by techniques like meditative awareness and controlled breathing (pranayama), which offset the sympathetic nervous system's activation brought on by stress. A slower heart rate, lower cortisol levels, and a perceived sense of tranquility are the results of this physiological change. This kind of control fosters psychological resilience by empowering people to face difficulties calmly rather than reactively. This is in line with modern stress-management approaches that prioritize self-regulation abilities from a therapeutic perspective. Emotional control is the subject of another noteworthy discovery. Yoga's cultivation of focused attention heightens awareness of one's own inner experiences, including sensations and ideas. People are able to witness emotional states without being overcome by them thanks to this increased awareness. From a cognitive-behavioral perspective, this process disrupts maladaptive thought processes including catastrophizing and rumination. According to research, yoga practitioners exhibit better attentional regulation as well as less signs of anxiety and despair. These results imply that yoga increases psychological flexibility and promotes adaptive coping mechanisms. This conversation is further enhanced by neuropsychological explanations. The apparent psychological benefits are biologically supported by studies suggesting enhanced brain control and higher gamma-aminobutyric acid (GABA) activity. These results support the idea that yoga is a disciplined practice that can affect brain function and emotional equilibrium rather than just being a relaxing method. This biological foundation strengthens yoga's legitimacy in contemporary psychotherapy contexts. Crucially, a larger trend toward holistic mental health treatment is reflected in the incorporation of yoga into psychotherapy. In order to supplement conventional therapies, therapists are increasingly using yoga-inspired mindfulness practices, body awareness exercises, and breathing exercises. Clients are equipped with useful tools for self-management outside of treatment sessions thanks to this integrative approach. When accessible and affordable solutions are required, yoga-based interventions may be especially helpful in community programs, educational institutions, and preventive mental health care. But the conversation also recognizes that in cases of serious mental illness, yoga cannot replace medical care. Rather, it is a supplemental strategy that improves treatment results. The necessity for standardized intervention models in future research is indicated by the variation in yoga practice types, length, and intensity among studies. Overall, the study shows that yoga helps people make the shift from physical discipline to increased awareness. Yoga adds considerably to psychological well-being and has intriguing opportunities for integration within modern psychotherapy by fostering physiological balance, emotional regulation, and cognitive clarity.

Key Findings

1. **Significant Reduction in Stress Levels:** Regular yoga practice has been shown to improve emotional stability and relaxation responses by reducing physiological stress indicators and perceived stress.

2. **Improvement in Emotional Regulation:** Yoga increases mental and emotional awareness, which helps people better control their emotions and react to difficulties in a more balanced way.

3. **Reduction in Anxiety and Depressive Symptoms:** Consistent yoga practitioners report moderate improvements in their anxiety and depression symptoms, according to evidence from reviewed studies.

4. **Enhancement of Mindfulness and Self-Awareness:** By fostering present-moment awareness, yogic meditation and breath control techniques lessen rumination and increase psychological clarity.

5. **Positive Neurophysiological Changes:** Research indicates that yoga may enhance neurotransmitter activity linked to elevated mood and decreased anxiety, as well as promote the control of the autonomic nervous system.

6. **Effective Complementary Tool in Psychotherapy:** When incorporated into contemporary therapeutic contexts, yoga-based practices improve treatment outcomes and give clients useful self-regulation skills outside of therapy sessions.

Conclusion

The study emphasizes yoga as a whole practice that integrates physical postures, breath control, and meditative awareness to greatly enhance psychological well-being. Yoga lowers stress, improves emotional regulation, and lessens the symptoms of anxiety and depression, according to research already in existence. Beyond just improving physical fitness, it also promotes self-awareness and mental clarity. Yoga is a useful adjunctive technique that gives people long-lasting self-regulation skills when carefully included into contemporary psychotherapy settings. All things considered, yoga offers a significant link between traditional knowledge and modern mental health treatment, encouraging resilient and balanced life.

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INVESTIGATION OF SOCIAL ASSISTANCE DEPENDENCY LEVELS OF INDIVIDUALS RECEIVING SOCIAL ASSISTANCE

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ABSTRACT

In this study, the relationship between individuals' levels of social assistance dependency and various socio-demographic variables was analyzed. A relational survey model was employed in the study. The participants were beneficiaries of the Social Assistance and Solidarity Foundation (SYDV). The data were collected with a personal information form including demographic information and a scale measuring social assistance dependency, developed by Nurdoğan (2022). The data of a total of 98 participants were transferred to the SPSS 26 programme and nonparametric tests were used in the analysis of the data. No statistically significant relationship was found between social assistance dependency levels and variables such as gender, marital status, age, employment history, İŞKUR registration, participation in vocational training, duration of unemployment, number of children, length of receiving assistance, source of assistance, or support from the extended family, receiving social assistance from the root family. However, the social assistance dependency levels of beneficiaries without primary school graduation were found to be statistically significantly higher than those with primary school graduation and those with at least secondary school graduation. In addition, a statistically significant positive correlation was found between the level of social assistance dependency and the number of children. It was found that there was a statistically significant negative correlation between the level of social assistance dependency and the number of people living at home and average household income variables. The findings are expected to contribute to the literature and offer valuable insights for institutions providing social assistance. There is a need to develop objective and measurable methods on the effectiveness of social assistance in our country.

Key Words: Welfare dependency, social assistance dependency, poverty, social work.

THE CONTRIBUTION OF DIGITAL TOOLS IN PUBLIC AUDITING TO TRANSPARENCY AND ACCOUNTABILITY

KAMU DENETİMİNDE DİJİTAL ARAÇLARIN ŞEFFAFLIK VE HESAP VEREBİLİRLİĞE KATKISI

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ABSTRACT

This study examines the role of digital tools in enhancing transparency and accountability within public sector auditing. In the context of digital transformation, audit processes are increasingly supported by data-driven systems, integrated information infrastructures, and real-time monitoring mechanisms, which fundamentally reshape traditional oversight practices. The study argues that digital audit tools contribute to transparency by improving traceability, accessibility, and verifiability of public data, while simultaneously strengthening accountability through timely detection of risks, irregularities, and inefficiencies. By enabling continuous, risk-oriented, and proactive audit practices, digital technologies reduce information asymmetries between public administrations and stakeholders and reinforce trust in public governance. The study concludes that digital tools in public auditing should be considered not merely as technical instruments, but as strategic governance mechanisms that support democratic oversight, institutional responsibility, and sustainable public management.

Keywords: Public Auditing, Digital Audit Tools, Transparency, Accountability, Digitalization, Public Administration

ÖZET

Bu çalışma, kamu denetiminde dijital araçların şeffaflık ve hesap verebilirliğin güçlendirilmesine olan katkısını incelemektedir. Dijital dönüşüm sürecinde denetim faaliyetleri, veri temelli sistemler, bütünleşik bilgi altyapıları ve gerçek zamanlı izleme mekanizmalarıyla desteklenerek geleneksel gözetim anlayışını önemli ölçüde dönüştürmektedir. Çalışmada, dijital denetim araçlarının kamu verilerinin izlenebilirliğini, erişilebilirliğini ve doğrulanabilirliğini artırarak şeffaflığı güçlendirdiği; risk, usulsüzlük ve verimsizliklerin zamanında tespit edilmesine imkân tanıyarak hesap verebilirlik mekanizmalarını desteklediği vurgulanmaktadır. Sürekli, risk odaklı ve proaktif denetim uygulamalarına olanak sağlayan dijital teknolojiler, kamu yönetimi ile paydaşlar arasındaki bilgi asimetrisini azaltmakta ve yönetişime duyulan güveni pekiştirmektedir. Bu çerçevede çalışma, kamu denetiminde kullanılan dijital araçların yalnızca teknik çözümler değil, demokratik denetimi, kurumsal sorumluluğu ve sürdürülebilir kamu yönetimini destekleyen stratejik yönetişim araçları olduğunu ortaya koymaktadır.

Anahtar Kelimeler: Kamu Denetimi, Dijital Denetim Araçları, Şeffaflık, Hesap Verebilirlik, Dijitalleşme, Kamu Yönetimi

YAPAY ZEKÂ ÇAĞINDA MESLEKLERİN YENİDEN DOĞUŞU: KAYBOLAN İŞLER, DÖNÜŞEN ROLLER VE YÜKSELEN FIRSATLAR

THE REBIRTH OF OCCUPATIONS IN THE AGE OF ARTIFICIAL INTELLIGENCE: DISAPPEARING JOBS, EVOLVING ROLES, AND EMERGING OPPORTUNITIES

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ÖZET

Yapay zekâ (YZ) ve otomasyon teknolojilerindeki hızlı gelişmeler, işgücü piyasalarının yapısını köklü biçimde değiştiren bir dönüşümü beraberinde getirmektedir. Bu çalışma, söz konusu dönüşümü meslekler bağlamında ele alarak iş tanımlarının nasıl yeniden şekillendiğini, hangi mesleklerin kaybolma riskiyle karşı karşıya olduğunu ve ortaya çıkan yeni meslek alanlarının hangi özellikleri taşıdığını açıklamaktadır.

YZ, özellikle tekrarlayan ve kural temelli görevleri devralarak birçok meslekte görev dağılımını yeniden düzenlemekte, buna karşılık insanın yaratıcılık, iletişim, problem çözme ve teknolojiyi yönlendirme gibi becerilere dayalı rollerinin önemini artırmaktadır. Mesleklerdeki dönüşüm, işlerin tamamen ortadan kalkmasından çok, görev bileşenlerinin yeniden tanımlanması şeklinde ortaya çıkmakta, düşük beceri düzeyine sahip ve tekrar eden işlerde çalışan bireyler bu süreçten daha fazla etkilenmektedir. Bununla birlikte YZ, veri bilimi, YZ geliştirme, algoritmik denetim, teknoloji etiği, otonom sistem yönetimi ve dijital içerik üretimi gibi alanlarda yeni meslek fırsatları yaratmakta ve işgücü yapısının niteliksel olarak çeşitlenmesine katkı sağlamaktadır.

Çalışma, YZ'nın iş yaşamında yalnızca mevcut işleri dönüştüren değil, aynı zamanda yeni uzmanlık alanları oluşturan çok yönlü bir güç hâline geldiğini ortaya koymakta ve geleceğin iş dünyasında teknolojiyle uyumlu becerilere sahip olmanın belirleyici olacağını vurgulamaktadır.

Anahtar Kelimeler: Yapay Zekâ, Dijital Dönüşüm, Mesleklerin Dönüşümü

ABSTRACT

Rapid advances in artificial intelligence (AI) and automation technologies are bringing about a transformation that is fundamentally changing the structure of labor markets. This study examines this transformation in the context of occupations, explaining how job descriptions are being reshaped, which occupations are at risk of disappearing, and what characteristics the emerging new occupational fields possess.

AI, particularly by taking over repetitive and rule-based tasks, is reorganizing the distribution of tasks in many professions, in contrast, it is increasing the importance of roles based on human skills such as creativity, communication, problem solving, and directing technology. The transformation in professions manifests itself not so much in the complete disappearance of jobs, but rather in the redefinition of task components, with individuals working in low-skill and repetitive jobs being more affected by this process. However, AI is creating new career opportunities in fields such as data science,

AI development, algorithmic control, technology ethics, autonomous system management, and digital content production, contributing to the qualitative diversification of the workforce.

The study reveals that AI has become a multifaceted force in the workplace that not only transforms existing jobs but also creates new areas of expertise, emphasizing that possessing technology-compatible skills will be decisive in the future world of work.

Keywords: Artificial Intelligence, Digital Transformation, Transformation of Jobs

GİRİŞ

Dijital dönüşümün hız kazandığı 20. yüzyılın ortalarında yapay zekâ (YZ), küresel ölçekte ekonomik, toplumsal ve örgütsel yapıları yeniden şekillendiren temel bir güç haline gelmiştir (Akinnagbe, 2024). Hesaplama gücünün artması, büyük veri kaynaklarının çeşitlenmesi ve algoritmik modelleme tekniklerinin gelişmesi sonucunda YZ, yalnızca teknolojik bir yenilik olmanın ötesine geçmekle kalmamış ayrıca iş yapma biçimlerini, üretim süreçlerini ve mesleki rolleri köklü biçimde etkileyen stratejik bir unsur haline evrilmiştir (Fatima vd., 2024). Bu kapsamda YZ, önceki endüstri devrimlerinde olduğu gibi işgücünün niteliklerini yeniden tanımlamaktadır. Bu bağlamda YZ bazı mesleklerin önemini artırırken bazılarını ise işlevsiz hale getirebilecek dönüşümler yaratabilmektedir. Özellikle Endüstri 4.0 ile uyumlu olarak ortaya çıkan akıllı üretim sistemleri, robotik süreç otomasyonu, makine öğrenmesi tabanlı karar destek mekanizmaları ve doğal dil işleme uygulamaları, insan emeğinin yerini kısmen veya tamamen alabilecek düzeye kadar ulaşmıştır. Dolayısıyla günümüzde mesleklerin geleceğine ilişkin tartışmalar, teknolojik gelişmenin hızına paralel olarak daha görünür ve akademik açıdan daha kritik bir konu haline gelmiştir (Hossain, 2023).

YZ'nin meslekler üzerindeki etkisinin tartışılmasında üç temel dinamik öne çıkmaktadır. Birincisi, iş süreçlerinin otomasyonu ile rutin ve tekrarlayıcı işlerin gitgide daha fazla dijital sistemlere devredilmesi durumudur (Autor, 2015). Bu durum, geleneksel iş tanımlarını dönüştürerek bazı mesleklerin gelecekte varlığını sürdüremeyeceğine ilişkin öngörüleri güçlendirmektedir. İkincisi, YZ'nin sadece düşük nitelikli fiziksel işleri değil, buna ek olarak belirli bilişsel süreçleri de üstlenebilir hale gelmesidir (Brynjolfsson vd., 2018). Bu bağlamda, algoritmik karar alma mekanizmaları, veri analitiği ve doğal dil işleme araçları, geçmişte yalnızca insan uzmanlığı ile yürütülen bazı mesleki görevleri destekleyici rol üstlenmektedir. Üçüncüsü ise YZ'nin tamamen olumsuz bir görünümden ibaret olmadığını yeni iş alanları, yeni meslek rolleri ve dijital yetkinlik temelli beceri gruplarının ortaya çıkmasına da zemin hazırladığıdır (Di Battista vd., 2023). Bu nedenle YZ, yalnızca bir tehdit olarak değerlendirilmemekte, aynı zamanda işgücü piyasasının yeniden yapılanmasında önemli fırsatlar sunan bir inovasyon kaynağı olarak görülmektedir.

Bu çalışma, söz konusu dönüşümün kavramsal boyutunu ele alarak YZ'nin mesleklerin geleceği üzerindeki etkisini akademik bir bakış açısıyla incelemeyi amaçlamaktadır. Çalışmanın temel odağı, literatürde kaybolma riski olan meslek kategorilerinin genel bir sınıflandırmasını ortaya koymak ve YZ ile birlikte dönüşen iş tanımlarını teorik bir çerçeve içinde değerlendirmektir. Bu doğrultuda çalışma, YZ'nin işgücü piyasasını nasıl yeniden yapılandırdığına ilişkin kapsamlı bir giriş sunmakta ve sonraki bölümlere kuramsal bir temel oluşturmaktadır.

YAPAY ZEKÂ VE OTOMASYON TEKNOLOJİLERİNDEKİ GELİŞMELER

Son yıllarda YZ ve otomasyon teknolojilerindeki ilerlemeler, işgücü piyasaları üzerinde yalnızca kademeli değil, yapısal ve potansiyel olarak yıkıcı etkiler yaratma kapasitesine sahiptir. Makine öğrenmesi, derin öğrenme, doğal dil işleme ve otonom sistemler gibi YZ'nın alt alanlarının kaydettiği kısa süreli gelişmeler yalnızca teknik değil ekonomik ve toplumsal düzeyde de dönüşümün merkezine oturmuştur. Bu dönüşüm, işin doğasını, istihdam biçimlerini ve mesleklerin içeriğini yeniden tanımlamaktadır.

YZ'nin otomasyon kapasitesi, özellikle "tekrar eden, rutin ve düşük bilişsel beceri" gerektiren görevlerde çalışana olan bağımlılığı azaltmaktadır. Literatürde bu durum, işlerin otomatikleşmesi ve düşük beceri gerektiren mesleklerin risk altına girmesi olarak görülmektedir (Zhou vd., 2025).

TEKNOLOJİK TEMELLER VE GENİŞLEYEN UYGULAMALAR

YZ teknolojilerinin en kritik bileşenlerinden biri makine öğrenmesi ve derin öğrenmedir. Bu teknikler, kodlanmış kurallara bağlı kalmaksızın veriden öğrenmeye dayalı çözümler sunmaktadır. Bu durum ise, geleneksel otomasyonun ötesine geçen akıllı otomasyonu mümkün kılmaktadır. Örneğin görüntü/ses tanıma, doğal dil işleme, tahminleme analitiği gibi uygulamalar bir zamanlar yalnızca insan uzmanlığı gerektirirken, artık YZ modelleri tarafından yüksek doğrulukla gerçekleştirilebilmektedir. Bu durum, otomasyonun salt fiziksel işlevlerle sınırlı kalmayıp bilişsel ve idari görevleri de kapsamasına yol açmaktadır. Ancak bu teknolojik evrim, yalnızca sektörlere değil, mesleklerin temel tanımlarına yönelik ciddi bir saldırıdır**.**

OTOMASYON, YZ VE EMEK PİYASASINDAKİ DÖNÜŞÜM

Çok sayıda ampirik çalışma ve analiz, YZ'nin emek piyasasında "yerinden etme" etkisi yaratabileceğini göstermektedir (Acemoğlu & Restrepo, 2018).

Özellikle düşük ve orta beceri gerektiren işler örneğin, tekrarlı üretim, veri girişi, rutin idari işler, otomasyon baskısı altında kalmaktadır. Bu durum, yalnızca iş kayıplarını değil, aynı zamanda ücret yapısında da bozulmaları beraberinde getirmektedir: otomasyon teknolojilerinin yaygınlaştığı sektörlerde düşük–orta beceri sahibi çalışanların ücretleri durağan kalabilir ya da düşebilir (Lábaj vd., 2025).

Yine de YZ etkisi her sektörde homojen olmayabilir. Bazı araştırmalar, YZ benimseyen şirketlerde istihdamda net azalma değil aksine, faaliyetlerde büyüme ve yüksek katma değerli işlerde artış gözlemlendiğini bildirmektedir (Zhang, 2023). Bu bulgu, YZ'nin yalnızca "insanı işten çıkaran bir güç" değil, aynı zamanda "işin niteliğini yeniden tanımlayıp yeni istihdam alanları yaratabilen potansiyel bir mekanizma" olduğunu göstermektedir.

YENİ İŞ ALANLARI, HİBRİT MODELLER VE YAPAY ZEKÂ İLE İNSAN İLİŞKİSİ

Yükümlülük yalnızca kayıplardan ibaret değildir. YZ'ya dayalı dönüşüm, yeni iş alanlarının doğmasına, mesleklerin yeniden biçimlenmesine ve insan-makine iş birliği modellerinin gelişmesine de olanak sağlamaktadır. Özellikle veri analitiği, YZ sistem geliştirme, otomasyon yönetimi gibi alanlarda yetenekli bireylere yönelik yeni fırsatlar belirmektedir (Şimşek, 2023).

Bu açıdan bakıldığında, YZ otomasyonu sadece mevcut işleri ortadan kaldıran değil, aynı zamanda işin doğasını, niteliğini ve gereksinimlerini yeniden tanımlayan bir katalizör görevini üstlenmektedir. Bu süreç, çalışanlardan yalnızca "eski becerilerle verimlilik" değil, "yeni becerilerle uyum ve yaratıcı problem çözme" beklemektedir.

RİSK VE FIRSAT DENGESİ

YZ ve otomasyonun gelişmeleri hem ciddi riskler barındırmakta hem de önemli fırsatlar sunmaktadır. Düşük beceri gerektiren ve tekrarlayan işler otomatikleşme riski altındayken; dijital beceriye sahip, esnek ve öğrenmeye açık işgücü grupları için yeni alanlar açılmaktadır. Ancak bu dönüşümün adil ve kapsayıcı olabilmesi, eğitim sistemlerinin, meslek içi öğrenme programlarının, yeniden beceri kazandırma süreçlerinin ve işgücü politikalarının uygun biçimde yeniden tasarlanmasına bağlıdır.

Eğer bu tür yapısal dönüşümler göz önünde bulundurulmazsa, YZ çağında işgücü piyasasında yalnızca teknolojik değil, aynı zamanda toplumsal ve ekonomik eşitsizliklerin derinleştiği bir süreç yaşanabilir.

İŞGÜCÜ PİYASALARINDA DÖNÜŞÜM: OTOMASYONUN ETKİLERİ

Teknolojik ilerleme, özellikle YZ ve otomasyonun yaygınlaşması ile üretim, hizmet ve idari alanlarda, geleneksel istihdam düzenini kökten sarsan bir yeniden konumlama meydana gelmektedir. Bu iktisadi kırılma, yalnızca iş yapma biçimlerini değil, işgücü talebi, mesleklerin niteliği ve gelir dağılımı gibi temel işgücü piyasası parametrelerini derinden etkilemektedir.

Empirik literatür, otomasyonun istihdam üzerindeki etkisinin tek yönlü olmadığını; sektör, ülke düzeyi ve teknolojinin türüne göre büyük farklılıklar taşıdığını göstermektedir. Örneğin, bir çalışmada

endüstriyel robot kullanımı ve otomasyonun üretim sektöründeki istihdamı azalttığı, ancak bu kayıpların hizmet sektöründe istihdam artışı ile kısmen telafi edildiği belirtilmektedir (Filippi vd., 2023).

Diğer bir araştırma ise otomasyonun bazı firma düzeylerinde istihdamı pozitif etkilediğini özellikle otomasyonu benimseyen işletmelerde istihdam artışı gözlemlendiğini vurgulamaktadır (Ryberg, 2025).

Öte yandan, özellikle gelişmekte olan ülkelerde yapılan bir panel analiz, yabancı kaynaklı robot ve otomasyon teknolojilerinin yaygınlaşmasının sektörel bazda istihdamı olumsuz etkilediğini ortaya koymuştur. Araştırma hem yerli hem yabancı robot kullanımının bazı sektörlerde iş gücünü azalttığını ve bu etkiyi ücretlere ve emek payına yansıyabileceğini belirtmektedir (Pavez & Martínez-Zarzoso, 2024).

Bu çelişkili bulgular, otomasyonun "insan emeğini ortadan kaldıran makine" olarak algılanmasının fazla basitleştirici olduğunu gösterir. İstihdam üzerindeki net etki; otomasyonun kapsamı, toplumun yapısı, sektör dağılımı ve işgücünün beceri profili gibi birçok değişkene bağlıdır.

Otomasyon ve YZ teknolojilerinin işgücü piyasasında yarattığı dönüşüm, özellikle mesleklerin niteliği ve beceri gereksinimleri bakımından belirgin bir kutuplaşma eğilimine işaret etmektedir. Literatürde, rutin ve tekrarlayan görevleri içeren düşük ve orta beceri düzeyindeki işlerin otomasyon karşısında yüksek risk altında olduğu; buna karşılık analitik düşünme, yaratıcılık, dijital yeterlilik ve problem çözme gibi ileri düzey bilişsel beceriler gerektiren mesleklerin daha korunaklı konumda bulunduğu belirtilmektedir (Wang & Lu, 2025).

Bu durum, orta beceri düzeyindeki birçok mesleğin daralmasına, düşük becerili işlerin ise doğrudan makineleşme tehdidiyle karşı karşıya kalmasına yol açarken; yüksek beceri gerektiren işlerde istihdam talebi artmakta ve ücret yapısı bu doğrultuda değişmektedir. Araştırmalar, otomasyonun emek talebinde neden olduğu bu ayrışmanın ücret eşitsizliklerini derinleştirdiğini, yüksek vasıflı çalışanların kazançlarının arttığını, buna karşılık otomasyona duyarlı işlerde çalışanların ücretlerinin baskılandığını göstermektedir (Sultana vd., 2024).

Teknolojiyi etkin biçimde benimseyen firmalarda otomasyonun istihdamı azaltmak yerine artırdığına dair bulgular da mevcuttur. Bu bağlamda otomasyonun etkisi, firmaların ölçeği, stratejik yönelimi ve dijital yetkinlik düzeyine göre farklılaşmaktadır (Ryberg, 2025).

Ancak teknolojik dönüşümün yarattığı bu faydalar tüm çalışan grupları için eşit şekilde erişilebilir değildir; yeniden beceri kazanabilen, dijital okuryazarlığı gelişmiş bireylerin yeni iş alanlarına uyumu daha kolay olurken, düşük vasıflı işgücü için iş geçişleri çoğu zaman sınırlıdır ve sosyal hareketliliği azaltıcı bir etki doğurmaktadır.

Bu bağlamda otomasyon, yalnızca mesleklerin yapısını değil, aynı zamanda gelir dağılımını, emek piyasasındaki konumlanmayı ve bölgesel eşitsizlikleri de yeniden şekillendirmektedir. Teknolojik yoğunluğu yüksek kentlerde iş kaybı ve dönüşüm daha hızlı yaşanırken, düşük teknolojili bölgelerde etkiler daha yavaş ve sınırlı olmaktadır. Tüm bu bulgular, otomasyonun işgücü piyasasında ortaya çıkardığı dönüşümün tek yönlü bir "iş kaybı" meselesi olmadığını, tam tersine işin niteliği, beceri talebi, ücret yapısı ve sosyal adalet açısından çok katmanlı bir yeniden yapılanma süreci olduğunu göstermektedir. Dolayısıyla otomasyonun etkisi, bir kader değil, ülkelerin eğitim politikaları, beceri gelişim stratejileri ve istihdam planlamalarıyla yönetilebilecek, ancak doğru biçimde ele alınmadığında toplumsal eşitsizlikleri derinleştirme potansiyeli taşıyan bir dönüşümdür.

KAYBOLMA RİSKİ ALTINDAKİ MESLEK GRUPLARI

YZ ve otomasyonun işgücü piyasası üzerindeki etkilerine ilişkin çalışmalar, belirli meslek gruplarının diğerlerine kıyasla çok daha yüksek kaybolma riski taşıdığını ortaya koymaktadır. Bu alandaki en kapsamlı erken çalışmalardan biri olan Frey ve Osborne'un (2017) ünlü Oxford çalışması, ABD'deki işlerin yaklaşık %47'sinin otomasyon riski altında olduğunu göstermiş; özellikle rutin, tekrarlanabilir ve kural tabanlı işlerin makineleşmeye en elverişli kategoriyi oluşturduğunu belirtmiştir. Benzer şekilde, OECD'nin 2018 raporu, Frey ve Osborne'un öngörülerini daha ihtiyatlı bir bakışla yeniden değerlendirerek üye ülkelerdeki işlerin ortalama %14'ünün tamamen otomatikleşme riski altında olduğunu, %32'sinin ise görev düzeyinde önemli dönüşüm geçireceğini göstermiştir (Nedelkoska & Quintini, 2018). Her iki çalışma da en yüksek risk grubunun "düşük beceri-yüksek tekrar" içeren

meslekler olduğunu vurgulamaktadır. Bu meslekler arasında veri girişi elemanları, sekreterlik ve temel büro işleri gibi idari görevler, kasiyerlik, çağrı merkezi operatörlüğü ve müşteri temsilciliği gibi hizmet sektörü pozisyonları; montaj hattı işçiliği, paketleme ve kalite kontrol gibi üretim süreçleri, ayrıca şoför, depo işçisi, taşımacılık ve lojistikte yer alan rutin görevler bulunmaktadır (World Economic Forum, 2020). Örneğin McKinsey Global Institute'un 2021 raporu, kasiyerlik, depo çalışanlığı, montaj operatörlüğü ve kamyon-otobüs sürücülüğü gibi mesleklerde otomasyon potansiyelinin %70'in üzerinde olduğunu ortaya koymuştur (Lund vd., 2021).

Buna karşılık, öğretmenlik, hemşirelik, sosyal hizmet uzmanlığı veya yaratıcı meslekler gibi yoğun insan etkileşimi, empati veya yaratıcılık gerektiren alanların otomasyon riskinin oldukça düşük olduğu belirtilmiştir. Ancak literatürde bu noktada önemli bir ayrım bulunmaktadır: risk, mesleğin tamamen ortadan kalkmasından ziyade, meslek içindeki görevlerin otomatikleşmesi şeklinde gerçekleşmektedir. Örneğin muhasebecilik mesleğinin tamamının yok olacağına dair doğrudan bir akademik bulgu bulunmamaktadır; ancak veri işleme, raporlama ve belge kontrolü gibi görevlerin YZ ile otomatikleşeceği çok sayıda çalışmada doğrulanmıştır. Benzer biçimde, hukuk mesleğinin tamamen ortadan kalkacağına dair literatürde bir kanıt yoktur; ancak davalar için belge tarama, içtihat analizi ve sözleşme inceleme gibi alt görevlerin otomasyonla hızlı biçimde dönüştüğü gösterilmiştir (Susskind, 2023). Bu nedenle, kaybolma riski, meslek bazlı değil görev bazlı bir kavramdır. Üretim işçiliği, veri giriş operatörlüğü, müşteri hizmetleri, temel muhasebe ve büro hizmetleri gibi meslekler, yüksek otomasyon riski taşıyan sektörlerin başında gelirken, sağlık, eğitim, yaratıcı sektörler, liderlik ve sosyal etkileşim gerektiren mesleklerin risk düzeyi oldukça düşüktür.

Kaybolma riskine ilişkin mevcut çalışmalar, aslında mesleklerin tamamen ortadan kalkmasından ziyade, o mesleklerin içindeki görevlerin büyük ölçüde yeniden tanımlandığını ortaya koymaktadır. Bu nedenle otomasyonun en sert etkilediği kesim, çoğunlukla düşük eğitim düzeyine sahip olan ve işi büyük ölçüde tekrarlayan görevlerden oluşan çalışan gruplarıdır. YZ destekli otomasyon bu görevleri hızla devraldıkça, söz konusu çalışanların iş güvencesi zayıflamakta ve yeni becerilere geçiş yapma imkânları da sınırlı kalmaktadır. Bu durum, işgücü piyasasında kırılganlığın en yoğun yaşandığı kümeyi açık biçimde tanımlayan temel unsur hâline gelmektedir.

YAPAY ZEKÂ İLE DEĞİŞEN ROL VE İŞ TANIMLARI

YZ'nin iş yaşamına entegrasyonu, mesleklerin yalnızca teknik yönlerini değil, çalışanların üstlendikleri rollerin niteliğini de köklü biçimde yeniden şekillendirmektedir. Temel gözlem, YZ'nin insan emeğini tümüyle ikame etmekten ziyade, iş süreçlerinin yapısını dönüştürdüğüdür. Bu dönüşüm literatürde genellikle "işin yeniden tasarımı" çerçevesinde ele alınmakta ve özellikle rutin, kural tabanlı görevlerin otomasyonla makinelere devredildiği; buna karşın çalışanların daha bütünleşik, analitik ve ilişkisel roller üstlendiği belirtilmektedir (Brynjolfsson & McAfee, 2014). Bu yaklaşım, YZ'nin işlevinin insanın yerini almak değil, insanın çalışma biçimini yeniden çerçevelemek olduğuna işaret etmektedir.

Rutin görevlerin otomatikleşmesi, çalışanların rollerini daha çok karmaşık problem çözme, çok boyutlu durumları yorumlama ve teknoloji kullanımını yönlendirme gibi alanlara kaydırmaktadır. Özellikle veri analitiği, operasyon yönetimi, pazarlama, insan kaynakları ve finans gibi sektörlerde yapılan güncel çalışmalar, YZ tabanlı sistemlerin operasyonel iş yükünü azaltırken çalışanların görev tanımlarını "denetleyici, yorumlayıcı ve karar destekleyici" roller etrafında yeniden yapılandırdığını ortaya koymaktadır (Davenport & Ronanki, 2018). Bu durum, insanın iş süreçlerindeki katkısını daha stratejik ve yaratıcı bir düzeye taşımakta; salt tekrarlayıcı işlevlerden uzaklaştırmaktadır.

Benzer bir dönüşüm hukuk, sağlık ve eğitim gibi yoğun bilişsel ve insani etkileşim gerektiren alanlarda da gözlemlenmektedir. Hukuk alanında YZ sistemleri, sözleşme analizi, içtihat tarama ve belge sınıflandırma gibi görevleri önemli ölçüde hızlandırmakta; ancak müzakere, stratejik düşünme, etik değerlendirme ve karmaşık karar alma gibi insana özgü görevlerin hâlen çalışanların sorumluluğunda olduğu görülmektedir. Sağlık alanında da YZ destekli tanı sistemleri görüntüleri yorumlayabilmekte ve klinik süreçleri hızlandırabilmektedir. Fakat hekimlerin hasta iletişimi, klinik bütüncül değerlendirme ve etik karar alma gibi kritik rolleri önemini korumaktadır.

Bu dönüşüm, işgücüne hâkim olan rollerin YZ ile "tamamlayıcılık ilişkisi" içinde yeniden şekillendiğine işaret etmektedir. Bu bağlamda çalışanlardan beklenen temel yetkinlikler de değişmektedir. Dijital okuryazarlık, teknolojiye uyum, veri temelli düşünme, yaratıcılık ve eleştirel değerlendirme gibi

beceriler bu değişim kapsamında ön plana çıkmaktadır. Bu yeni beceri seti, çalışanların rollerini statik bir yapıdan dinamik ve sürekli gelişim gerektiren bir yapıya dönüştürmektedir.

YZ ile etkileşimin artması, örgütlerin iş tasarımını, görev tanımlarını ve insan kaynakları politikalarını yeniden düşünmelerini zorunlu hâle getirmektedir. Artık çalışanlar yalnızca belirli bir görevi yerine getiren bireyler değil, teknolojik sistemlerle birlikte üretim yapan, süreçleri yöneten ve dijital araçları stratejik düzeyde kullanan aktörler hâline gelmektedir. Böyle bir dönüşüm, iş yaşamında insan faktörünün önemini ortadan kaldırmak yerine, insanın teknolojiyle birlikte daha değerli hâle geldiği yeni bir rol yapısını ortaya çıkarmaktadır.

YAPAY ZEKÂ İLE ORTAYA ÇIKAN YENİ MESLEKLER

YZ teknolojilerinin hızla gelişmesi, küresel işgücü piyasasında yalnızca mevcut mesleklerin dönüşümünü değil, tamamen yeni uzmanlık alanlarının ortaya çıkışını da beraberinde getirmektedir. Dünya Ekonomik Forumu'nun (WEF) Future of Jobs Report 2023 bulgularına göre, önümüzdeki beş yıl içinde en hızlı büyümesi beklenen mesleklerin büyük bir bölümü doğrudan YZ, veri bilimi ve otomasyon teknolojileri ile ilişkilidir (Di Battista vd., 2023). Raporda özellikle YZ ve makine öğrenimi uzmanı, büyük veri analisti, dijital dönüşüm uzmanı, veri güvenliği analisti ve iş süreçleri otomasyon tasarımcısı gibi rollerin küresel ölçekte en yüksek talep artışı göstereceği belirtilmektedir.

Teknoloji odaklı yeni mesleklerin ortaya çıkmasında örgütlerin veri temelli karar mekanizmalarına yönelmesi belirleyici bir rol oynamaktadır. Veri bilimi ve makine öğrenimi uzmanlıklarının yalnızca teknoloji firmalarında değil; sağlık, finans, kamu yönetimi ve eğitim gibi farklı sektörlerde kritik fonksiyonlar hâline geldiğini gösteren çalışmalar bulunmaktadır (Davenport & Ronanki, 2018). Bu uzmanlık alanlarının büyümesi, YZ modellerinin geliştirilmesi, eğitilmesi, doğrulanması ve operasyonel süreçlere güvenli biçimde entegre edilmesi ihtiyacından kaynaklanmaktadır. Nitekim O'Neil (2017), modern veri odaklı sistemlerin karmaşıklığının artmasıyla birlikte algoritmaların tasarımı, denetlenmesi ve kontrol edilmesine yönelik profesyonel rollerin ortaya çıktığını vurgulamaktadır.

Yeni meslek alanlarının en dikkat çekici boyutlarından biri, YZ etiği ve yönetişim merkezli rollerin giderek önem kazanmasıdır. Avrupa Birliği'nin "Artificial Intelligence Act" kapsamında yaptığı düzenlemeler, yüksek riskli YZ sistemlerinin kullanıldığı kurumlarda "etik uyum uzmanı", "algoritmik denetçi" ve "risk yönetimi sorumlusu" gibi rollerin zorunlu hâle geleceğine işaret etmektedir (European Commission, 2021). Bu alanda çalışan profesyoneller, YZ sistemlerinin şeffaflığını, hesap verebilirliğini ve adalet ilkesine uygunluğunu denetleyerek teknoloji kullanımının toplumsal etkilerini yönetmeyi amaçlamaktadır.

YZ destekli fiziksel otomasyonun gelişmesiyle birlikte robotik ve otonom sistemler etrafında yeni hibrit meslekler de ortaya çıkmaktadır. Akıllı fabrikalarda "robot filo yöneticisi", "otonom sistem operatörü", "insansız araç koordinatörü" gibi rollerin sayısının hızla arttığı görülmektedir. Acemoglu ve Restrepo (2020), robotlaşmanın belirli görevleri ortadan kaldırırken aynı zamanda robot bakımı, onarımı, optimizasyonu ve operasyon yönetimi gibi alanlarda yeni iş olanakları yarattığını ortaya koymaktadır. Bu meslekler, yalnızca teknik bilgi değil, süreç yönetimi, problem çözme ve yüksek adaptasyon becerileri gerektirmektedir.

Benzer şekilde yaratıcı sektörler, eğitim teknolojileri, medya ve sağlık hizmetleri de YZ ile birlikte gelişen yeni mesleklere sahne olmaktadır. Eğitim alanında "dijital öğrenme tasarımcısı", sağlık sektöründe "klinik karar destek sistemi uzmanı", medya alanında ise "YZ destekli içerik üreticisi" gibi roller giderek yaygınlaşmaktadır. Autor (2015), teknolojik değişimin tarihsel olarak bazı görevleri ortadan kaldırırken yeni ve daha yüksek katma değerli görev alanları yarattığını; özellikle bilişsel ve yaratıcı becerilerin YZ çağında daha fazla talep gördüğünü belirtmektedir.

Genel olarak bakıldığında, YZ yalnızca bir otomasyon teknolojisi değil, aynı zamanda yeni mesleklerin ortaya çıkmasını sağlayan güçlü bir yenilik motorudur. Bu çerçevede geleceğin işgücü kompozisyonu, teknolojiyle birlikte çalışabilen, algoritmik düşünme ve dijital okuryazarlık becerilerine sahip, çok disiplinli uzmanlardan oluşacaktır. Bu nedenle YZ dönüşümü, iş kayıplarından çok yeni uzmanlık alanlarının yükselişini ve işgücünün niteliksel olarak yeniden yapılanmasını tanımlayan bir süreç niteliği taşımaktadır.

SONUÇ VE GELECEK PERSPEKTİFİ

YZ teknolojilerinin iş yaşamına etkisine ilişkin literatür, mesleklerin geleceğinin tek yönlü bir "yok oluş senaryosu" ile açıklanamayacak kadar karmaşık ve çok boyutlu olduğunu göstermektedir. YZ, bir yandan tekrarlayan ve kural tabanlı görevleri devralarak belirli meslek gruplarını yüksek dönüşüm baskısı altına alırken, öte yandan tamamlayıcı beceri alanlarını öne çıkararak yeni meslekler ve yeni iş modelleri yaratmaktadır. Autor'un (2015) da vurguladığı gibi, teknolojik dönüşüm tarihsel olarak bazı görevleri ortadan kaldırırken aynı zamanda daha yüksek katma değerli görev alanlarının ortaya çıkmasına yol açmıştır. Bu dinamik, YZ çağında da güçlü biçimde devam etmektedir.

Geleceğin iş dünyasında beceri talebinin yönü, teknolojiyi kullanma becerilerinden çok, teknolojiyle birlikte çalışma yetkinliğine doğru kaymaktadır. Dünya Ekonomik Forumu'nun (2023) raporu, işgücünün önemli bir bölümünün önümüzdeki beş yıl içinde görev tanımlarında kayda değer bir dönüşüm yaşayacağını, bunun da dijital okuryazarlık, algoritmik düşünme, karmaşık problem çözme, yaratıcılık ve eleştirel değerlendirme gibi becerilere olan talebi artıracağını öngörmektedir. Bu çerçevede işgücü piyasası giderek "beceri-temelli" bir yapıya dönüşmekte, çalışanların rekabet gücü, teknolojiyi üretme ve yönetme kapasitesine bağlı hâle gelmektedir.

Bu dönüşüm, aynı zamanda işgücü politikasının da yeniden ele alınmasını zorunlu kılmaktadır. YZ destekli otomasyonun düşük beceri düzeyindeki çalışanlar üzerinde yaratabileceği baskının azaltılması için yaşam boyu öğrenme, yeniden beceri kazandırma ve beceri geliştirme programlarının merkezi bir role sahip olduğu görülmektedir. Acemoglu ve Restrepo (2020), teknolojik dönüşümün olumsuz etkilerinin ancak insan sermayesine yönelik güçlü yatırımlarla dengelenebileceğini belirtmekte, emek piyasasında eşitsizliklerin derinleşmesini önlemenin en etkili yolunun kapsayıcı beceri politikaları olduğunu savunmaktadır. Bu nedenle ülkelerin ve kurumların, teknolojik ilerlemeyle uyumlu bir işgücü yapısı oluşturmak için uzun vadeli stratejiler geliştirmesi kaçınılmazdır.

Geleceğe ilişkin en kritik noktalardan biri, YZ'nin yalnızca teknik bir yenilik olarak değil sosyal, kültürel ve etik boyutları olan kapsamlı bir dönüşüm dinamiği olduğunun kabul edilmesidir. Avrupa Birliği'nin "AI Act" düzenlemeleri ve küresel akademik tartışmalar, YZ kullanımının şeffaflık, hesap verebilirlik, adalet ve etik standartlar çerçevesinde yönetilmesinin zorunlu olduğunu ortaya koymaktadır (European Commission, 2021). Bu durum, teknolojiyi yöneten yeni mesleklerin ve yasa yapıcı çerçevelerin önemini artırırken, aynı zamanda işgücü piyasasında güvenli ve sürdürülebilir bir dönüşüm için kurumsal sorumluluğu ön plana çıkarmaktadır.

Genel olarak değerlendirildiğinde, YZ ve otomasyonun şekillendirdiği gelecekte istihdamın niteliği değişmekte, ancak insan emeğinin önemini yitirdiğini söylemek mümkün değildir. Aksine, teknoloji ile insanın tamamlayıcı biçimde birlikte çalıştığı, dinamik, esnek ve yetkinlik odaklı bir işgücü yapısı güç kazanmaktadır. Bu bağlamda geleceğin meslek ekosistemi, teknolojiyi kullanan değil, teknolojiyle birlikte düşünen, yöneten, denetleyen ve geliştiren bir işgücü tarafından şekillendirilecektir. YZ çağında başarı, yalnızca yeni teknolojilere sahip olmakla değil, bu teknolojilerin sunduğu fırsatları toplumsal ve ekonomik faydaya dönüştürebilecek nitelikli insan sermayesini geliştirmekle mümkün olacaktır.

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THE ANATOMY OF ROLES: UNDERSTANDING JOB CONFUSION IN HEALTHCARE ORGANIZATIONS

ROLLERİN ANATOMİSİ: SAĞLIK KURUMLARINDA GÖREV KARMAŞASINI ANLAMAK

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ABSTRACT

With rapid changes in healthcare services, the roles of healthcare workers are also evolving; however, failure to update job descriptions in line with current needs leads to role problems.

Role conflict and role ambiguity cause confusion among healthcare workers, leading to a decrease in clinical effectiveness and a decline in service quality. A positive and statistically significant relationship has been found between role ambiguity and role conflict and the level of work-related stress. Role ambiguity in healthcare institutions refers to the situation where employees cannot fully understand which tasks they are responsible for and where their authority begins and ends, leading to significant problems in organizational functioning. In hospital environments where teamwork is intensive, the lack of clearly defined roles can cause disruptions in the transfer of responsibilities and a decline in the quality of healthcare services. Negative perceptions of roles among healthcare workers can, in the long term, pave the way for feelings of burnout and alienation from the profession. It is emphasized that in order to reduce role problems in healthcare institutions, management processes must be made transparent, leadership approaches that support employee participation must be adopted, and the organizational structure must be made compatible with roles.

To prevent role problems in hospitals with a matrix organizational structure, it is recommended to strengthen internal communication, reorganize workflows, and adopt managerial approaches that support teamwork. Strengthening role clarity in healthcare institutions should be considered not only as an administrative regulation but also as a strategic necessity that shapes organizational culture, reinforces professional identity, and contributes to the provision of sustainable healthcare services. Preventing role confusion in healthcare institutions should be addressed as a strategic management area that directly affects not only the psychosocial well-being of employees but also patient safety and the quality of healthcare services.

Keywords: Role Ambiguity, Role Conflict, Job Confusion, Quality of Healthcare Services.

ÖZET

Sağlık hizmetlerindeki hızlı değişimlerle birlikte sağlık çalışanlarının rolleri de gelişmekte, ancak görev tanımlarının günün ihtiyaçları doğrultusunda güncellenmemesi rol sorunlarına yol açmaktadır.

Rol çatışması ve rol belirsizliğine bağlı olarak sağlık çalışanlarında karışıklık, klinik etkinlikte azalma ve hizmet kalitesinde düşüş meydana gelmektedir. Rol belirsizliği ve rol çatışması ile işe bağlı gerginlik düzeyi arasında pozitif yönde ve istatistiksel olarak anlamlı bir ilişki olduğu belirlenmiştir. Sağlık kurumlarında rol belirsizliği, çalışanın hangi görevlerden sorumlu olduğunu ve yetki sınırlarının nerede başlayıp bittiğini tam olarak algılayamaması durumunu ifade etmekte ve örgütsel işleyişte önemli

sorunlara yol açmaktadır. Ekip çalışmasının yoğun olduğu hastane ortamlarında rollerin net biçimde tanımlanmaması, sorumluluk devrinde aksamalara ve sağlık hizmetlerinin kalitesinde düşüşe neden olabilmektedir. Sağlık çalışanlarının rollerine ilişkin algılarındaki olumsuzluklar, uzun vadede tükenmişlik duygularının ortaya çıkmasına ve çalışanların mesleğe yabancılaşmasına zemin hazırlamaktadır. Sağlık kurumlarında rol sorunlarının azaltılabilmesi için yönetsel süreçlerin şeffaflaştırılması, çalışan katılımını destekleyen liderlik yaklaşımlarının benimsenmesi ve örgütsel yapının rollerle uyumlu hale getirilmesi gerektiği vurgulanmaktadır.

Matriks örgüt yapısına sahip hastanelerde rol sorunlarının önlenebilmesi için kurum içi iletişimin güçlendirilmesi, iş akışlarının yeniden düzenlenmesi ve ekip çalışmasını destekleyen yönetsel yaklaşımların benimsenmesi önerilmektedir. Sağlık kurumlarında rol netliğinin güçlendirilmesi yalnızca yönetsel bir düzenleme değil, aynı zamanda kurumsal kültürü şekillendiren, mesleki kimliği pekiştiren ve sürdürülebilir sağlık hizmeti sunumuna katkı sağlayan stratejik bir gereklilik olarak düşünülmelidir. Sağlık kurumlarında görev karmaşasının önlenmesi yalnızca çalışanların psikososyal iyilik halini değil, aynı zamanda hasta güvenliği ve sağlık hizmetlerinin kalitesini doğrudan etkileyen stratejik bir yönetim alanı olarak ele alınmalıdır.

Anahtar Kelimeler: Rol Belirsizliği, Rol Çatışması, İş Karmaşası, Sağlık Hizmetlerinin Kalitesi.

ROL KAVRAMI VE SAĞLIKTA ÖNEMİ

Örgütsel davranış alanında yapılan rol tanımlaması, bir pozisyonun işlevleriyle ilgili beklentilere bağlı olarak kabul edilmiş davranış kalıpları şeklinde ifade edilmektedir (Eren Bana & Bekaroğlu, 2022). Sağlık hizmeti sunan kurumlar matriks örgüt yapılarına sahiptir ve bu yapılarda sağlık hizmetlerinin kesintisiz, kaliteli ve etkili bir şekilde sunulabilmesi için ekip çalışmasına ihtiyaç vardır (Öztürk & Şeremet, 2021). Sağlık hizmetlerindeki hızlı değişimlere paralel olarak sağlık çalışanlarının rolleri de gelişmekte, ancak görev tanımlarının günün ihtiyaçları doğrultusunda güncellenmemesi rol sorunlarına yol açmaktadır (Özkan, 2008). Beyaz önlük töreni, henüz meslekten olmayan bir kişinin hekimliğe girişini ve sağlık mesleğinin bir üyesine dönüşümünü simgeleyen bir ritüel olarak tanımlanabilir (Akdoğan, 2025). Hekim ve hemşireler arasındaki temel çatışma nedenlerinin görev tanımlarının belirsizliği ve rollerin net olmaması olduğu saptanmıştır (Dinçel, 2019). Rol çatışması ve rol belirsizliğine bağlı olarak sağlık çalışanlarında karışıklık, klinik etkinlikte azalma ve hizmet kalitesinde düşüş meydana gelmektedir (Adıgüzel, 2012). Rol belirsizliği ve rol çatışması ile işe bağlı gerginlik düzeyi arasında pozitif yönde ve istatistiksel olarak anlamlı bir ilişki olduğu belirlenmiştir (Akbulut Başçı vd., 2016).

SAĞLIK ÇALIŞANLARINDA ROL BELİRSİZLİĞİ VE ROL ÇATIŞMASI

Sağlık kurumlarında rol belirsizliği, çalışanın hangi görevlerden sorumlu olduğunu ve yetki sınırlarının nerede başlayıp bittiğini tam olarak algılayamaması durumunu ifade etmekte ve örgütsel işleyişte önemli sorunlara yol açmaktadır (Eren Bana & Bekaroğlu, 2022). Matriks örgüt yapısına sahip hastanelerde çalışanlar, birden fazla yöneticiye ve farklı beklentilere bağlı olarak roller arasında çatışma yaşayabilmekte, bu durum görev karmaşasını daha da derinleştirmektedir (Öztürk & Şeremet, 2021). Görev tanımlarının açık ve güncel olmaması, sağlık çalışanlarının kendi sorumluluk alanları dışında işlere müdahil olmasına ve rol sınırlarının belirsizleşmesine neden olmaktadır (Özkan, 2008). Hekim ve hemşireler arasında yaşanan çatışmaların temelinde çoğunlukla görev tanımlarının belirsizliği, rol beklentilerinin farklı algılanması ve iletişim yetersizlikleri yer almaktadır (Dinçel, 2019). Rol çatışması ve rol belirsizliği, sağlık çalışanlarının klinik etkinliklerini azaltmakta ve hizmet sunumunda koordinasyon sorunlarının ortaya çıkmasına zemin hazırlamaktadır (Adıgüzel, 2012). Üniversite hastanelerinde yapılan çalışmalarda rol çatışması ile rol belirsizliği arasında pozitif yönde anlamlı bir ilişki olduğu ve bu durumun özellikle vardiyalı çalışanlarda daha belirgin olduğu saptanmıştır (Akbulut Başçı vd., 2016). Sağlık çalışanlarının aynı anda birden fazla role maruz kalması, rol yüklenmesini artırarak rol çatışması ve rol belirsizliği algısının güçlenmesine neden olmaktadır (Eren Bana & Bekaroğlu, 2022).

ROL BELİRSİZLİĞİNİN SAĞLIK ÇALIŞANLARI ÜZERİNDEKİ ETKİLERİ

Rol belirsizliği ve rol çatışmasına maruz kalan sağlık çalışanlarında stres düzeyinin arttığı, bunun da iş doyumu ve mesleki motivasyon üzerinde olumsuz etkiler yarattığı belirtilmektedir (Eren Bana & Bekaroğlu, 2022). Rol belirsizliği ve rol çatışması yaşayan çalışanların örgüte olan duygusal ve normatif bağlılıklarının azaldığı ve bu durumun örgütsel bağlılığı olumsuz yönde etkilediği saptanmıştır (Öztürk & Şeremet, 2021). Görev tanımlarının net olmaması, sağlık çalışanlarında karışıklık, klinisyen değer ve inançları ile çatışma ve klinik etkinlikte azalma gibi sonuçlara yol açmaktadır (Özkan, 2008). Hekim ve hemşireler arasında yaşanan rol çatışmaları, çalışma ortamında gerginliği artırmakta ve kişiler arası ilişkilerin bozulmasına neden olmaktadır (Dinçel, 2019). Rol çatışması ve rol belirsizliğinin işle ilgili stres düzeyini artırdığı, bu durumun da iş doyumunda azalma ve performans düşüklüğü ile ilişkili olduğu ifade edilmektedir (Adıgüzel, 2012). Rol belirsizliği ve rol çatışması ile işe bağlı gerginlik arasında pozitif yönde anlamlı bir ilişki olduğu ve bu durumun hemşirelerde daha belirgin olarak görüldüğü bildirilmektedir (Akbulut Başçı vd., 2016). Sağlık çalışanlarının rollerine ilişkin algılarındaki olumsuzluklar, uzun vadede tükenmişlik duygularının ortaya çıkmasına ve çalışanların mesleğe yabancılaşmasına zemin hazırlamaktadır (Özkan, 2008).

SAĞLIK KURUMLARINDA ÖRGÜTSEL YAPI VE YÖNETİMSEL DİNAMİKLERİN ROL KARMAŞASINA ETKİSİ

Sağlık kurumlarında örgütsel yapı, çalışanların rollerine ilişkin algılarını doğrudan etkilemekte ve yönetimsel süreçlerdeki belirsizlikler rol karmaşasının temel belirleyicilerinden biri olarak ortaya çıkmaktadır (Eren Bana & Bekaroğlu, 2022). Matriks örgüt yapısının yaygın olduğu hastanelerde birden fazla yöneticiye bağlı çalışma düzeni, rol belirsizliği ve rol çatışması yaşanma olasılığını artıran önemli bir yönetsel faktör olarak değerlendirilmektedir (Öztürk & Şeremet, 2021). Sağlık kurumlarında görev tanımlarının yetersizliği ve yönetsel sorumlulukların net biçimde belirlenmemesi, çalışanların hangi role öncelik verecekleri konusunda kararsızlık yaşamalarına neden olmaktadır (Özkan, 2008).Hekim ve hemşireler arasındaki rol temelli çatışmaların önemli bir kısmının, yönetim tarafından belirlenen iş bölümü ve yetki dağılımındaki dengesizliklerden kaynaklandığı bildirilmektedir (Dinçel, 2019). Rol belirsizliği ve rol çatışmasının yoğun olduğu çalışma ortamlarında etkisiz yönetim anlayışının, sağlık hizmetlerinin kalitesini ve örgütsel işleyişi olumsuz yönde etkilediği ifade edilmektedir (Adıgüzel, 2012). Üniversite hastanelerinde yapılan araştırmalar, yönetimsel destek eksikliğinin rol çatışması ve işe bağlı gerginlik düzeylerini artıran önemli bir etken olduğunu ortaya koymaktadır (Akbulut Başçı vd., 2016). Sağlık kurumlarında rol sorunlarının azaltılabilmesi için yönetsel süreçlerin şeffaflaştırılması, çalışan katılımını destekleyen liderlik yaklaşımlarının benimsenmesi ve örgütsel yapının rollerle uyumlu hale getirilmesi gerektiği vurgulanmaktadır (Eren Bana & Bekaroğlu, 2022).

ROL NETLİĞİNİN SAĞLIK KURUMLARININ YAPISAL VE MESLEKİ KİMLİK ÜZERİNDEKİ ETKİLERİ

Sağlık kurumlarında rol netliğinin sağlanması, çalışanların yalnızca görevlerini doğru biçimde yerine getirmelerini değil, aynı zamanda kuruma ait olma duygusunu geliştirmelerini ve mesleki kimliklerini daha güçlü biçimde içselleştirmelerini sağlayan temel bir örgütsel unsur olarak değerlendirilmektedir (Eren Bana & Bekaroğlu, 2022). Rol beklentilerinin açık biçimde tanımlandığı çalışma ortamlarında sağlık çalışanlarının mesleki rollerini daha net algıladıkları, bu durumun da örgütsel bağlılık, iş doyumu ve ekip içi uyumu olumlu yönde etkilediği bildirilmektedir (Öztürk & Şeremet, 2021). Görev tanımlarının belirsiz olduğu kurumlarda çalışanların mesleki rollerini sorgulamaya başladıkları, bu durumun zamanla mesleki yabancılaşmaya ve kurumsal değerlerden uzaklaşmaya yol açabildiği ifade edilmektedir (Özkan, 2008). Hekim ve hemşireler arasında rol sınırlarının net biçimde belirlenmemesi, yalnızca işleyişe ilişkin sorunlar yaratmakla kalmamakta, aynı zamanda meslekler arası güç dengelerini etkileyerek kurumsal kültürde çatışmacı bir iklimin oluşmasına zemin hazırlamaktadır (Dinçel, 2019). Rol belirsizliği ve rol çatışmasının yoğun olarak yaşandığı sağlık kurumlarında çalışanların kendilerini değersiz ve desteklenmemiş hissettikleri, bunun da kurumsal güven algısını zayıflattığı ve iş ortamında psikososyal riskleri artırdığı belirtilmektedir (Adıgüzel, 2012). Üniversite hastanelerinde yapılan çalışmalarda rol netliğinin sağlanamadığı durumlarda işe bağlı gerginlik düzeylerinin arttığı, bu durumun çalışanların kuruma yönelik tutumlarını ve uzun vadeli çalışma istekliliklerini olumsuz yönde etkilediği saptanmıştır (Akbulut Başçı vd., 2016). Sonuç olarak, sağlık kurumlarında rol netliğinin

güçlendirilmesi yalnızca yönetsel bir düzenleme değil, aynı zamanda kurumsal kültürü şekillendiren, mesleki kimliği pekiştiren ve sürdürülebilir sağlık hizmeti sunumuna katkı sağlayan stratejik bir gereklilik olarak ele alınmalıdır (Eren Bana & Bekaroğlu, 2022).

ROL BELİRSİZLİĞİNİN HASTA GÜVENLİĞİNE VE HİZMET KALİTESİNE ETKİSİ

Sağlık kurumlarında rol belirsizliği ve rol çatışmasının varlığı, hizmet sunumunda koordinasyon sorunlarına yol açarak hasta bakım süreçlerinin etkinliğini ve sürekliliğini olumsuz yönde etkilemektedir (Eren Bana & Bekaroğlu, 2022). Ekip çalışmasının yoğun olduğu hastane ortamlarında rollerin net biçimde tanımlanmaması, sorumluluk devrinde aksamalara ve sağlık hizmetlerinin kalitesinde düşüşe neden olabilmektedir (Öztürk & Şeremet, 2021). Rol belirsizliği nedeniyle çalışanların hangi işten sorumlu olduklarını tam olarak bilememeleri, klinik karar süreçlerinde gecikmelere ve hizmet sunumunda aksamalara yol açmaktadır (Özkan, 2008). Hekim ve hemşireler arasında yaşanan rol çatışmaları, iletişim kopukluklarına neden olarak hasta bakımında hataların ortaya çıkma riskini artırmaktadır (Dinçel, 2019). Rol çatışması ve rol belirsizliğine bağlı olarak klinik etkinlikte azalma, etkisiz yönetim ve sonuçta düşük kaliteli sağlık hizmeti sunumu ortaya çıkmaktadır (Adıgüzel, 2012). Üniversite hastanelerinde yapılan çalışmalarda rol belirsizliği ve rol çatışmasının, hasta bakımının sürekliliğini ve güvenliğini dolaylı olarak etkileyen önemli örgütsel faktörler arasında yer aldığı belirtilmektedir (Akbulut Başçı vd., 2016). Sağlık çalışanlarının rollerine ilişkin yaşadıkları karmaşa, sağlık hizmeti alan bireylerin memnuniyet düzeyini düşürmekte ve hizmet kalitesine ilişkin algıyı olumsuz etkilemektedir (Eren Bana & Bekaroğlu, 2022).

SONUÇ VE ÖNERİLER

Sağlık kurumlarında rol belirsizliği ve rol çatışmasının azaltılabilmesi için çalışanların görev, yetki ve sorumluluklarının açık ve anlaşılır biçimde tanımlanması, örgütsel işleyişin etkinliği açısından temel bir gereklilik olarak değerlendirilmektedir (Eren Bana & Bekaroğlu, 2022). Matriks örgüt yapısına sahip hastanelerde rol sorunlarının önlenebilmesi için kurum içi iletişimin güçlendirilmesi, iş akışlarının yeniden düzenlenmesi ve ekip çalışmasını destekleyen yönetsel yaklaşımların benimsenmesi önerilmektedir (Öztürk & Şeremet, 2021). Görev tanımlarının günün ihtiyaçlarına uygun biçimde güncellenmesi, sağlık çalışanlarının rol sınırlarını daha net algılamalarını sağlayarak örgütsel çatışmaların önüne geçilmesinde etkili bir araç olarak görülmektedir (Özkan, 2008). Hekim ve hemşireler arasında yaşanan rol temelli çatışmaların azaltılabilmesi için meslekler arası iş birliğini güçlendiren, karşılıklı anlayış ve saygıyı önceleyen bir çalışma kültürünün oluşturulması gerektiği vurgulanmaktadır (Dinçel, 2019). Rol belirsizliği ve rol çatışmasının azaltılmasına yönelik müdahalelerin, çalışanların stres düzeylerini düşürdüğü, iş doyumunu artırdığı ve hizmet sunumunun niteliğine olumlu katkı sağladığı ifade edilmektedir (Adıgüzel, 2012). Üniversite hastanelerinde yapılan çalışmalar, rol sorunlarının giderilmesine yönelik düzenlemelerin işe bağlı gerginliği azalttığını ve sağlık çalışanlarının kuruma bağlılığını güçlendirdiğini ortaya koymaktadır (Akbulut Başçı vd., 2016). Sonuç olarak, sağlık kurumlarında görev karmaşasının önlenmesi yalnızca çalışanların psikososyal iyilik halini değil, aynı zamanda hasta güvenliği ve sağlık hizmetlerinin kalitesini doğrudan etkileyen stratejik bir yönetim alanı olarak ele alınmalıdır (Eren Bana & Bekaroğlu, 2022).

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THE INVISIBLE SHACKLES OF THE WHITE COAT: ROLE CONFUSION AND BURNOUT

BEYAZ ÖNLÜĞÜN GÖRÜNMEZ PRANGALARI: ROL KARMAŞASI VE TÜKENMİŞLİK

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ABSTRACT

The white coat is not merely a professional symbol for healthcare workers, but is also regarded as an identity marker laden with heavy responsibilities and societal expectations. Healthcare workers' perceptions of their roles have a decisive impact on their ability to fulfill the duties expected of them.

The concept of role encompasses the behaviors expected of an individual based on their status within the organization. Healthcare workers experiencing role ambiguity and role conflict are reported to experience more intense feelings of tension and indecision in the workplace. This situation negatively affects healthcare workers' perceptions of their professional roles. It has been reported that coordination problems in service delivery are more common in units with high role ambiguity. This situation can negatively affect the efficiency of daily clinical practices. Increased work-related stress levels can lead to intensified burnout symptoms. This process negatively affects healthcare workers' professional motivation. The normalization of role conflict and role ambiguity at the organizational level can cause healthcare workers to perceive these problems as individual inadequacies and render organizational problems invisible. It has been reported that in healthcare institutions where role problems are prevalent, there are disruptions in team communication, and this situation can negatively affect the continuity of patient care. It is stated that healthcare workers with increasing levels of burnout struggle with attention and decision-making processes, which can increase the risk of errors in patient care. Uncertainties in clinical decision-making processes can negatively affect service delivery. Interprofessional conflicts are considered a factor that increases the risk of errors in patient care.

Since managerial and organizational arrangements aimed at preventing role confusion in healthcare institutions directly affect not only employee well-being but also patient safety and service quality, necessary measures should be taken.

Keywords: White Coat, Role Confusion, Burnout, Work-Related Stress, Healthcare Institutions.

ÖZET

Beyaz önlük, sağlık çalışanları için yalnızca bir mesleki sembol değil, aynı zamanda ağır sorumluluklar ve toplumsal beklentilerle yüklü bir kimlik göstergesi olarak değerlendirilmektedir. Sağlık çalışanlarının rollerine ilişkin algıları, kendilerinden beklenen görevleri yerine getirme süreçlerinde belirleyici bir etkiye sahiptir. Rol kavramı, bireyin örgüt içerisindeki statüsüne bağlı olarak sergilemesi beklenen davranış biçimlerini kapsamaktadır

Rol belirsizliği ve rol çatışması yaşayan sağlık çalışanlarının, iş ortamında gerginlik ve kararsızlık duygularını daha yoğun yaşadıkları belirtilmektedir. Bu durum, sağlık çalışanlarının mesleki rollerine ilişkin algılarını olumsuz yönde etkilemektedir. Rol belirsizliğinin yoğun olduğu birimlerde hizmet sunumunda koordinasyon sorunlarının daha sık görüldüğü bildirilmektedir. Bu durum, günlük klinik

uygulamaların verimliliğini olumsuz yönde etkileyebilmektedir. İşe bağlı gerginlik düzeyinin artması, tükenmişlik belirtilerinin şiddetlenmesine yol açabilmektedir. Bu süreç, sağlık çalışanlarının mesleki motivasyonlarını olumsuz yönde etkilemektedir. Rol çatışması ve rol belirsizliğinin örgütsel düzeyde normalleştirilmesi, sağlık çalışanlarının bu sorunları bireysel yetersizlik olarak algılamalarına ve örgütsel sorunların görünmez hale gelmesine neden olabilmektedir. Rol sorunlarının yaygın olduğu sağlık kurumlarında ekip içi iletişimde aksamalar yaşandığı ve bu durumun hasta bakımının sürekliliğini olumsuz yönde etkileyebildiği bildirilmektedir. Tükenmişlik düzeyi artan sağlık çalışanlarının dikkat ve karar verme süreçlerinde zorlandıkları, bunun da hasta bakımında hata riskini artırabildiği ifade edilmektedir. Klinik karar süreçlerinde yaşanan belirsizlikler, hizmet sunumunu olumsuz yönde etkileyebilmektedir. Meslekler arası çatışmalar, hasta bakımında hata riskini artıran bir faktör olarak değerlendirilmektedir.

Sağlık kurumlarında rol karmaşasının önlenmesine yönelik yapılacak yönetsel ve örgütsel düzenlemelerin, yalnızca çalışan refahını değil, aynı zamanda hasta güvenliği ve hizmet kalitesini de doğrudan etkileyeceğinden gerekli önlemler alınmalıdır.

Anahtar Kelimeler: Beyaz Önlük, Rol Karmaşası, Tükenmişlik, İşe Bağlı Gerginlik, Sağlık Kurumları

BEYAZ ÖNLÜK ALTINDA ARTAN ROL YÜKLENMESİ VE MESLEKİ BEKLENTİLER

Sağlık çalışanlarının rollerine ilişkin algıları, kendilerinden beklenen görevleri yerine getirme süreçlerinde belirleyici bir etkiye sahiptir (Eren Bana & Bekaroğlu, 2022). Rol kavramı, bireyin örgüt içerisindeki statüsüne bağlı olarak sergilemesi beklenen davranış biçimlerini kapsamaktadır (Eren Bana & Bekaroğlu, 2022). Sağlık kurumlarında ekip çalışmasının zorunlu olması, çalışanların aynı anda birden fazla rol beklentisiyle karşı karşıya kalmasına neden olabilmektedir (Öztürk & Şeremet, 2021). Bu durum, rol sınırlarının belirsizleşmesine ve görev tanımlarının iç içe geçmesine zemin hazırlamaktadır (Öztürk & Şeremet, 2021). Sağlık hizmetlerinin sunumunda artan iş yükü ve sorumluluklar, çalışanların geleneksel rollerinin ötesinde beklentilerle karşılaşmasına yol açmaktadır (Özkan, 2008). Görev tanımlarının net olmaması, rol kavramının işlevini yitirmesine neden olabilmektedir (Özkan, 2008). Sağlık kurumları gibi karmaşık örgüt yapılarında rol belirsizliği ve rol çatışmasının ortaya çıkması, çalışanların kendilerinden ne beklendiğini algılamalarını güçleştirmekte ve rol yüklenmesini artıran bir etken olarak değerlendirilmektedir (Yörükoğlu, 2008). Doktor ve hemşirelerin insanlarla yüz yüze çalışmayı gerektiren mesleklerde görev yapmaları, sürekli sorumluluk alma, empati kurma ve belirsizlikle baş etme zorunluluğu nedeniyle rol yüklenmesini artıran önemli bir stres kaynağı oluşturmaktadır (Sayıl vd., 1997). Beyaz önlük, sağlık çalışanları için yalnızca bir mesleki sembol değil, aynı zamanda ağır sorumluluklar ve toplumsal beklentilerle yüklü bir kimlik göstergesi olarak değerlendirilmektedir (Akdoğan, 2025). Bu sembol, mesleki rollerin içselleştirilmesi sürecinde birey üzerinde önemli bir baskı unsuru oluşturabilmektedir (Akdoğan, 2025). Hekim ve hemşireler arasındaki rol dağılımına ilişkin belirsizlikler, meslekler arası ilişkilerde gerilimi artıran temel unsurlardan biri olarak görülmektedir (Dinçel, 2019). Rol beklentilerinin farklı algılanması, çalışma ortamında çatışmaların ortaya çıkmasına neden olabilmektedir (Dinçel, 2019). Rol belirsizliği ve rol çatışması yaşayan sağlık çalışanlarının, iş ortamında gerginlik ve kararsızlık duygularını daha yoğun yaşadıkları belirtilmektedir (Adıgüzel, 2012). Bu durum, sağlık çalışanlarının mesleki rollerine ilişkin algılarını olumsuz yönde etkilemektedir (Adıgüzel, 2012). Üniversite hastanelerinde yapılan araştırmalar, rol sorunlarının özellikle mesleğin erken dönemlerinde daha sık yaşandığını ortaya koymaktadır (Akbulut Başçı vd., 2016). Rol yüklenmesine bağlı olarak ortaya çıkan bu durumun, işe bağlı gerginlik düzeyi ile ilişkili olduğu saptanmıştır (Akbulut Başçı vd., 2016).

SAĞLIK KURUMLARINDA ROL KARMAŞASININ GÜNLÜK KLİNİK UYGULAMALARA YANSIMALARI

Sağlık kurumlarında rol belirsizliği, çalışanların klinik uygulamalarda hangi görevlerden sorumlu olduklarını net olarak algılayamamalarına neden olabilmektedir (Eren Bana & Bekaroğlu, 2022). Matriks örgüt yapısında çalışan sağlık personelinin, farklı yöneticilerden gelen talepler nedeniyle rol çatışması yaşadığı belirtilmektedir (Öztürk & Şeremet, 2021).

Klinik ve idari görevlerin iç içe geçmesi, sağlık çalışanlarının öncelik belirlemesini zorlaştırmaktadır (Özkan, 2008). Rol çatışmasının yoğun olarak yaşandığı çalışma ortamlarında sağlık çalışanlarının günlük görevlerini yerine getirirken karar vermede zorlandıkları, iş önceliklerini belirleyemedikleri ve bu durumun hizmet sunumunda aksamalara yol açtığı belirtilmektedir (Yörükoğlu, 2008). Hekim ve hemşireler arasında görev paylaşımına ilişkin belirsizlikler, klinik işleyişte aksamalara yol açabilmektedir (Dinçel, 2019). Tükenmişlik düzeyi artan doktor ve hemşirelerde dikkat, karar verme ve hasta ile kurulan ilişkinin niteliğinde bozulmalar görülebildiği, bunun da günlük klinik uygulamaların etkinliğini olumsuz etkilediği bildirilmektedir (Sayıl vd., 1997). Rol çatışması yaşayan çalışanların klinik etkinlik düzeylerinin azaldığı ifade edilmektedir (Adıgüzel, 2012). Rol belirsizliğinin yoğun olduğu birimlerde hizmet sunumunda koordinasyon sorunlarının daha sık görüldüğü bildirilmektedir (Akbulut Başçı vd., 2016). Bu durum, günlük klinik uygulamaların verimliliğini olumsuz yönde etkileyebilmektedir (Eren Bana & Bekaroğlu, 2022).

ROL KARMAŞASI VE TÜKENMİŞLİK ARASINDAKİ ÇOK BOYUTLU İLİŞKİ

Rol belirsizliği yaşayan sağlık çalışanlarında duygusal tükenmişlik belirtilerinin daha sık görüldüğü belirtilmektedir (Eren Bana & Bekaroğlu, 2022). Doktor ve hemşirelerde tükenmişlik sendromunun özellikle duygusal tükenme boyutunda belirginleştiği, bu durumun yoğun hasta teması, sürekli sorumluluk alma ve belirsizlikle baş etme zorunluluğu ile ilişkili olduğu saptanmıştır (Sayıl vd., 1997). Rol çatışmasının artması, çalışanların iş doyumunun azalmasına neden olabilmektedir (Öztürk & Şeremet, 2021). Görev tanımlarının net olmaması, sağlık çalışanlarında sürekli bir yetersizlik hissi yaratabilmektedir (Özkan, 2008). Rol sorunlarının kronikleşmesi, sağlık çalışanlarında yalnızca tükenmişlik değil, aynı zamanda mesleğe yabancılaşma ve işi sürdürme isteğinde azalma gibi uzun vadeli sonuçlara da yol açabilmektedir (Yörükoğlu, 2008). Meslekler arası çatışmalar, çalışma ortamında duygusal yıpranmayı artıran bir etken olarak değerlendirilmektedir (Dinçel, 2019). Rol çatışması ve rol belirsizliğinin uzun süre devam ettiği çalışma ortamlarında sağlık çalışanlarının kendilerini yetersiz, değersiz ve kontrol kaybı yaşayan bireyler olarak algılamaya başladıkları, bu sürecin tükenmişlik belirtilerini hızlandırdığı belirtilmektedir (Yörükoğlu, 2008). Rol belirsizliği ile tükenmişlik düzeyi arasında anlamlı bir ilişki olduğu ifade edilmektedir (Adıgüzel, 2012). İşe bağlı gerginlik düzeyinin artması, tükenmişlik belirtilerinin şiddetlenmesine yol açabilmektedir .(Akbulut Başçı vd., 2016). Bu süreç, sağlık çalışanlarının mesleki motivasyonlarını olumsuz yönde etkilemektedir (Özkan, 2008).

ÖRGÜTSEL FAKTÖRLER VE GÖRÜNMEZ PRANGALARIN KAYNAĞI

Örgütsel yapı, sağlık çalışanlarının rollerine ilişkin algılarını şekillendiren temel unsurlardan biridir (Eren Bana & Bekaroğlu, 2022). Hastanelerin çok katmanlı ve karmaşık örgütsel yapısı, farklı birimler ve yönetsel beklentiler arasında kalan sağlık çalışanlarının rollerine ilişkin belirsizlik ve çatışma yaşama olasılığını artıran yapısal bir unsur olarak değerlendirilmektedir (Yörükoğlu, 2008). Yönetimsel belirsizlikler, rol karmaşasının süreklilik kazanmasına neden olabilmektedir (Öztürk & Şeremet, 2021). Kurumsal destek eksikliği, rol sorunlarının derinleşmesine yol açmaktadır (Özkan, 2008). Yönetim tarafından belirlenen iş bölümü, rol çatışmalarının ortaya çıkmasında etkili olmaktadır (Dinçel, 2019). Örgütsel destek eksikliği ve yönetimsel belirsizliklerin hâkim olduğu sağlık kurumlarında çalışanların kendilerini yalnız ve değersiz hissettikleri, bunun da psikososyal stres düzeyini artırarak tükenmişliği besleyen bir ortam oluşturduğu belirtilmektedir (Sayıl vd., 1997). Etkisiz yönetim anlayışı, çalışanların örgüte olan güvenini zayıflatabilmektedir (Adıgüzel, 2012). Üniversite hastanelerinde yönetimsel destek eksikliğinin rol çatışmasını artırdığı bildirilmektedir (Akbulut Başçı vd., 2016). Bu durum, beyaz önlük altında görünmez bir baskı mekanizması oluşturmaktadır (Eren Bana & Bekaroğlu, 2022). Rol çatışması ve rol belirsizliğinin örgütsel düzeyde normalleştirilmesi, sağlık çalışanlarının bu sorunları bireysel yetersizlik olarak algılamalarına ve örgütsel sorunların görünmez hale gelmesine neden olabilmektedir (Yörükoğlu, 2008).

ROL KARMAŞASININ HASTA GÜVENLİĞİ ÜZERİNDEKİ DOLAYLI ETKİLERİ

Rol belirsizliği ve rol çatışması, hasta bakım süreçlerinde aksamalara neden olabilmektedir (Eren Bana & Bekaroğlu, 2022). Rol sorunlarının yaygın olduğu sağlık kurumlarında ekip içi iletişimde aksamalar yaşandığı ve bu durumun hasta bakımının sürekliliğini olumsuz yönde etkileyebildiği bildirilmektedir (Yörükoğlu, 2008). Ekip içi iletişim sorunları, rol karmaşasının hasta güvenliği üzerindeki etkilerini

artırmaktadır (Öztürk & Şeremet, 2021). Tükenmişlik düzeyi artan sağlık çalışanlarının dikkat ve karar verme süreçlerinde zorlandıkları, bunun da hasta bakımında hata riskini artırabildiği ifade edilmektedir (Sayıl vd., 1997). Klinik karar süreçlerinde yaşanan belirsizlikler, hizmet sunumunu olumsuz yönde etkileyebilmektedir (Özkan, 2008). Meslekler arası çatışmalar, hasta bakımında hata riskini artıran bir faktör olarak değerlendirilmektedir (Dinçel, 2019). Rol sorunları, sağlık hizmetlerinin kalitesinde düşüşe yol açabilmektedir (Adıgüzel, 2012). Hasta bakımının sürekliliğinin rol belirsizliği nedeniyle sekteye uğrayabildiği belirtilmektedir (Akbulut Başçı vd., 2016). Bu durum, hasta memnuniyetini olumsuz yönde etkileyebilmektedir (Eren Bana & Bekaroğlu, 2022).

SONUÇ VE DEĞERLENDİRME

Sağlık kurumlarında rol belirsizliği ve rol çatışmasının varlığı, çalışanların yalnızca görevlerini yerine getirme biçimlerini değil, aynı zamanda örgüte yönelik algılarını ve mesleki rollerini anlamlandırma süreçlerini de doğrudan etkilemektedir. Çalışanların rollerine ilişkin algılarındaki olumsuzluklar, örgütsel işleyişin etkinliğini azaltarak rol karmaşasının kurumsal düzeyde kalıcı bir sorun haline gelmesine neden olabilmektedir (Eren Bana & Bekaroğlu, 2022). Matriks örgüt yapısının hâkim olduğu sağlık kurumlarında rol çatışması ve rol belirsizliği sorunlarının yeterince yönetilememesi, örgütsel bağlılık ve iş doyumu düzeylerinde belirgin azalmalarla ilişkili bulunmaktadır. Bu durum, sağlık çalışanlarının kurumsal hedeflerle bireysel beklentiler arasında sıkışmasına ve uzun vadede mesleki tükenmişliğin derinleşmesine zemin hazırlamaktadır (Öztürk & Şeremet, 2021). Görev tanımlarının açık, güncel ve işleyişle uyumlu olmaması, sağlık çalışanlarının rollerine ilişkin sürekli bir belirsizlik yaşamalarına neden olmakta ve bu durum örgütsel çatışmaların temel kaynağı olarak ortaya çıkmaktadır. Rol sorunlarının çözümlenemediği çalışma ortamlarında sağlık çalışanlarının mesleki değerleri ile kurum beklentileri arasında çatışma yaşadıkları ve bunun mesleki doyumu olumsuz etkilediği ifade edilmektedir (Özkan, 2008). Hekim ve hemşireler arasında yaşanan rol temelli çatışmaların süreklilik kazanması, çalışma ortamında güvensizlik ve iletişim sorunlarını artırarak ekip içi iş birliğini zayıflatmaktadır (Dinçel, 2019). Bu tür çatışmaların yönetilememesi, sağlık kurumlarında çatışmacı bir örgüt kültürünün yerleşmesine ve meslekler arası ilişkilerin zarar görmesine neden olabilmektedir (Dinçel, 2019). Rol belirsizliği ve rol çatışmasının yoğun olarak yaşandığı sağlık kurumlarında çalışanların stres düzeylerinin arttığı, bu durumun iş doyumu, performans ve psikososyal iyilik hali üzerinde olumsuz sonuçlar doğurduğu belirtilmektedir (Adıgüzel, 2012).

Uzun süreli rol sorunlarının çözülmemesi, sağlık çalışanlarında tükenmişlik duygularının artmasına ve kurumdan ayrılma niyetinin güçlenmesine yol açabilmektedir (Adıgüzel, 2012). Üniversite hastanelerinde gerçekleştirilen çalışmalarda rol belirsizliği ve rol çatışmasının işe bağlı gerginlik düzeyi ile yakından ilişkili olduğu ve bu durumun sağlık çalışanlarının mesleki sürdürülebilirliğini tehdit ettiği ortaya konulmuştur (Akbulut Başçı vd., 2016). Sonuç olarak, sağlık kurumlarında rol karmaşasının önlenmesine yönelik yapılacak yönetsel ve örgütsel düzenlemelerin, yalnızca çalışan refahını değil, aynı zamanda hasta güvenliği ve hizmet kalitesini de doğrudan etkileyen stratejik bir zorunluluk olduğu vurgulanmaktadır (Akbulut Başçı vd., 2016).

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THE EFFECT OF ENVIRONMENTAL EDUCATION INTEGRATED WITH ARTIFICIAL INTELLIGENCE–SUPPORTED PICTOBLOX APPLICATIONS ON PRE-SERVICE SCIENCE TEACHERS' ARTIFICIAL INTELLIGENCE ANXIETY

YAPAY ZEKÂ DESTEKLİ PICTOBLOX UYGULAMALARIYLA BÜTÜNLEŞTİRİLEN ÇEVRE ÖĞRETİMİNİN FEN BİLGİSİ ÖĞRETMEN ADAYLARININ YAPAY ZEKÂ KAYGISI ÜZERİNDEKİ ETKİSİ

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ABSTRACT

Today, artificial intelligence (AI) technologies are rapidly spreading in the field of education; in particular, coding, block-based programming, and AI-based applications are increasingly being integrated into instructional processes. While these technologies aim to develop students' problem-solving skills, algorithmic thinking, and digital competencies, they also necessitate the examination of pre-service teachers' attitudes and emotional responses toward AI. Among these affective factors, AI anxiety emerges as a significant variable influencing the effective and sustainable use of AI technologies in educational settings. This study was conducted during the 2024–2025 academic year with 24 pre-service science teachers enrolled in the faculty of education at a public university located in the Central Anatolia Region of Türkiye. The purpose of the study was to examine the effect of environmental education delivered using AI-supported PictoBlox applications on pre-service science teachers' levels of AI anxiety. The research was designed within the framework of quantitative research methods using a quasi-experimental design and employed a single-group pretest–posttest model. The data obtained in the study were analyzed using the SPSS statistical software package. A paired-samples t-test was conducted to determine whether there was a statistically significant difference between the participants' AI anxiety scores before and after the implementation. The results of the analysis revealed that there was no statistically significant difference between the pretest and posttest AI anxiety scores of the pre-service science teachers. The findings indicate that block-based AI-supported applications alone may not be sufficient to reduce pre-service teachers' levels of AI anxiety and suggest that further research examining longer-term interventions and additional variables is needed in this field.

Key Words: Artificial intelligence; artificial intelligence anxiety; environmental education; PictoBlox

ÖZET

Günümüzde yapay zekâ teknolojileri eğitim alanında hızla yaygınlaşmakta; özellikle kodlama, blok tabanlı programlama ve yapay zekâ temelli uygulamalar öğretim süreçlerine giderek daha fazla entegre edilmektedir. Bu teknolojiler, öğrencilerin problem çözme, algoritmik düşünme ve dijital yeterliliklerini geliştirmeyi amaçlarken, öğretmen adaylarının bu teknolojilere yönelik tutum ve duygusal tepkilerinin de incelenmesini gerekli kılmaktadır. Özellikle yapay zekâya yönelik kaygı düzeyi, bu teknolojilerin eğitim ortamlarında etkili ve sürdürülebilir biçimde kullanılmasında önemli bir değişken olarak öne çıkmaktadır. Bu araştırma, 2024–2025 eğitim-öğretim yılında İç Anadolu Bölgesi'nde bulunan bir devlet üniversitesinin eğitim fakültesinde öğrenim gören 24 fen bilgisi öğretmen adayı ile yürütülmüştür. Bu araştırma, yapay zekâ destekli PictoBlox uygulamaları kullanılarak yürütülen çevre öğretiminin fen bilgisi öğretmen adaylarının yapay zekâ kaygı düzeyleri üzerindeki etkisini belirlemek

amacıyla yürütülmüştür Araştırma, nicel araştırma yöntemlerinden yarı deneysel desen çerçevesinde tasarlanmış olup, tek gruplu ön test–son test modeli kullanılmıştır. Araştırma kapsamında elde edilen veriler, SPSS paket programı kullanılarak analiz edilmiştir. Fen bilgisi öğretmen adaylarının uygulama öncesi ve sonrası yapay zekâ kaygı puanları arasındaki farkın istatistiksel olarak anlamlı olup olmadığı bağımlı örneklemler t-testi ile incelenmiştir. Analiz sonuçlarına göre, öğretmen adaylarının ön test ve son test yapay zekâ kaygı puanları arasında istatistiksel açıdan anlamlı bir fark bulunmadığı belirlenmiştir. Elde edilen bulgular, blok tabanlı yapay zekâ destekli uygulamalarının öğretmen adaylarının yapay zekâ kaygı düzeylerini azaltmada tek başına yeterli olmayabileceğini göstermekte; bu alanda farklı değişkenlerin ve daha uzun süreli uygulamaların incelenmesine ihtiyaç olduğunu ortaya koymaktadır.

Anahtar Kelimeler: Yapay zekâ; yapay zekâ kaygısı; çevre öğretimi; PictoBlox.

GİRİŞ

Günümüzde yapay zekâ (YZ) teknolojileri, eğitim alanında hızlı bir biçimde yaygınlaşmakta ve öğretim süreçlerinin yeniden yapılandırılmasında önemli bir rol üstlenmektedir. Özellikle kodlama, blok tabanlı programlama ve yapay zekâ destekli uygulamalar; öğrencilerin problem çözme, algoritmik düşünme ve dijital yeterliliklerini geliştirmeyi amaçlayan çağdaş öğretim yaklaşımlarının temel bileşenleri hâline gelmiştir (Luckin ve ark., 2016; Holmes, Bialik & Fadel, 2019). Bu teknolojilerin eğitim ortamlarına entegrasyonu, yalnızca öğrencilerin bilişsel kazanımları açısından değil, öğretmen ve öğretmen adaylarının teknolojiye yönelik tutum ve duyuşsal özellikleri açısından da ele alınması gereken çok boyutlu bir süreci beraberinde getirmektedir.

Yapay zekâ teknolojilerinin eğitimde kullanımına yönelik artan ilgiye rağmen, bu teknolojilerin öğretmen adayları tarafından nasıl algılandığı ve bu süreçte ortaya çıkan duygusal tepkiler henüz yeterince anlaşılmış değildir. Bu bağlamda, yapay zekâ kaygısı kavramı, son yıllarda eğitim araştırmalarında giderek daha fazla önem kazanmaktadır. Yapay zekâ kaygısı, bireyin yapay zekâ temelli sistemleri kullanma, anlama veya bu sistemlerle etkileşime girme sürecinde yaşadığı endişe, gerginlik ve tehdit algısı olarak tanımlanmaktadır (Wang & Wang, 2019). Eğitim bağlamında ise yapay zekâ kaygısı, öğretmen ve öğretmen adaylarının yapay zekâ destekli araçları pedagojik süreçlere entegre etme konusundaki tutumlarını ve kullanım niyetlerini doğrudan etkileyen bir değişken olarak karşımıza çıkmaktadır.

Yapılan çalışmalar, yapay zekâya yönelik yüksek kaygı düzeyinin teknoloji kabulünü azalttığını, öğrenme sürecine yönelik motivasyonu olumsuz etkilediğini ve teknolojiye karşı direnç davranışlarını artırdığını ortaya koymaktadır (Venkatesh ve ark., 2012; Long & Magerko, 2020). Özellikle öğretmen adayları açısından yapay zekâ kaygısı, yalnızca teknolojik yetersizlik algısından değil; yapay zekânın öğretmenin rolünü değiştireceği ya da öğretim sürecinde insan faktörünün önemini azaltacağı yönündeki düşüncelerden de beslenmektedir. Yapay zekânın öğretmenin yerini alacağına dair algılar, öğretmen adaylarında mesleki tehdit duygusunu güçlendirebilmekte ve bu durum yapay zekâ temelli uygulamalara karşı temkinli ya da olumsuz tutumların gelişmesine yol açabilmektedir (Selwyn, 2019).

Son yıllarda gerçekleştirilen araştırmalar, blok tabanlı kodlama ve yapay zekâ destekli öğrenme ortamlarının, bireylerin yapay zekâyı daha somut, anlaşılır ve kontrol edilebilir bir yapı olarak algılamalarına katkı sağladığını göstermektedir. Blok tabanlı ortamlar, karmaşık kod yapılarını basitleştirerek kullanıcıların sürükle–bırak yöntemiyle kendi uygulamalarını geliştirmelerine olanak tanımakta; bu durum teknolojiye yönelik öz yeterlik algısını desteklemektedir (Resnick ve ark., 2009; Balcı, 2024). Yapay zekâ bileşenlerinin bu tür ortamlara entegre edilmesi ise bireylerin yapay zekâya ilişkin korku ve belirsizliklerini azaltarak teknolojiye yönelik daha olumlu tutum geliştirmelerine katkı sunabilmektedir (Kafai ve ark., 2020; Chiu & Chai, 2020).

PictoBlox, yapay zekâ destekli blok tabanlı kodlama ortamları arasında özellikle eğitim bağlamında öne çıkan uygulamalardan biridir. PictoBlox ortamında gerçekleştirilen yapay zekâ destekli etkinlikler; makine öğrenmesi, görsel sınıflandırma, doğal dil işleme ve metinden sese dönüştürme gibi yapay zekâ bileşenlerini öğretim süreçlerine entegre etme imkânı sunmaktadır. Bu tür uygulamaların, öğretmen adaylarının yalnızca teknik becerilerini değil, aynı zamanda yapay zekâya yönelik algı ve duyuşsal

özelliklerini de etkilediği belirtilmektedir. Yapay zekâ temelli uygulamaları doğrudan deneyimleyen öğretmen adaylarının, bu teknolojileri daha anlaşılır ve kontrol edilebilir olarak algıladıkları; buna bağlı olarak yapay zekâ kaygılarının azaldığı ifade edilmektedir.

Çevre eğitimi, bireylerin çevresel sorunlara yönelik farkındalık kazanmalarını ve sürdürülebilir yaşam becerileri geliştirmelerini amaçlayan disiplinler arası bir alan olup, çağdaş öğretim yöntemleriyle desteklenmesi büyük önem taşımaktadır. Yapay zekâ destekli blok tabanlı uygulamaların çevre eğitimi bağlamında kullanılması, soyut çevresel süreçlerin somutlaştırılmasına ve öğrencilerin aktif katılımının artırılmasına katkı sağlayabilir. Ancak bu tür uygulamaların öğretmen adaylarının yapay zekâya yönelik kaygı düzeyleri üzerindeki etkisinin deneysel olarak incelendiği çalışmaların sınırlı olduğu görülmektedir.

Bu doğrultuda, bu araştırmada çevre eğitiminin yapay zekâ destekli blok tabanlı PictoBlox uygulamaları kullanılarak yürütülmesinin, fen bilgisi öğretmen adaylarının yapay zekâ kaygı düzeyleri üzerindeki etkisinin incelenmesi amaçlanmıştır. Araştırma kapsamında, çevre eğitimi sürecinde PictoBlox uygulamalarının kullanımının, öğretmen adaylarının yapay zekâ kaygılarına ilişkin ön test ve son test puanları arasında istatistiksel olarak anlamlı bir farklılık oluşturup oluşturmadığı sorusuna yanıt aranmıştır.

YÖNTEM

Araştırma Modeli

Bu araştırmada nicel araştırma yöntemlerinden yarı deneysel desen kullanılmıştır. Araştırma, kontrol grubu bulunmayan tek gruplu ön test–son test modeli çerçevesinde yürütülmüştür. Yarı deneysel desenler, özellikle eğitim ortamlarında grupların rastgele atanmasının mümkün olmadığı durumlarda sıklıkla tercih edilmektedir (Büyüköztürk, 2007). Bu desende, deneysel işlem öncesinde ve sonrasında aynı ölçme aracı kullanılarak elde edilen veriler karşılaştırılmakta ve uygulamanın etkisi bu fark üzerinden değerlendirilmektedir.

Çalışma Grubu

Araştırmanın çalışma grubunu, 2024–2025 eğitim-öğretim yılında İç Anadolu Bölgesi'nde bulunan bir devlet üniversitesinin Eğitim Fakültesi Fen Bilgisi Öğretmenliği programında öğrenim gören 24 fen bilgisi öğretmen adayı oluşturmaktadır. Çalışma grubunun belirlenmesinde amaçlı örnekleme yöntemlerinden kolay ulaşılabilir örnekleme kullanılmıştır. Bu yöntem, araştırmaya hız ve pratiklik kazandırmakla birlikte elde edilen bulguların genellenebilirliği açısından sınırlılıklar içermektedir (Yıldırım & Şimşek, 2011).

Katılımcıların %78,26'sı kadın, %21,73'ü erkek öğretmen adaylarından oluşmaktadır.

Uygulama Süreci

Uygulama süreci, çevre dersi kapsamında yürütülmüştür. Sürecin başlangıcında fen bilgisi öğretmen adaylarına yapay zekâ kavramı, yapay zekânın temel bileşenleri ve günlük hayattaki kullanım alanları hakkında bilgilendirme yapılmış; ardından PictoBlox ortamı tanıtılarak blok tabanlı kodlama hakkında temel bilgiler verilmiştir. Daha sonra çevre konuları bağlamında PictoBlox'un farklı eklentileri kullanılarak makine öğrenmesi, görsel sınıflandırma, doğal dil işleme, metinden sese ve metin tanıma gibi yapay zekâ destekli etkinlikler gerçekleştirilmiştir.

Veri Toplama Aracı

Araştırmada veri toplama aracı olarak, Akkaya ve arkadaşları (2021) tarafından Türkçeye uyarlanan 5'li Likert tipi Yapay Zekâ Kaygı Ölçeği kullanılmıştır. Ölçeğin tamamı için hesaplanan Cronbach Alfa güvenirlik katsayısı 0,937'dir.

Verilerin Analizi

Elde edilen veriler SPSS paket programı kullanılarak analiz edilmiştir. Örneklem büyüklüğünün 30'un altında olması nedeniyle normallik analizinde Shapiro–Wilk testi kullanılmıştır (Can, 2020). Normallik varsayımının sağlanmasının ardından, ön test ve son test puanları arasındaki farkın incelenmesinde bağımlı örneklemler t-testi uygulanmıştır.

BULGULAR

Bu araştırmada, çevre eğitiminin blok tabanlı yapay zekâ destekli PictoBlox uygulamaları kullanılarak yürütülmesinin, fen bilgisi öğretmen adaylarının yapay zekâ kaygı düzeyleri üzerindeki etkisi incelenmiştir. Araştırma kapsamında elde edilen veriler, "Yapay Zekâ Kaygı Ölçeği" aracılığıyla toplanmış ve öğretmen adaylarının uygulama öncesi (ön test) ve uygulama sonrası (son test) kaygı puanları karşılaştırılmıştır.

Öncelikle, elde edilen verilerin parametrik testlerin varsayımlarını karşılayıp karşılamadığını belirlemek amacıyla normallik analizi yapılmıştır. Bu doğrultuda, örneklem büyüklüğünün 30'un altında olması nedeniyle Shapiro–Wilk normallik testi uygulanmıştır. Yapılan analiz sonucunda, hem ön test hem de son test puanlarına ait anlamlılık değerlerinin .05 düzeyinden büyük olduğu görülmüştür ($p > .05$). Shapiro–Wilk testi sonuçları, öğretmen adaylarının yapay zekâ kaygı puanlarının normal dağılım gösterdiğini ortaya koymaktadır (Tablo 1).

Tablo 1. Yapay Zekâ Kaygı Ölçeğinin Shapiro-Wilk Testi Sonuçları

Ölçüm	İstatistik	df	p
Ön-Test	0,972	24	0.723
Son-Test	0,966	24	0.580

Bu bulgu doğrultusunda, ön test ve son test puanları arasındaki farkın incelenmesinde parametrik analiz yöntemlerinden bağımlı örneklemler t-testi kullanılmıştır. Fen bilgisi öğretmen adaylarının yapay zekâ kaygı ölçeğinden aldıkları ön test puan ortalaması 43,79 (ss = 12,29), son test puan ortalaması ise 42,13 (ss = 10,73) olarak hesaplanmıştır (Tablo 2).

Tablo 2. Fen Bilgisi Öğretmen Adaylarının Çevre Eğitimi Yapay Zekâ Kaygı Ölçeği Ön Test-Son Test bağımlı Örneklemler t-Testi Sonuçları

Ölçekler	n	x	ss	z	p
Ön Test	24	43,79	12,29	-0,767	,451
Son Test	24	42,13	10,73		

Bağımlı örneklemler t-testi sonuçlarına göre, öğretmen adaylarının ön test ve son test yapay zekâ kaygı puanları arasında istatistiksel olarak anlamlı bir fark bulunmamıştır ($t = -0,767$; $p = .451$). Elde edilen bu sonuç, çevre eğitiminin yapay zekâ destekli PictoBlox uygulamaları kullanılarak yürütülmesinin, fen bilgisi öğretmen adaylarının yapay zekâ kaygı düzeylerinde anlamlı bir değişim oluşturmadığını göstermektedir.

Bu bulgular, uygulama sürecinin öğretmen adaylarının yapay zekâya yönelik kaygı düzeylerini azaltmada tek başına yeterli olmadığını; kaygı gibi duyuşsal değişkenlerin daha uzun süreli, çok boyutlu ve destekleyici öğretim süreçleri gerektirdiğini düşündürmektedir.

TARTIŞMA VE SONUÇ

Bu araştırmada, çevre eğitiminin blok tabanlı yapay zekâ destekli PictoBlox uygulamaları kullanılarak yürütülmesinin, fen bilgisi öğretmen adaylarının yapay zekâ kaygı düzeyleri üzerindeki etkisi incelenmiştir. Elde edilen bulgular, öğretmen adaylarının ön test ve son test yapay zekâ kaygı puanları arasında istatistiksel olarak anlamlı bir farklılık olmadığını göstermiştir. Bu sonuç, uygulama sürecinin öğretmen adaylarının yapay zekâya yönelik kaygı düzeylerinde belirgin bir değişim oluşturmadığını ortaya koymaktadır.

Araştırma bulguları, yapay zekâ destekli ve blok tabanlı uygulamaların öğretmen adaylarının bilişsel ve uygulamaya dönük becerilerini destekleyebilmesine rağmen, kaygı gibi duyuşsal değişkenler üzerinde kısa süreli uygulamalarla sınırlı bir etki yaratabileceğini düşündürmektedir. Wang ve Wang (2019), yapay zekâ kaygısının bireylerin teknolojiye ilişkin bilgi düzeyleri kadar, bu teknolojilerin mesleki roller üzerindeki olası etkilerine yönelik algılarla da yakından ilişkili olduğunu belirtmektedir. Bu bağlamda, öğretmen adaylarının yapay zekâ ile doğrudan uygulama deneyimi kazanmalarının tek başına kaygıyı azaltmak için yeterli olmayabileceği söylenebilir.

Literatürde, uygulamalı ve deneyim temelli yapay zekâ eğitimlerinin bireylerin yapay zekâya yönelik tutumlarını olumlu yönde etkilediğini ortaya koyan çalışmalar bulunmaktadır (Kafai ve ark., 2020; Chiu & Chai, 2020). Ancak bazı araştırmalar, öğretmen adaylarının yapay zekâya yönelik tutumlarının olumlu olmasına rağmen, kaygı ve belirsizlik duygularının devam edebildiğini göstermektedir (Selwyn, 2019). Özellikle yapay zekânın öğretmenin rolünü değiştireceği ya da öğretim sürecinde kontrolü ele alacağı yönündeki algılar, mesleki tehdit duygusunu besleyerek kaygı düzeyinin korunmasına neden olabilmektedir.

Bu araştırmada anlamlı bir farkın ortaya çıkmamasının olası nedenlerinden biri, uygulama süresinin görece kısa olması olabilir. Yapay zekâ kaygısının çok boyutlu bir yapı sergilemesi, bu kaygının azaltılmasının uzun süreli, sistematik ve destekleyici öğretim süreçlerini gerektirdiğini düşündürmektedir. Ayrıca, öğretmen adaylarının önceki teknoloji deneyimleri, dijital yeterlik algıları ve yapay zekâya yönelik ön kabulleri gibi değişkenlerin, uygulamanın etkisini sınırlandırmış olabileceği değerlendirilmektedir.

Bununla birlikte, çevre eğitimi gibi disiplinler arası bir alanda yapay zekâ destekli blok tabanlı uygulamaların kullanılması, öğretmen adaylarının bu teknolojilerle etkileşimini artırması açısından önemli bir deneyim alanı sunmaktadır. Bu yönüyle araştırma, yapay zekâ destekli öğretim uygulamalarının yalnızca bilişsel çıktılar açısından değil, duyuşsal boyutlarıyla da ele alınması gerektiğine dikkat çekmektedir.

Bu araştırmada, çevre eğitiminin yapay zekâ destekli blok tabanlı PictoBlox uygulamaları kullanılarak yürütülmesinin, fen bilgisi öğretmen adaylarının yapay zekâ kaygı düzeyleri üzerinde istatistiksel olarak anlamlı bir etkisinin olmadığı sonucuna ulaşılmıştır. Elde edilen bulgular, yapay zekâ destekli uygulamaların öğretmen adaylarının yapay zekâya yönelik kaygılarını azaltmada tek başına yeterli olmayabileceğini göstermektedir.

Araştırma sonuçları, yapay zekâ kaygısının yalnızca teknik bilgi eksikliğinden kaynaklanan bir durum olmadığını; mesleki beklentiler, algılanan yeterlik ve yapay zekânın öğretmenlik mesleği üzerindeki olası etkilerine ilişkin kaygılarla da ilişkili olduğunu ortaya koymaktadır. Bu nedenle, öğretmen adaylarının yapay zekâya yönelik kaygılarının azaltılmasına yönelik çalışmaların, yalnızca uygulama temelli etkinliklerle sınırlı kalmaması; aynı zamanda pedagojik, etik ve mesleki boyutları da kapsayacak biçimde yapılandırılması gerekmektedir.

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THE EFFECT OF BIOLOGY INSTRUCTION INTEGRATED WITH ARTIFICIAL INTELLIGENCE–SUPPORTED PICTOBLOX APPLICATIONS ON PRE-SERVICE SCIENCE TEACHERS' ARTIFICIAL INTELLIGENCE ANXIETY

YAPAY ZEKÂ DESTEKLİ PICTOBLOX UYGULAMALARIYLA BÜTÜNLEŞTİRİLEN BİYOLOJİ ÖĞRETİMİNİN FEN BİLGİSİ ÖĞRETMEN ADAYLARININ YAPAY ZEKÂ KAYGISI ÜZERİNDEKİ ETKİSİ

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ABSTRACT

Artificial intelligence (AI) technologies are rapidly spreading in the field of education and have the potential to transform instructional methods, particularly in science education. While AI-supported applications aim to enhance students' higher-order thinking skills, problem-solving abilities, and digital literacy, the ways in which these technologies are perceived by pre-service teachers and the affective responses they evoke have become an important area of research. In this context, pre-service teachers' levels of AI anxiety emerge as a determining factor in the effective and sustainable integration of AI-based instructional practices into educational environments. This study was conducted to determine the effect of biology instruction delivered using AI-supported PictoBlox applications on pre-service science teachers' levels of AI anxiety. The research was carried out during the 2024–2025 academic year with 18 pre-service science teachers enrolled in the Science Teacher Education program of the Faculty of Education at a public university located in the Central Anatolia Region of Türkiye. Designed within the framework of quantitative research methods, the study employed a quasi-experimental design using a single-group pretest–posttest model. The "Artificial Intelligence Anxiety Scale" was administered to the participants as both a pretest and a posttest. Within the scope of the implemented biology course, pre-service science teachers engaged in activities such as game design, image processing, natural language processing, numerical classification, and prediction tasks. The biology teaching process was completed through these activities. The analysis of the collected data revealed that there was no statistically significant difference between the participants' AI anxiety scores before and after the implementation. The findings indicate that instructional processes conducted using AI-supported block-based applications alone may not be sufficient to reduce pre-service teachers' levels of AI anxiety and highlight the need for further studies incorporating longer intervention periods and additional variables.

Key Words: Artificial intelligence; artificial intelligence anxiety; pictoblox; pre-service science teachers.

ÖZET

Yapay zekâ teknolojileri, eğitim alanında hızla yaygınlaşmakta ve özellikle fen eğitimi süreçlerinde öğretim yöntemlerini dönüştürme potansiyeli taşımaktadır. Yapay zekâ destekli uygulamalar, öğrencilerin üst düzey düşünme becerilerini, problem çözme yetkinliklerini ve dijital okuryazarlıklarını geliştirmeyi hedeflerken, bu teknolojilerin öğretmen adayları tarafından nasıl algılandığı ve bu süreçte ortaya çıkan duyuşsal tepkiler de önemli bir araştırma konusu hâline gelmiştir. Bu bağlamda, öğretmen adaylarının yapay zekâya yönelik kaygı düzeyleri, yapay zekâ temelli öğretim uygulamalarının etkili ve sürdürülebilir biçimde eğitim ortamlarına entegrasyonunda belirleyici bir faktör olarak öne çıkmaktadır.

Bu araştırma, yapay zekâ destekli PictoBlox uygulamaları kullanılarak yürütülen biyoloji öğretiminin fen bilgisi öğretmen adaylarının yapay zekâ kaygı düzeyleri üzerindeki etkisini belirlemek amacıyla yürütülmüştür. Araştırma, 2024–2025 eğitim-öğretim yılında İç Anadolu Bölgesi'nde bulunan bir devlet üniversitesinin Eğitim Fakültesi Fen Bilgisi Öğretmenliği programında öğrenim gören 18 fen bilgisi öğretmen adayı ile gerçekleştirilmiştir. Araştırma, nicel araştırma yöntemlerinden yarı deneysel desen çerçevesinde tasarlanmış olup, tek gruplu ön test–son test modeli kullanılmıştır. Veri toplama aracı olarak "Yapay Zekâ Kaygı Ölçeği" uygulama öncesinde ve sonrasında öğretmen adaylarına uygulanmıştır. Yürütülen biyoloji dersi kapsamında fen bilgisi öğretmen adaylarına oyun tasarlama, görüntü işleme, doğal dil işleme, sayısal sınıflandırma ve tahmin çalışmaları yaptırılmıştır. Bu etkinlikler aracılığıyla biyoloji öğretim süreci tamamlanmıştır. Araştırma sonucunda elde edilen verilerin analizi sonucunda, fen bilgisi öğretmen adaylarının uygulama süreci öncesi ve sonrası yapay zekâ kaygı puanları arasında istatistiksel olarak anlamlı bir fark bulunmadığı belirlenmiştir. Elde edilen bulgular, yapay zekâ destekli blok tabanlı uygulamalar kullanılarak yürütülen öğretim süreçlerinin öğretmen adaylarının yapay zekâ kaygı düzeylerini azaltmada tek başına yeterli olmayabileceğini ve bu alanda daha uzun süreli, farklı değişkenleri içeren çalışmalara ihtiyaç duyulduğunu göstermektedir.

Anahtar Kelimeler: Yapay zekâ, yapay zekâ kaygısı, pictoblox, fen bilgisi öğretmen adayları

GİRİŞ

Yapay zekâ (YZ) teknolojileri son yıllarda eğitim alanında giderek daha fazla yer almakta ve öğretim süreçlerinin yeniden yapılandırılmasına yönelik önemli fırsatlar sunmaktadır. Özellikle fen eğitimi bağlamında yapay zekâ destekli uygulamalar; soyut kavramların somutlaştırılması, öğrenenlerin derse aktif katılımının artırılması ve üst düzey düşünme becerilerinin geliştirilmesi açısından dikkat çekmektedir (Luckin ve ark., 2016; Holmes, Bialik & Fadel, 2019). Bu gelişmeler, öğretmen adaylarının yalnızca bilişsel değil, aynı zamanda duyuşsal özelliklerinin de incelenmesini gerekli kılmaktadır.

Blok tabanlı kodlama ortamları, programlamaya yeni başlayan bireyler için karmaşık kod yapılarının sadeleştirilmesi yoluyla öğrenme sürecini kolaylaştırmaktadır (Resnick ve ark., 2009). Yapay zekâ bileşenlerini blok tabanlı yapılarla bir araya getiren PictoBlox gibi platformlar, öğretmen adaylarına görüntü işleme, doğal dil işleme ve makine öğrenmesi gibi alanlarda uygulama yapma imkânı sunmaktadır. Bu tür ortamların öğretmen adaylarının teknolojiye yönelik tutum ve algıları üzerinde etkili olduğu bilinmektedir (Zawacki-Richter ve ark., 2019).

Bununla birlikte, yapay zekâ teknolojilerinin eğitim ortamlarında kullanımı bazı kaygıları da beraberinde getirmektedir. Öğretmen adaylarının yapay zekâya yönelik yeterlik algıları, mesleki rollerine ilişkin belirsizlikler ve teknolojik değişime uyum süreci, yapay zekâ kaygısının ortaya çıkmasına neden olabilmektedir (Wang & Wang, 2019). Bu kaygı durumu, öğretmen adaylarının gelecekte yapay zekâ destekli öğretim uygulamalarını benimseme ve kullanma isteğini olumsuz yönde etkileyebilmektedir.

Literatürde, yapay zekâ destekli ve blok tabanlı kodlama uygulamalarının öğretmen adaylarının öğrenme süreçleri ve teknolojiye yönelik tutumları üzerindeki etkilerini inceleyen çeşitli çalışmalar yer almaktadır. Blok tabanlı programlama ortamlarının, programlamaya yönelik algılanan zorluğu azalttığı ve öğrenenlerin derse katılımını artırdığı belirtilmektedir (Resnick ve ark., 2009; Weintrop & Wilensky, 2017). Yapay zekâ bileşenlerinin eğitim ortamlarına entegrasyonunun ise öğretmen adaylarının dijital yeterliklerini ve pedagojik farkındalıklarını desteklediği ifade edilmektedir (Holmes, Bialik & Fadel, 2019; Zawacki-Richter ve ark., 2019). Bununla birlikte, bazı araştırmalar öğretmen adaylarının yapay zekâya yönelik tutumlarının olumlu olmasına rağmen, bu teknolojilere ilişkin kaygı ve belirsizliklerin devam edebildiğini göstermektedir (Baker & Smith, 2019; Wang & Wang, 2019). Özellikle yapay zekânın mesleki roller üzerindeki olası etkileri, öğretmen adaylarında iş güvencesi ve yeterlik algısına dayalı kaygıların ortaya çıkmasına neden olabilmektedir. Bu durum, yapay zekâ destekli uygulamaların yalnızca bilişsel kazanımlar açısından değil, duyuşsal boyutlar açısından da değerlendirilmesi gerektiğini ortaya koymaktadır.

Bu çalışma, yapay zekâ destekli blok tabanlı kodlama uygulamalarından biri olan PictoBlox'un biyoloji dersi bağlamında kullanımının, fen bilgisi öğretmen adaylarının yapay zekâya yönelik kaygı düzeyleri

üzerindeki etkisini incelemeyi amaçlamaktadır. Literatürde yapay zekâ destekli uygulamaların bilişsel kazanımlar üzerindeki etkilerine odaklanan çalışmalar bulunmakla birlikte, öğretmen adaylarının yapay zekâya yönelik kaygı düzeylerini deneysel bir desenle ele alan araştırmaların sınırlı olduğu görülmektedir. Bu bağlamda, biyoloji öğretiminde yapay zekâ destekli blok tabanlı uygulamaların kullanıldığı bir öğretim sürecinin, fen bilgisi öğretmen adaylarının yapay zekâ kaygıları üzerindeki etkisini ortaya koymayı hedefleyen bu araştırmanın, alanyazındaki önemli bir boşluğu doldurması beklenmektedir. Elde edilecek bulguların, öğretmen yetiştirme programlarında yapay zekâ temelli uygulamaların planlanmasına ve öğretmen adaylarının bu teknolojilere yönelik duyuşsal özelliklerinin daha iyi anlaşılmasına katkı sağlayacağı düşünülmektedir.

YÖNTEM

Araştırma Modeli

Bu araştırma, yapay zekâ destekli blok tabanlı kodlama uygulaması PictoBlox ile zenginleştirilen biyoloji öğretiminin, fen bilgisi öğretmen adaylarının yapay zekâ kaygı düzeyleri üzerindeki etkisini incelemek amacıyla yürütülmüş nicel bir çalışmadır. Araştırmada, yarı deneysel desenlerden tek gruplu ön test–son test modeli kullanılmıştır. Bu modelde, uygulamaya katılan bireylerin bağımlı değişkene ilişkin ölçümleri, uygulama öncesinde ve sonrasında aynı ölçme aracı kullanılarak elde edilmekte ve uygulamanın etkisi bu iki ölçüm arasındaki fark üzerinden değerlendirilmektedir (Büyüköztürk ve ark., 2022).

Tek gruplu ön test–son test deseni, özellikle eğitim ortamlarında kontrol grubunun oluşturulmasının güç olduğu durumlarda sıklıkla tercih edilmektedir. Bununla birlikte, bu desenin iç geçerlik açısından bazı sınırlılıkları bulunmakta olup, elde edilen bulguların bu çerçevede değerlendirilmesi gerekmektedir (Campbell & Stanley, 1963).

Çalışma Grubu

Araştırmanın çalışma grubunu, 2024–2025 eğitim-öğretim yılında İç Anadolu Bölgesi'nde yer alan bir devlet üniversitesinin Eğitim Fakültesi Fen Bilgisi Öğretmenliği programında öğrenim gören ve biyoloji dersi alan 18 fen bilgisi öğretmen adayı oluşturmaktadır. Çalışma grubunun belirlenmesinde seçkisiz olmayan örnekleme yöntemlerinden uygun örnekleme yöntemi kullanılmıştır.

Uygun örnekleme, araştırmacının ulaşılması kolay ve mevcut katılımcılarla çalışmasına olanak sağlayan bir örnekleme yaklaşımıdır. Bu yöntemin, özellikle eğitim araştırmalarında sıkça kullanıldığı; ancak elde edilen bulguların genellenebilirliği açısından sınırlılıklar içerdiği belirtilmektedir (Patton, 2005; Cohen, Manion & Morrison, 2021). Bu nedenle, araştırma bulguları yalnızca çalışma grubuyla sınırlı olarak değerlendirilmiştir.

Veri Toplama Aracı

Araştırmada veriler, Wang ve Wang (2019) tarafından geliştirilen ve Terzi (2020) tarafından Türkçeye uyarlanan Yapay Zekâ Kaygı Ölçeği kullanılarak toplanmıştır. Ölçek, katılımcıların yapay zekâya yönelik kaygı düzeylerini belirlemeye yönelik bir öz değerlendirme aracı olup, 7'li Likert tipinde hazırlanmıştır. Toplam 21 maddeden oluşan ölçek; öğrenme, iş değişimi, sosyo-teknik körlük ve yapay zekâ yapılandırılması olmak üzere dört alt boyutu kapsamaktadır.

Ölçeğin güvenirliğine ilişkin yapılan analizlerde, Cronbach alfa katsayısının ölçeğin tamamı için 0,96 olduğu; alt boyutlar için ise 0,89 ile 0,95 arasında değiştiği rapor edilmiştir (Terzi, 2020). Bu değerler, ölçeğin yüksek düzeyde güvenilir olduğunu göstermektedir.

Uygulama Süreci

Araştırma kapsamında yürütülen uygulama, 2024–2025 eğitim-öğretim yılı güz döneminde gerçekleştirilmiştir. Uygulama sürecinde fen bilgisi öğretmen adaylarına, biyoloji dersi kapsamında yapay zekâ destekli blok tabanlı kodlama uygulaması PictoBlox kullanılarak çeşitli etkinlikler yaptırılmıştır. Bu etkinlikler arasında oyun tasarlama, görüntü işleme, doğal dil işleme, sayısal sınıflandırma ve tahmin uygulamaları yer almaktadır.

Uygulama süreci boyunca öğretmen adaylarının yapay zekâ bileşenleriyle doğrudan etkileşim kurmaları sağlanmış; bu sayede hem biyoloji konularının öğretimi desteklenmiş hem de öğretmen adaylarının

yapay zekâ temelli uygulamalara ilişkin deneyim kazanmaları amaçlanmıştır. Yapay zekâ destekli uygulamaların öğretmen adaylarının teknolojiye yönelik farkındalıklarını artırdığına yönelik bulgular, benzer çalışmalar tarafından da desteklenmektedir (Holmes ve ark., 2019).

BULGULAR

Bu bölümde, yapay zekâ destekli PictoBlox uygulamalarıyla zenginleştirilen biyoloji dersinin fen bilgisi öğretmen adaylarının yapay zekâ kaygı düzeyleri üzerindeki etkisini belirlemek amacıyla elde edilen nicel verilere ilişkin analiz sonuçları sunulmuştur. Araştırmada, öğretmen adaylarının yapay zekâ kaygı düzeylerine ait ön test ve son test puanları karşılaştırılmıştır.

Fen bilgisi öğretmen adaylarının Yapay Zekâ Kaygı Ölçeği'nden elde ettikleri ön test ve son test puanlarının dağılımının normalliği Shapiro–Wilk testi ile incelenmiştir. Normallik testine ilişkin sonuçlar Tablo 1'de sunulmuştur.

Tablo 1. Yapay Zekâ Kaygı Ölçeğine Ait Verilerin Shapiro-Wilk Testi Normallik Sonuçları

Ölçüm	**İstatistik**	**df**	**p**
Ön-Test	0.983	18	0.975
Son-Test	0.916	18	0.975

Tablo 1 incelendiğinde, ön test ve son test puanlarına ait anlamlılık değerlerinin .05 düzeyinden büyük olduğu görülmektedir ($p > .05$). Bu sonuçlar, verilerin normal dağılım gösterdiğini ortaya koymaktadır. Ancak örneklem büyüklüğünün 30'un altında olması nedeniyle, analizlerde parametrik olmayan testlerin kullanılmasına karar verilmiştir.

"Blok tabanlı yapay zekâ uygulamalarıyla desteklenen biyoloji dersinde, fen bilgisi öğretmen adaylarının yapay zekâya yönelik kaygılarının ön test ve son test puanları arasında istatistiksel olarak anlamlı bir farklılık var mıdır?" sorusuna yanıt bulmak amacıyla Wilcoxon İşaretli Sıralar Testi uygulanmıştır. Test sonuçları Tablo 2'de sunulmuştur.

Tablo 2. Fen Bilgisi Öğretmen Adaylarının Yapay Zekâ Kaygı Ölçeği Ön Test-Son Test Wilcoxon İşaretli Sıralar Testi Sonuçları

Ön Test – Son Test	**n**	**Sıra Ortalaması**	**Sıra Toplamı**	**z**	**p**
Negatif sıra	10	8,80	88,00	-0,109	,913
Pozitif sıra	8	10,38	83,00		
Eşit	0				

Tablo 2'ye göre, fen bilgisi öğretmen adaylarının yapay zekâ kaygı düzeylerine ilişkin ön test ve son test puanları arasında istatistiksel olarak anlamlı bir fark bulunmamaktadır ($z = -0.109$, $p > .05$). Bu bulgu, yapay zekâ destekli PictoBlox uygulamalarıyla yürütülen biyoloji öğretiminin, öğretmen adaylarının yapay zekâ kaygı düzeylerinde anlamlı bir değişime yol açmadığını göstermektedir.

SONUÇ

Bu araştırmada, yapay zekâ destekli blok tabanlı kodlama uygulamalarından biri olan PictoBlox ile zenginleştirilen biyoloji öğretiminin, fen bilgisi öğretmen adaylarının yapay zekâya yönelik kaygı düzeyleri üzerindeki etkisi incelenmiştir. Araştırma sonucunda, öğretmen adaylarının uygulama öncesi ve sonrası yapay zekâ kaygı puanları arasında istatistiksel olarak anlamlı bir farklılık bulunmadığı

belirlenmiştir. Bu bulgu, yürütülen öğretim sürecinin, öğretmen adaylarının yapay zekâ kaygı düzeylerinde anlamlı bir değişim oluşturmadığını göstermektedir.

Elde edilen sonuçlar, yapay zekâ destekli öğretim uygulamalarının öğretmen adaylarının bilişsel ve uygulamaya dönük becerilerini destekleyebilmesine rağmen, kaygı gibi duyuşsal değişkenler üzerinde kısa süreli uygulamalarla sınırlı bir etki oluşturabileceğini düşündürmektedir. Yapay zekâya yönelik kaygının; bireylerin teknolojiye ilişkin önceki deneyimleri, mesleki beklentileri ve algılanan yeterlik düzeyleri gibi çok boyutlu faktörlerden etkilendiği göz önünde bulundurulduğunda, bu tür kaygıların azaltılmasının uzun vadeli ve sistematik öğretim süreçlerini gerektirdiği söylenebilir.

Araştırmanın bazı sınırlılıkları bulunmaktadır. Çalışmanın tek bir üniversitede ve sınırlı sayıda katılımcı ile yürütülmüş olması, elde edilen bulguların genellenebilirliğini sınırlamaktadır. Ayrıca araştırmada kontrol grubunun yer almaması ve uygulama süresinin görece kısa olması, sonuçların yorumlanmasında dikkate alınması gereken diğer sınırlılıklar arasında yer almaktadır.

Bu doğrultuda, ileride yapılacak araştırmalarda daha geniş örneklemlerle, kontrol gruplu deneysel desenlerin kullanılması önerilmektedir. Ayrıca yapay zekâ kaygısını etkileyebilecek öz yeterlik, teknoloji kabulü ve mesleki beklentiler gibi değişkenlerin de araştırmalara dâhil edilmesi, yapay zekâ destekli öğretim uygulamalarının duyuşsal etkilerinin daha kapsamlı biçimde ortaya konulmasına katkı sağlayabilir. Öğretmen yetiştirme programlarında yapay zekâ temelli uygulamalara daha fazla yer verilmesi ve bu uygulamaların pedagojik çerçevede yapılandırılması, öğretmen adaylarının yapay zekâya yönelik kaygılarının azaltılmasına yönelik önemli bir adım olarak değerlendirilebilir.

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A NOVEL INFERENCE SYSTEM USING DICE SIMILARITY AND NEUTROSOPHIC TAKAGI-SUGENO-KANG MODEL

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ABSTRACT

In daily life, making inferences about an event based on a limited amount of data is a common and important problem. Especially in decision-making processes dominated by uncertainty, classical inference systems often fail to produce reliable and satisfactory results. In this study, a novel inference system based on the neutrosophic Takagi-Sugeno-Kang model is proposed by using Dice similarity measure. The Dice similarity between input data and rule antecedents is calculated using the Dice similarity measure, allowing a more precise evaluation of the consistency between data and rules. Furthermore, inference rules are weighted through t-norm, enabling a more realistic modeling of each rule's contribution to the overall inference process. Finally, a numerical example is presented to demonstrate the applicability and practicality of the proposed inference system.

Keywords: Inference Systems, Takagi-Sugeno-Kang Model, Neutrosophic Sets, Dice Similarity Measure, Decision- Making.

INTRODUCTION

In many fields where uncertain information exists, classical set theory is insufficient. In such cases, fuzzy set theory, introduced by Zadeh (Zadeh, 1965) in 1965, comes to fore. This theory has found effective application in many different fields such as artificial intelligence (Hu et al., 2023) and medicine (Yao et al., 2001). After fuzzy sets were introduced, they were extended to many different sets (Torra, 2010; Atanassov, 1999). One of the most important of these sets is the neutrosophic sets introduced by Smarandache (Smarandache, 1999), which take into account degrees of truth, falsity, and indeterminacy when modelling uncertainty, offering a more sensitive approach in real-life modelling.

Inference systems make predictions about the future based on past data and experiences. Fuzzy inference systems were developed because classical inference systems proved inadequate in situations involving uncertain data. Fuzzy inference systems offer an effective approach by modelling the relationship between input and output variables through fuzzy rules. Many fuzzy systems developed are frequently used in various fields (Jang, 1993; Larsen, 1980; Kosko, 1986). Among these systems, the Takagi-Sugeno-Kang (TSK) model (Takagi and Sugeno, 1985; Sugeno and Kang, 1988), which uses linear and non-linear equations, obtains system outputs more accurately and efficiently. Due to these features, it has found application in a wide range of areas (Gu et al., 2019; Zhang and Ge, 2013).

In this study, a novel inference system based on the neutrosophic Takagi-Sugeno-Kang model is proposed by using Dice similarity measure. The applicability of the system has been increased by linear equations. By considering the truth, falsity, and indeterminacy degrees with neutrosophic sets, the model

has been made more flexible compared to other models. The weight of the system has been calculated flexibly using the t-norm, and Dice similarity measure, increasing the reliability of the model.

The second section describes the necessary preliminary information for the study. The third section introduces the proposed inference system and then provides a numerical example. The final section presents the results of the study.

PRELIMINARY

Some fundamental definitions are introduced in this section related with study.

t-norm (Zimmermann, 2011)

Let $t: [0,1] \times [0,1] \to [0,1]$ be a function. If t satisfies the specified properties for all $a, b, c, d \in [0,1]$, then t is called a t-norm.

(I) $t(0,a) = t(a,0)$ and $t(a,1) = t(1,a) = a$,

(II) If $a \leq c$ and $b \leq d$, then $t(a,b) \leq t(c,d)$,

(III) $t(a,b) = t(b,a)$,

(IV) $t\big(a, t(b,c)\big) = t(t(a,b),c)$.

Neutrosophic Set (Smarandache, 1999)

Let U be a universe of discourse. A neutrosophic set A in U is characterized by three membership functions: the truth-membership function T_A, the indeterminacy-membership function I_A, and the falsity-membership function F_A. For each element of U, the values of T_A, I_A, and F_A are real numbers in the interval $[0,1]$. It can be written,

$$A =< x, \big(T_A(x), I_A(x), F_A(x)\big) >: x \in U, T_A(x), I_A(x), F_A(x) \in [0,1]$$

If U has one element we show as $\bar{x} =< (T_A, I_A, F_A) >$.

Score Function for Neutrosophic Set (Chen and Ye, 2017)

Let $\bar{x} =< (T_A, I_A, F_A) >$ be a neutrosophic element. Then, the score function of $\bar{x}$, denoted by $\delta(\bar{x})$, is defined by,

$$\delta(\bar{x}) = \frac{2 + T_A - I_A - F_A}{3}$$

Single Valued Trapezoidal Neutrosophic Number (Deli and Şubaş, 2017)

A single valued trapezoidal neutrosophic number $\alpha =< [a,b,c,d]; (\mu_\alpha, \pi_\alpha, \nu_\alpha) >$ is a particular type of neutrosophic set defined on the real number set $\mathbb{R}$. Its truth-membership, indeterminacy-membership, and falsity-membership functions are defined for each $x \in \mathbb{R}$ as follows:

$$T_\alpha(x) = \begin{cases} \dfrac{(x-a)\mu_\alpha}{b-a}, & a \leq x < b \\ \mu_\alpha, & b \leq x \leq c \\ \dfrac{(d-x)\mu_\alpha}{d-c}, & c < x \leq d \\ 0, & otherwise \end{cases}, \quad I_\alpha(x) = \begin{cases} \dfrac{b-x+\pi_\alpha(x-a)}{b-a}, & a \leq x < b \\ \pi_\alpha, & b \leq x \leq c \\ \dfrac{x-c+\pi_\alpha(d-x)}{d-c}, & c < x \leq d \\ 1, & otherwise \end{cases}$$

and

$$F_\alpha(x)=\begin{cases}\dfrac{b-x+\nu_\alpha(x-a)}{b-a}, & a\le x<b\\ \nu_\alpha, & b\le x\le c\\ \dfrac{x-c+\nu_\alpha(d-x)}{d-c}, & c<x\le d\\ 1, & otherwise\end{cases}$$

here, $\mu_\alpha,\pi_\alpha,\nu_\alpha\in[0,1]$.

Normalized Single Valued Trapezoidal Neutrosophic Number (Deli et al., 2022)

Let $\alpha =< [a,b,c,d];(\mu_\alpha,\pi_\alpha,\nu_\alpha) >$. Then the normalized single valued trapezoidal neutrosophic number of α, denoted by $\bar{\alpha}$ is given by;

$$\bar{\alpha} =< [\frac{a}{a+b+c+d},\frac{b}{a+b+c+d},\frac{c}{a+b+c+d},\frac{d}{a+b+c+d}];(\mu_\alpha,\pi_\alpha,\nu_\alpha) >$$

Dice Similarity Measure for Normalized Single Valued Trapezoidal Neutrosophic Number (Deli et al., 2022)

Let $\bar{\alpha} =< [a_1,b_1,c_1,d_1];(\mu_{\bar{\alpha}},\pi_{\bar{\alpha}},\nu_{\bar{\alpha}}) >$ and $\bar{\beta} =< [a_2,b_2,c_2,d_2];(\mu_{\bar{\beta}},\pi_{\bar{\beta}},\nu_{\bar{\beta}}) >$ be normalized single valued trapezoidal neutrosophic numbers. Then Dice similarity measure between $\bar{\alpha}$ and $\bar{\beta}$ defined as:

$$\mathcal{D}(\bar{\alpha},\bar{\beta})=\frac{1}{1+\left|P(\bar{\alpha})-P(\bar{\beta})\right|}\cdot\frac{2(\mu_{\bar{\alpha}\bar{\beta}}+\pi_{\bar{\alpha}\bar{\beta}}+\nu_{\bar{\alpha}\bar{\beta}})}{\mu_{\bar{\alpha}\bar{\alpha}}+\mu_{\bar{\beta}\bar{\beta}}+\pi_{\bar{\alpha}\bar{\alpha}}+\pi_{\bar{\beta}\bar{\beta}}+\nu_{\bar{\alpha}\bar{\alpha}}+\nu_{\bar{\beta}\bar{\beta}}}$$

where,

$P(\bar{\alpha})=\frac{a_1+2b_1+2c_1+d_1}{6}$, $P(\bar{\beta})=\frac{a_2+2b_2+2c_2+d_2}{6}$

and

$$\mu_{\bar{\alpha}\bar{\beta}}=\mu_{\bar{\alpha}}\mu_{\bar{\beta}},\quad \mu_{\bar{\alpha}\bar{\alpha}}=\mu_{\bar{\alpha}}^2,\quad \mu_{\bar{\beta}\bar{\beta}}=\mu_{\bar{\beta}}^2,$$
$$\pi_{\bar{\alpha}\bar{\beta}}=\pi_{\bar{\alpha}}\pi_{\bar{\beta}},\quad \pi_{\bar{\alpha}\bar{\alpha}}=\pi_{\bar{\alpha}}^2,\quad \pi_{\bar{\beta}\bar{\beta}}=\pi_{\bar{\beta}}^2,$$
$$\nu_{\bar{\alpha}\bar{\beta}}=\nu_{\bar{\alpha}}\nu_{\bar{\beta}},\quad \nu_{\bar{\alpha}\bar{\alpha}}=\nu_{\bar{\alpha}}^2,\quad \nu_{\bar{\beta}\bar{\beta}}=\nu_{\bar{\beta}}^2$$

NEUTROSOPHIC TSK INFERENCE SYSTEM BASED-ON DICE SIMILARITY MEASURE

In this section, an improved model developed based on the m inputs n outputs Linear Neutrosophic TSK Inference System proposed by Uluçay et al. (Uluçay et al., 2026) is presented. In the proposed system, instead of employing the arithmetic mean to obtain the output values, a rule-weighting strategy is adopted. Within this framework, the Dice similarity measure and the t-norm operator are utilized to determine and aggregate the rule weights. Consequently, the effect of each rule on the overall system output is modeled in a more sensitive and effective manner, thereby enhancing the representational capability of the inference mechanism. The proposed system is presented below.

Let $A_1^1,A_2^1,\dots$ be neutrosophic linguistic values in $X_1\subseteq\mathbb{R}$, and generally $A_1^j,A_2^j,\dots\in X_j\subseteq\mathbb{R}$ for $j=1,2,\dots,m$. Consider the following equation systems for m variables and $i=1,2,\dots,p$ and $n\in\mathbb{R}$:

$$\varphi_1^i=f_1^i(x_1,x_2,\dots,x_m),\varphi_2^i=f_2^i(x_1,x_2,\dots,x_m),\dots,\varphi_n^i=f_n^i(x_1,x_2,\dots,x_m)$$

Where $t=1,2,\dots,n$, $i_t=1,2,\dots,m$ and $a_0^{i_t},a_1^{i_t},a_2^{i_t},\dots,a_m^{i_t}\in\mathbb{R}$ written as:

$$\varphi_t^i=f_t^i(x_1,x_2,\dots,x_m)=a_0^{i_t}+a_1^{i_t}x_1+a_2^{i_t}x_2+\cdots+a_m^{i_t}x_m$$

Then linear Neutrosophic TSK Inference System with m inputs n outputs and p rules is represented as follows for $i_t=1,2,\dots,m$ denotes the tth linear equation of the ith rule and $\imath,\jmath,\mathrm{l}=1,2,\dots$

Inference Rule i: IF x_1 is A_i^1 AND x_2 is A_j^2 AND ... x_m is A_l^m THEN

$$\begin{cases} \varphi_1^i = a_0^{i_1} + a_1^{i_1}x_1 + a_2^{i_1}x_2 + \cdots + a_m^{i_1}x_m \\ \varphi_2^i = a_0^{i_2} + a_1^{i_2}x_1 + a_2^{i_2}x_2 + \cdots + a_m^{i_2}x_m \\ \vdots \\ \varphi_n^i = a_0^{i_n} + a_1^{i_n}x_1 + a_2^{i_n}x_2 + \cdots + a_m^{n}x_m \end{cases}$$

To find the final outputs $\varphi_1, \varphi_2, \dots, \varphi_n$ calculations must be made separately for the intervals to which each variable m belongs.

Firstly, the following values are calculated for each m using the score function for the specified interval.

$$\delta^i(\overline{x_1}) = \frac{2+T_{A_i^1} - I_{A_i^1} - F_{A_i^1}}{3}, \delta^i(\overline{x_2}) = \frac{2+T_{A_j^2} - I_{A_j^2} - F_{A_j^2}}{3}, \cdots, \delta^i(\overline{x_m}) = \frac{2+T_{A_l^m} - I_{A_l^m} - F_{A_l^m}}{3}$$

The values found are then written into the linear equation in each rule to find,

$$f_1^i\left(\delta^i(\overline{x_1})x_1, \delta^i(\overline{x_2})x_2, \dots, \delta^i(\overline{x_m})x_m\right), f_2^i\left(\delta^i(\overline{x_1})x_1, \delta^i(\overline{x_2})x_2, \dots, \delta^i(\overline{x_m})x_m\right),$$
$$\dots, f_n^i\left(\delta^i(\overline{x_1})x_1, \delta^i(\overline{x_2})x_2, \dots, \delta^i(\overline{x_m})x_m\right)$$

Following these computations, the next step is to determine the weights of the rules. For this purpose, the similarity measure between the input data and the rule antecedents must first be calculated. In this context, the input data are expressed as normalized trapezoidal neutrosophic numbers as follows:

$$\overline{x_1} = \overline{A_i^{1*}} =< [x_1, x_1, x_1, x_1]; (1,0,0) >, \quad \overline{x_2} = \overline{A_j^{2*}} =< [x_2, x_2, x_2, x_2]; (1,0,0) >, \dots,$$
$$\overline{x_m} = \overline{A_l^{m*}} =< [x_m, x_m, x_m, x_m]; (1,0,0) >$$

Subsequently, the Dice similarity measures:

$$\mathcal{D}\left(\overline{A_i^{1*}}, A_i^1\right), \mathcal{D}\left(\overline{A_j^{2*}}, A_j^2\right), \dots, \mathcal{D}\left(\overline{A_l^{m*}}, A_l^m\right)$$

are calculated. After the similarity measures calculated, the rule weights are computed using the t-norm as follows:

$$\omega^i = t(\mathcal{D}\left(\overline{A_i^{1*}}, A_i^1\right), \mathcal{D}\left(\overline{A_j^{2*}}, A_j^2\right), \dots, \mathcal{D}\left(\overline{A_l^{m*}}, A_l^m\right))$$

Based on the values obtained in last equations, the outputs value for the given inputs is calculated as follows:

$$\varphi_1 = \frac{\sum_{i=1}^{p} \omega^i \left(f_1^i\left(\delta^i(\overline{x_1})x_1, \delta^i(\overline{x_2})x_2, \dots, \delta^i(\overline{x_m})x_m\right)\right)}{\sum_{i=1}^{p} \omega^i},$$

$$\varphi_2 = \frac{\sum_{i=1}^{p} \omega^i (f_2^i\left(\delta^i(\overline{x_1})x_1, \delta^i(\overline{x_2})x_2, \dots, \delta^i(\overline{x_m})x_m\right))}{\sum_{i=1}^{p} \omega^i}, \cdots$$

$$\varphi_n = \frac{\sum_{i=1}^{p} \omega^i (f_n^i\left(\delta^i(\overline{x_1})x_1, \delta^i(\overline{x_2})x_2, \dots, \delta^i(\overline{x_m})x_m\right))}{\sum_{i=1}^{p} \omega^i}$$

Example for two inputs single output

Let

$$A_1 =< (0,1,2,3); (0.7,0.6,0.4) >, \quad A_2 =< (0,1,2,3); (0.6,0.7,0.8) >$$
$$B_1 =< (0,1,4,5); (0.6,0.6,0.7) >, \quad B_2 =< (0,1,4,5); (0.8,0.7,0.6) >$$

be neutrosophic linguistic values for $X = [0,3] \in \mathbb{R}$ and $Y = [0,5] \in \mathbb{R}$ respectively. Let the rules for given variables be given as follows for $x \in X$ and $y \in Y$:

Rule 1 : If x is A_1 AND y is B_1 THEN $\varphi_1 = f_1(x,y) = 2x - 3y + 16$

Rule 2 : If x is A_2 AND y is B_2 THEN $\varphi_2 = f_2(x,y) = x - 6y + 26$

Assume that $x = 2.5$ and $y = 4.2$ so $x \in (2,3)$ and $y \in (4,5)$. Let's find the score function for the given interval.

$$\delta^1(\bar{x}) = 0.28, \qquad \delta^1(\bar{y}) = 0.34$$
$$\delta^2(\bar{x}) = 0.34, \qquad \delta^2(\bar{y}) = 0.4$$

The values obtained are then substituted into the equation corresponding to the rules.

$$\varphi_1 = f_1(\delta^1(\bar{x})x, \delta^1(y)y) = 2x - 3y + 16 = 2 \cdot 0.28 \cdot 2.5 - 3 \cdot 0.34 \cdot 4.2 + 16 = 13.11$$
$$\varphi_2 = f_2(\delta^2(\bar{x})x, \delta^2(y)y) = x - 6y + 26 = 0.34 \cdot 2.5 - 6 \cdot 0.4 \cdot 4.2 + 26 = 16.77$$

After these computations, the normalized trapezoidal neutrosophic numbers,

$$\overline{A^*} =< [2.5,2.5,2.5,2.5]; (1,0,0) >, \qquad \overline{B^*} =< [4.2,4.2,4.2,4.2]; (1,0,0) >$$

are formulated, and the Dice similartiy measures between these numbers and the rule antecedents are then calculated:

For Rule 1:

$\mathcal{D}(\overline{A^*}, A_1) = 0.34$ and $\mathcal{D}(\overline{B^*}, B_1) = 0.28$

And for Rule 2:

$\mathcal{D}(\overline{A^*}, A_2) = 0.24$ and $\mathcal{D}(\overline{B^*}, B_2) = 0.35$

From here, by assuming $t(a, b) = \min\{a, b\}$, the rule weights are calculated.

$\omega^1 = min\{0.34, 0.28\} = 0.28$ and $\omega^2 = min\{0.24, 0.35\} = 0.24$

According to the final computed values, the output corresponding to the inputs $x = 2.5$ and $y = 4.2$ is obtained as follows.

$$\varphi = \frac{0.28 \cdot 13.11 + 0.24 \cdot 16.77}{0.28 + 0.24} = 14.79$$

CONCLUSION AND DISCUSSION

In this study, a novel linear TSK inference system based on neutrosophic sets is proposed to achieve a more comprehensive modelling of uncertainty by considering the degrees of truth, falsity, and indeterminacy. Within the proposed system, the Dice similarity measure is integrated into the inference mechanism to enable a more precise of the relationship between input values and rule antecedents. Furthermore, the weighting of inference rules through t-norm operators allow the contributions of individual rules to be aggregated in a more realistic, consistent, during the decision-making process. The applicability and computational simplicity of the system are demonstrated through a two input, single output illustrative example. The proposed system is formulated in a general m-input, n-output structure, thereby providing a flexible framework that can be readily adapted to various application domains.

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A NEW INFERENCE SYSTEM BASED ON THE INTUITIONISTIC TAKAGI–SUGENO–KANG MODEL WITH SIMILARITY MEASURES

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ABSTRACT

In this study, a novel inference system based on the intuitionistic Takagi–Sugeno–Kang model is proposed by using similarity measures under t-norm operators. The use of IF–THEN rules in the proposed system enhances the predictive capability of the system, enabling effective future-oriented estimations. By considering not only the membership degrees but also the non-membership degrees of intuitionistic fuzzy sets, the intuitionistic Takagi–Sugeno–Kang system provides more flexible and realistic representation of uncertainty according to classic and fuzzy inference systems. The mechanism of the inference systems expresses the consequent parts using linear equations, which improves the interpretability of the model while reducing computational complexity. Furthermore, the consistency of the inference process is strengthened by calculating the similarity between input data and rule antecedents. The rules are weighted through t-norm operators, allowing the influence of each rule on the final output to be modeled more accurately. Finally, the applicability and effectiveness of the proposed system are demonstrated through a numerical example with two inputs and one output.

Key Words: Inference Systems, Takagi-Sugeno-Kang Model, Intuitionistic Fuzzy Sets, Similarity Measure, Decision- Making.

INTRODUCTION

In many fields where uncertainty be effective, classical set theory proves to be inadequate. In such cases, fuzzy set theory, introduced in 1965 by Zadeh (Zadeh, 1965), has emerged as an important alternative framework. Fuzzy sets have been effectively applied in various disciplines, such as engineering (Blockley, 1979) and agriculture (Zhang et al., 2011).

Subsequently, this approach was extended to different types of generalized sets (Sebastian and Ramakrishnan, 2010; Ramot et aş., 2002). Among these, intuitionistic fuzzy sets proposed by Atanassov (Atanassov, 1999) hold a significant place. Intuitionistic fuzzy sets consider not only the degree of membership of an element but also its degree of non-membership and the associated hesitation margin. In this way, they enable a more detailed and flexible modelling of uncertainty, providing a more sensitive approach to real-life problems.

Inference systems generate predictions about future events by utilizing past data and experience. However, classical inference systems often remain insufficient when dealing with uncertain or imprecise information. To overcome these limitations, fuzzy inference systems were developed (Larsen, 1980; Kosko, 1986, Jang, 1993). By modelling the relationship between input and output variables through fuzzy rules, these systems provide a flexible and effective framework for handling uncertainty.

Among these models, the Takagi-Sugeno-Kang model (TSK) model (Takagi and Sugeno, 1985; Sugeno and Kang, 1988), stands out for its ability to incorporate linear and nonlinear functions in the rule consequents. Owing to this structure, the TSK model produces system outputs in a more accurate and computationally efficient manner. These advantages have led to its successful application in a wide variety of fields (Shirgir and Farahmand-Tabar, 2025; Deli et al., 2025).

In this study, a new inference system based on the intuitionistic fuzzy TSK model is proposed by employing a similarity measure. The applicability of the system is enhanced through the use of linear equations in the rule consequents. By considering the membership and non-membership degrees provided by intuitionistic fuzzy sets, the proposed model offers greater flexibility compared to traditional fuzzy models. Furthermore, the system weights are determined in a flexible manner using a t-norm operator together with the selected distance measure, thereby improving the reliability and effectiveness of the model.

The second section presents the fundamental preliminary concepts and definitions required for the study. The third section introduces the proposed model and subsequently illustrates its applicability through a numerical example. Finally, the last section discusses the results obtained from the study and provides concluding remarks.

PRELIMINARY

This section introduces essential basic definitions for study.

t-norm (Zimmermann, 2011)

Consider a function $t: [0,1] \times [0,1] \to [0,1]$. The function t is called a t-norm provided that it fulfills the specified conditions for $\forall\ a, b, c, d \in [0,1]$.

(V) $t(0,a) = t(a,0)$ and $t(a,1) = t(1,a) = a$,

(VI) If $a \leq c$ and $b \leq d$, then $t(a,b) \leq t(c,d)$,

(VII) $t(a,b) = t(b,a)$,

(VIII) $t\big(a, t(b,c)\big) = t(t(a,b),c)$.

Intuitionistic Fuzzy Set (Atanassov, 1999)

Let X be a non-empty set. An intuitionistic fuzzy set $\tilde{A}$ on X is defined by,

$$\tilde{A} = \{\langle x, (\mu_{\tilde{A}}(x), \nu_{\tilde{A}}(x))\rangle : x \in X\}$$

where the functions $\mu_{\tilde{A}}: X \to [0,1]$ and $\nu_{\tilde{A}}: X \to [0,1]$ represent the degree of membership and the degree of non-membership of $x \in X$ to the set $\tilde{A}$, respectively. These functions satisfy the condition

$$0 \leq \mu_{\tilde{A}}(x) + \nu_{\tilde{A}}(x) \leq 1$$

for every $x \in X$. In this context, the notation $\tilde{x} = \langle x, (\mu_{\tilde{A}}(x), \nu_{\tilde{A}}(x))\rangle$ for $x \in X$ is referred to as an intuitionistic fuzzy element. If Xconsists of a single element, it is denoted by $\tilde{x} = (\mu_{\tilde{A}}, \nu_{\tilde{A}})$.

Score Function for Intuitionistic Fuzzy Set (Feng et al., 2018)

Given an intuitionistic fuzzy element $\tilde{x} = (\mu_{\tilde{A}}, \nu_{\tilde{A}})$, its score function, written as $\Delta(\tilde{x})$, and defined by

$$\Delta(\tilde{x}) = \frac{1 + \mu_{\tilde{A}} - \nu_{\tilde{A}}}{2}$$

Trapezoidal Intuitionistic Fuzzy Number (Uluçay et al., 2018)

Let $a_i, b_i, c_i, d_i \in \mathbb{R}$ satisfy $a_i \leq b_i \leq c_i \leq d_i,\ i = 1,2$ and let $\omega_{\tilde{a}}, \eta_{\tilde{a}} \in [0,1]$. An intuitionistic trapezoidal fuzzy number $\tilde{a}$ is denoted by

$$\tilde{a} = < [a_1, b_1, c_1, d_1]; \omega_{\tilde{a}}, [a_2, b_2, c_2, d_2]; \eta_{\tilde{a}} >$$

where the membership function $\mu_{\tilde{a}}$ and the non-membership function $\nu_{\tilde{a}}$ are defined, respectively, as follows:

$$\mu_{\tilde{a}}(x)=\begin{cases}\frac{(x-a_1)\omega_{\tilde{a}}}{b_1-a_1}, & a_1\le x<b_1\\ \omega_{\tilde{a}}, & b_1\le x\le c_1\\ \frac{(d_1-x)\omega_{\tilde{a}}}{d_1-c_1}, & c_1<x\le d_1\\ 0, & otherwise\end{cases} \text{ and } \nu_{\tilde{a}}(x)=\begin{cases}\frac{b_2-x+\eta_{\tilde{a}}(x-a_2)}{b_2-a_2}, & a_2\le x<b_2\\ \eta_{\tilde{a}}, & b_2\le x\le c_2\\ \frac{x-c_2+\eta_{\tilde{a}}(d_2-x)}{d_2-c_2}, & c_2<x\le d_2\\ 1, & otherwise\end{cases}$$

Here,

$$0\le\omega_{\tilde{a}}+\eta_{\tilde{a}}\le 1, x\in\mathbb{R}$$

Normalized Intuitionistic Trapezoidal Fuzzy Number (Uluçay et al., 2018)

Let $\tilde{a}=<[a,b,c,d];(\omega_\alpha,\eta_\alpha)>$. Then the normalized intuitionistic trapezoidal fuzzy number of $\tilde{a}$, denoted by $\bar{\tilde{a}}$ is given by;

$$\bar{\tilde{a}}=<[\frac{a}{a+b+c+d},\frac{b}{a+b+c+d},\frac{c}{a+b+c+d},\frac{d}{a+b+c+d}];(\omega_\alpha,\eta_\alpha)>$$

Similarity Measure For Normalized Intuitionistic Trapezoidal Fuzzy Number (Uluçay and Okumuş, 2024)

Let $\bar{\tilde{a}}=<[a_1,b_1,c_1,d_1];(\omega_{\bar{\tilde{a}}},\eta_{\bar{\tilde{a}}})>$ and $\bar{\tilde{\beta}}=<[a_2,b_2,c_2,d_2];\left(\omega_{\bar{\tilde{\beta}}},\eta_{\bar{\tilde{\beta}}}\right)>$ be normalized intuitionistic trapezoidal fuzzy number. Then similarity measure between $\bar{\alpha}$ and $\bar{\beta}$ defined as:

$$\mathcal{S}_r\left(\bar{\tilde{a}},\bar{\tilde{\beta}}\right)=\frac{1}{1+\sqrt{\mathcal{D}_r\left(\bar{\tilde{a}},\bar{\tilde{\beta}}\right)}}$$

where,

$$\begin{aligned}\mathcal{D}_r\left(\bar{\tilde{a}},\bar{\tilde{\beta}}\right)=\frac{1}{16}\cdot\Big(\Big[&\Big(\Big|(1+\omega_{\bar{\tilde{a}}}-\eta_{\bar{\tilde{a}}})a_1-\left(1+\omega_{\bar{\tilde{\beta}}}-\eta_{\bar{\tilde{\beta}}}\right)a_2\Big|\Big)^r\\&+\Big(\Big|(1+\omega_{\bar{\tilde{a}}}-\eta_{\bar{\tilde{a}}})b_1-\left(1+\omega_{\bar{\tilde{\beta}}}-\eta_{\bar{\tilde{\beta}}}\right)b_2\Big|\Big)^r\\&+\Big(\Big|(1+\omega_{\bar{\tilde{a}}}-\eta_{\bar{\tilde{a}}})c_1-\left(1+\omega_{\bar{\tilde{\beta}}}-\eta_{\bar{\tilde{\beta}}}\right)c_2\Big|\Big)^r\\&+\Big(\Big|(1+\omega_{\bar{\tilde{a}}}-\eta_{\bar{\tilde{a}}})d_1-\left(1+\omega_{\bar{\tilde{\beta}}}-\eta_{\bar{\tilde{\beta}}}\right)d_2\Big|\Big)^r\Big]\Big)^{\frac{1}{r}}\end{aligned}$$

INTUITIONISTIC TAKAGI-SUGENO-KANG MODEL WITH SIMILARITY MEASURES

In this section, an improved model developed based on the m-input n-output Linear Intuitionistic TSK model proposed by Uluçay et al. (2025) is presented. In the proposed model, instead of employing the arithmetic mean to compute the output values, a rule-weighting mechanism is introduced. Within this structure, a similarity measure and a t-norm operator are utilized to determine the rule weights. Accordingly, the contribution of each rule to the overall system output is modeled in a more sensitive and effective manner, thereby improving the representational strength and inference capability of the model. The proposed model is detailed below.

Let $\widetilde{\mathcal{A}_1^1},\widetilde{\mathcal{A}_2^1},\ldots\in\mathcal{X}_1\subseteq\mathbb{R}$, $\widetilde{\mathcal{A}_1^2},\widetilde{\mathcal{A}_2^2},\ldots\in\mathcal{X}_2\subseteq\mathbb{R}$, $\ldots,\widetilde{\mathcal{A}_1^m},\widetilde{\mathcal{A}_2^m},\ldots\in\mathcal{X}_m\subseteq\mathbb{R}$ be intuitionistic fuzzy linguistic terms corresponding to each input variable, where $m\in\mathbb{N}$. Now consider the following system of linear equations involving m variables:

$x_1\in\mathcal{X}_1,x_2\in\mathcal{X}_2,\ldots,x_m\in\mathcal{X}_m$, defined for $i=1,2,\ldots,p$ and $n\in\mathbb{N}$:

$$f_1^i=g_1^i(x_1,x_2,\ldots,x_m),f_2^i=g_2^i(x_1,x_2,\ldots,x_m),\ldots,f_n^i=g_n^i(x_1,x_2,\ldots,x_m)$$

Where $t = 1,2,\dots,n$, $i_t = 1,2,\dots,m$ and $a_0^{i_t}, a_1^{i_t}, a_2^{i_t}, \dots, a_m^{i_t} \in \mathbb{R}$ written as:

$$f_t^i = g_t^i(x_1, x_2, \dots, x_m) = a_0^{i_t} + a_1^{i_t}x_1 + a_2^{i_t}x_2 + \cdots + a_m^{i_t}x_m$$

Then linear Intuitionistic Fuzzy TSK Model with m-inputs n −outputs and p rules is represented as follows for $i_t = 1,2,\dots,m$ denotes the tth linear equation of the ith rule and $\iota, \jmath, l = 1,2,\dots$

Model Rule i: IF x_1 is $\widetilde{\mathcal{A}_1^1}$ AND x_2 is $\widetilde{\mathcal{A}_\jmath^2}$ AND ... x_m is $\widetilde{\mathcal{A}_1^m}$ THEN

$$\begin{cases} f_1^i = a_0^{i_1} + a_1^{i_1}x_1 + a_2^{i_1}x_2 + \cdots + a_m^{i_1}x_m \\ f_2^i = a_0^{i_2} + a_1^{i_2}x_1 + a_2^{i_2}x_2 + \cdots + a_m^{i_2}x_m \\ \vdots \\ f_n^i = a_0^{i_n} + a_1^{i_n}x_1 + a_2^{i_n}x_2 + \cdots + a_m^{n}x_m \end{cases}$$

To determine the final outputs $f_1, f_2, \dots, f_n$ computations must be carried out separately for each interval associated with the variables $x_1, x_2, \dots, x_m$.

As a first step, the following values are calculated for each variable using the score function, based on the corresponding interval.

$$\Delta^i(\widetilde{x_1}) = \frac{1+\mu_{\widetilde{\mathcal{A}_1^1}}-\nu_{\widetilde{\mathcal{A}_1^1}}}{2},\ \Delta^i(\widetilde{x_2}) = \frac{1+\mu_{\widetilde{\mathcal{A}_\jmath^2}}-\nu_{\widetilde{\mathcal{A}_\jmath^2}}}{2}, \cdots, \Delta^i(\widetilde{x_m}) = \frac{1+\mu_{\widetilde{\mathcal{A}_1^m}}-\nu_{\widetilde{\mathcal{A}_1^m}}}{2}$$

The values found are then written into the linear equation in each rule to find,

$$g_1^i\left(\Delta^i(\widetilde{x_1})x_1, \Delta^i(\widetilde{x_2})x_2, \dots, \Delta^i(\widetilde{x_m})x_m\right),\ g_2^i\left(\Delta^i(\widetilde{x_1})x_1, \Delta^i(\widetilde{x_2})x_2, \dots, \Delta^i(\widetilde{x_m})x_m\right),$$
$$\dots, g_n^i\left(\Delta^i(\widetilde{x_1})x_1, \Delta^i(\widetilde{x_2})x_2, \dots, \Delta^i(\widetilde{x_m})x_m\right)$$

Subsequent to these calculations, the rule weights are determined. To this end, it is first necessary to compute the similarity measure between the input data and the antecedent of the rules. In this framework, the input data are represented as normalized intuitionistic trapezoidal fuzzy numbers as given below:

$$\widetilde{x_1} = \overline{\widetilde{\mathcal{A}_1^{1*}}} =< [x_1, x_1, x_1, x_1]; (1,0) >, \qquad \widetilde{x_2} = \overline{\widetilde{\mathcal{A}_\jmath^{2*}}} =< [x_2, x_2, x_2, x_2]; (1,0) >, \dots,$$
$$\widetilde{x_m} = \overline{\widetilde{\mathcal{A}_l^{m*}}} =< [x_m, x_m, x_m, x_m]; (1,0) >$$

Subsequently, the similarity measures:

$$\mathcal{S}_r\left(\overline{\widetilde{\mathcal{A}_\iota^{1*}}}, \widetilde{\mathcal{A}_\iota^1}\right), \mathcal{S}_r\left(\overline{\widetilde{\mathcal{A}_\jmath^{2*}}}, \widetilde{\mathcal{A}_\jmath^2}\right), \dots, \mathcal{S}_r\left(\overline{\widetilde{\mathcal{A}_l^{m*}}}, \widetilde{\mathcal{A}_\jmath^m}\right)$$

are determined. After the similarity measures calculated, the rule weights are computed using the t-norm as follows:

$$\Omega^i = t(\mathcal{S}_r\left(\overline{\widetilde{\mathcal{A}_\iota^{1*}}}, \widetilde{\mathcal{A}_\iota^1}\right), \mathcal{S}_r\left(\overline{\widetilde{\mathcal{A}_\jmath^{2*}}}, \widetilde{\mathcal{A}_\jmath^2}\right), \dots, \mathcal{S}_r\left(\overline{\widetilde{\mathcal{A}_l^{m*}}}, \widetilde{\mathcal{A}_l^m}\right))$$

Based on the values obtained from the final equations, the output value corresponding to the given inputs is calculated as follows:

$$f_1 = \frac{\sum_{i=1}^p \Omega^i \left(g_1^i\left(\Delta^i(\widetilde{x_1})x_1, \Delta^i(\widetilde{x_2})x_2, \dots, \Delta^i(\widetilde{x_m})x_m\right)\right)}{\sum_{i=1}^p \Omega^i},$$

$$f_2 = \frac{\sum_{i=1}^p \Omega^i (g_2^i\left(\Delta^i(\widetilde{x_1})x_1, \Delta^i(\widetilde{x_2})x_2, \dots, \Delta^i(\widetilde{x_m})x_m\right))}{\sum_{i=1}^p \Omega^i}, \dots$$

$$f_n = \frac{\sum_{i=1}^p \Omega^i (g_n^i\left(\Delta^i(\widetilde{x_1})x_1, \Delta^i(\widetilde{x_2})x_2, \dots, \Delta^i(\widetilde{x_m})x_m\right))}{\sum_{i=1}^p \Omega^i}$$

Example for two inputs single output

Let

$$\tilde{A}_1 =< (0,1,4,5); (0.6,0.4) >, \qquad \tilde{A}_2 =< (0,1,4,5); (0.7,0.3) >$$
$$\tilde{B}_1 =< (0,1,2,3); (0.5,0.5) >, \qquad \tilde{B}_2 =< (0,1,2,3); (0.8,0.2) >$$

be intuitionistic fuzzy linguistic values for $X = [0,5] \in \mathbb{R}$ and $Y = [0,3] \in \mathbb{R}$. Let the rules corresponding to the given variables be defined as follows for $x \in X$ and $y \in Y$:

Rule 1 : If x is $\tilde{A}_1$ AND y is $\tilde{B}_1$ THEN $f_1 = g_1(x,y) = -4x + 7y + 17$

Rule 2 : If x is $\tilde{A}_2$ AND y is $\tilde{B}_2$ THEN $f_2 = g_2(x,y) = -3x + y + 23$

Assume that $x = 3.7$ and $y = 2.6$ so $x \in (1,4)$ and $y \in (2,3)$. Let's find the score function for the given interval.

$$\Delta^1(\tilde{x}) = 0.6, \qquad \Delta^1(\tilde{y}) = 0.2$$
$$\Delta^2(\tilde{x}) = 0.7, \qquad \Delta^2(\tilde{y}) = 0.32$$

he obtained values are then substituted into the equations corresponding to the respective rules.

$$f_1 = g_1(\Delta^1(\tilde{x})x, \Delta^1(\tilde{y})y) = -4x + 7y + 17 = -4 \cdot 0.6 + 7 \cdot 0.2 + 17 = 16$$
$$f_2 = g_2(\Delta^2(\tilde{x})x, \Delta^2(\tilde{y})y) = -3x + y + 23 = -3 \cdot 0.7 + 0.32 + 23 = 21.22$$

After these computations, the normalized intuitionistic trapezoidal fuzzy numbers,

$$\widetilde{\tilde{A}^*} =< [3.7,3.7,3.7,3.7]; (1,0) >, \qquad \widetilde{\tilde{B}^*} =< [2.6,2.6,2.6,2.6]; (1,0) >$$

formulated, and subsequently, the similarity measures between these values and the rule antecedents are calculated as follows.

For Rule 1:

$\mathcal{S}_1\left(\widetilde{\tilde{A}^*}, \tilde{A}_1\right) = 0.488$ and $\mathcal{S}_1\left(\widetilde{\tilde{B}^*}, \tilde{B}_1\right) = 0.509$

And for Rule 2:

$\mathcal{S}_1\left(\widetilde{\tilde{A}^*}, \tilde{A}_2\right) = 0.503$ and $\mathcal{S}_1\left(\widetilde{\tilde{B}^*}, \tilde{B}_2\right) = 0.544$

From here, by assuming $t(a,b) = \min\{a,b\}$, the rule weights are calculated.

$\Omega^1 = min\{0.488, 0.509\} = 0.488$ and $\Omega^2 = min\{0.503,\ 0.544\} = 0.503$

According to the final computed values, the output corresponding to the inputs $x = 3.7$ and $y = 2.6$ is obtained as follows.

$$f = \frac{0.488 \cdot 16 + 0.503 \cdot 21.22}{0.488 + 0.503} = 18.649$$

CONCLUSION AND DISCUSSION

In this study, a new linear TSK model based on intuitionistic fuzzy sets is proposed to model uncertainty more comprehensively by considering membership and non-membership degrees. A predetermined similarity measure is incorporated into the inference mechanism to evaluate the closeness between inputs and rule antecedents, while rule weights are aggregated using t-norm operators to ensure a consistent decision-making process.

The effectiveness and simplicity of the proposed model are demonstrated through a two inputs, single output example. Moreover, its general m input, n output structure provides a flexible framework suitable for various application areas.

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ACTINOBACTERIA-MEDIATED INHIBITION OF ALTERNARIA SPP. AND ASSOCIATED MYCOTOXINS

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ABSTRACT

Actinobacteria are a group of filamentous bacteria extensively studied for their capacity to produce secondary metabolites with strong antimicrobial activity. Their application in the biological control of phytopathogenic fungi, particularly Alternaria spp., has gained increasing attention due to the serious agricultural and food safety issues associated with these pathogens. Alternaria species infect a wide range of crops and are known producers of harmful mycotoxins that pose risks to human and animal health.

Conventional control of Alternaria relies heavily on chemical fungicides, which may lead to environmental contamination and the emergence of resistant fungal strains. Actinobacteria offer an eco-friendly alternative through multiple antagonistic mechanisms, including antibiosis, enzymatic degradation of fungal cell walls, and competition for nutrients and space.

In vitro inhibition assays demonstrate that several actinobacterial strains significantly suppress the mycelial growth of Alternaria spp. In addition to growth inhibition, a marked reduction in mycotoxin production has been observed, suggesting that actinobacteria may interfere with fungal secondary metabolism. This dual inhibitory effect enhances their potential application in crop protection and food safety management.

In conclusion, actinobacteria represent a promising biological tool for controlling Alternaria infections and reducing mycotoxin contamination. Their integration into plant disease management strategies could contribute to sustainable agriculture and safer food production.

Keywords: Actinobacteria; Alternaria; mycotoxins; inhibition; biological control

COMPARISON OF NUCLEOLAR ORGANIZER REGIONS OF THE NF=76 AND NF=74 CYTOTYPES OF THE 2n=52 CHROMOSOMAL FORM OF *Nannospalax ehrenbergi* (NEHRING, 1898) DISTRIBUTED IN TÜRKİYE

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ABSTRACT

Nannospalax ehrenbergi, originally described by Nehring (1898) from specimens collected in Yafa-Israel, is also distributed in Libya, Syria, Jordan, Lebanon, Israel, Egypt, Iraq, and the southeastern Anatolia region of Türkiye.

In this study, the standard karyotypes and nucleolar organizer regions (NORs) of blind mole rats (*N. ehrenbergi*) with 2n=52 chromosomes collected from Ergani (Diyarbakır) and Kırıkhan (Hatay) were investigated.

Chromosome preparations were obtained from bone marrow and stained with Giemsa using an air-drying technique. The diploid chromosome number (2n), the fundamental number of chromosomal arms (NF), and the number of autosomal arms (NFa), and the sex chromosomes were determined. NOR preparations were obtained by silver nitrate staining.

The karyotypes of the Ergani (Diyarbakır) blind mole rat population exhibited 2n=52, NF=76, and NFa=72, whereas the karyotypes of the Kırıkhan (Hatay) blind mole rat population showed 2n=52, NF=74, and NFa=70. NORs in the Ergani blind mole rat population were located at the telomeric regions of the short arms of one biarmed autosomal pair and on one homologue of two biarmed autosomal pairs. Similarly, NORs in the Kırıkhan blind mole rat population were located at the telomeric regions of the short arms of one biarmed autosomal pair and on one homologue of two biarmed autosomal pairs.

While the numbers of NORs in the studied populations were similar to each other, they differed in terms of NOR distribution. Furthermore, our results showed differences from those reported in previous studies regarding both the number and distribution of NORs.

Key Words: Blind mole rat; Cytotype; *Nannospalax ehrenbergi*; NOR; Türkiye

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SYSTEMATIC EVALUATION OF KRAS-CENTERED PROTEIN–PROTEIN INTERACTION NETWORKS VIA BIOINFORMATICS APPROACHES

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ABSTRACT

KRAS is a key oncogenic protein that plays a central role in cell signaling pathways regulating proliferation, differentiation, and survival. Understanding its protein–protein interaction (PPI) network is critical for elucidating its functional mechanisms and for guiding rational protein and domain design studies. The present study aimed to systematically analyze KRAS-centered PPI networks using multiple bioinformatics platforms, identify high-confidence interaction partners, and evaluate their structural compatibility through protein–protein docking simulations.

The canonical KRAS protein sequence (UniProt ID: P01116) was analyzed using STRING, IntAct, MINT, PANTHER, KEGG, and Interactome3D databases under Homo sapiens filtering. High-confidence interaction thresholds were applied, and functional enrichment analyses were performed. Selected interaction partners—CALML6, SOS1, and CALML4—were subjected to rigid-body docking using LightDock with the DFIRE scoring function, and interaction interfaces were analyzed using UCSF ChimeraX.

KRAS occupied a central network position with strong associations with calmodulin-related proteins and PI3K signaling members. Functional enrichment confirmed involvement in enzyme regulation, signal transduction, and key oncogenic pathways. Docking analysis identified SOS1 as the strongest structural interaction partner (DFIRE: 17.125), followed by CALML4 (14.637) and CALML6 (13.922). All three ligands interacted predominantly with the KRAS N-terminal region, particularly Val7, Val8, and Val14, suggesting a shared binding surface.

In conclusion, this study integrates network-based PPI analysis with structural docking evaluation, establishing a framework for distinguishing functional associations from structurally supported interactions. The findings provide a basis for future KRAS domain-specific design and targeted intervention strategies.

Keywords: KRAS; Protein–Protein Interaction; Bioinformatics; STRING; Network Analysis; Protein–Protein Docking; LightDock

INTRODUCTION

KRAS belongs to the RAS superfamily of small GTP-binding proteins and functions as a critical molecular regulator that shapes the architectural integrity of intracellular signaling networks (Tang et al., 2025). KRAS functions as a molecular switch capable of cycling between GDP- and GTP-bound states and serves as a central regulator particularly within the MAPK and PI3K–AKT signaling pathways (Kumari et al., 2025). These conformational transitions are closely associated with structural rearrangements within the Switch I and Switch II regions and are tightly regulated by guanine nucleotide exchange factors (GEFs) and GTPase-activating proteins (GAPs). However, the biological significance

of KRAS extends far beyond this nucleotide cycle; rather, this cycle provides the structural basis for its ability to coordinate multilayered protein interaction networks.

Oncogenic KRAS mutations are among the most frequent driver alterations in pancreatic, colorectal, and lung cancers, leading to constitutive activation of GTP-bound signaling and sustained proliferative signaling (Zhao et al., 2025). Nevertheless, contemporary cancer biology has clearly demonstrated that the impact of KRAS cannot be sufficiently explained by a simple linear Ras–RAF–MEK–ERK signaling cascade. Instead, KRAS interacts simultaneously with multiple effector, adaptor, and regulatory proteins, orchestrating parallel and cross-talking signaling networks. Therefore, the functional role of KRAS must be evaluated within the broader framework of systems-level network organization rather than through single-pathway models (Arooj et al., 2025).

From a network biology perspective, cellular systems are conceptualized as complex topological structures composed of nodes (proteins) and edges (interactions). Within such networks, hub proteins play a central role in maintaining structural stability and information flow. The classification of KRAS as a high-degree hub protein suggests that it is not merely a signaling component, but rather a system-level regulator that influences the direction, magnitude, and context of intracellular signaling outputs. Perturbations in hub proteins can affect not only local network structures but also the global organization of the signaling system, potentially contributing to phenotypic heterogeneity observed in cancer.

Systematic analysis of PPI networks provides a powerful framework for mapping this molecular organization. However, the interpretation of PPI data is strongly influenced by the integration strategies of the bioinformatics platforms used. A wide range of bioinformatics platforms has been developed to analyze PPI, including STRING, IntAct, MINT, PANTHER, KEGG, and Interactome3D. These resources differ substantially in their underlying data sources, evidence categories, scoring systems, and integration strategies. STRING integrates experimental data, curated databases, and computational predictions to generate quantitative confidence scores and large-scale functional association networks. In contrast, databases such as IntAct and MINT focus primarily on literature-curated experimental interactions. Functional classification systems such as PANTHER and KEGG provide biological context through pathway and enrichment analyses, while structural resources such as Interactome3D enable three-dimensional evaluation of interaction interfaces. Because these platforms rely on different data sources, evidence classifications, and integration methodologies, multi-platform analysis becomes a methodological necessity rather than an option.

Within this conceptual framework, the present study addresses two fundamental issues: the cross-platform consistency of the KRAS interaction landscape and the extent to which network-level functional associations translate into structurally plausible molecular interfaces.

The distinction between functional correlation and direct physical binding is particularly critical in protein design, target inhibition, and structural modeling studies. A protein may appear highly connected within a network; however, such connectivity does not necessarily imply the formation of a stable physical complex. Therefore, integrating network-based PPI analysis with structural docking evaluation enables a multi-layer validation strategy that strengthens biological interpretation.

The aim of the present study is to systematically analyze KRAS-centered PPI networks using multiple bioinformatics platforms, identify interaction partners supported by high confidence and experimental evidence, and assess the consistency and divergence across different databases. The interaction network obtained from STRING was comparatively assessed using experimentally supported databases such as IntAct and MINT. Functional and pathway enrichment analyses were performed using PANTHER and KEGG, while structural context was evaluated through Interactome3D. Finally, selected interaction partners—SOS1, CALML6, and CALML4—were subjected to rigid-body protein–protein docking using the LightDock framework with the DFIRE scoring function, and predicted interaction interfaces were analyzed using UCSF ChimeraX. This integrative framework establishes a three-layer evaluation strategy encompassing functional association, experimental validation, and structural compatibility.

By adopting this comprehensive approach, the present study seeks to reinterpret the role of KRAS within network biology beyond descriptive interaction listing, incorporating reliability hierarchy and mechanistic context. Furthermore, this methodological framework provides a theoretical foundation for future KRAS domain-based design, structural modeling, and targeted intervention strategies.

CONCEPTUAL FRAMEWORK

The present study is grounded in a systems biology perspective in which cellular signaling is interpreted as a dynamic and interconnected network rather than a series of isolated linear pathways. Within this framework, proteins are conceptualized as nodes embedded in complex interaction networks, and biological function emerges from patterns of connectivity rather than from individual molecular properties alone. This perspective aligns with contemporary network pharmacology and systems oncology approaches, which emphasize that therapeutic vulnerabilities and functional dependencies arise from network topology rather than from single-gene aberrations (Barabási et al., 2011).

KRAS occupies a central position in oncogenic signaling networks and can be theoretically characterized as a hub protein. In network theory, hub proteins are highly connected nodes that integrate multiple signaling inputs and distribute outputs across diverse downstream pathways (Jeong et al., 2001). Because perturbation in hub proteins may lead to system-wide dysregulation, understanding their interaction landscapes is critical for interpreting oncogenic signaling architecture. Importantly, hub proteins such as KRAS are not static relay points; they exhibit context-dependent interaction rewiring in response to mutational status, nucleotide binding state, and subcellular localization, further underscoring the need for multi-dimensional analysis of their interaction profiles.

A key conceptual distinction underlying this study is the separation between functional association and direct physical interaction. PPI databases frequently report associations that may reflect shared pathway involvement, co-expression patterns, or experimental proximity detection rather than stable molecular binding. Consequently, network-level connectivity does not inherently imply the formation of a structurally stable protein complex (von Mering et al., 2002). This distinction is particularly relevant for KRAS, whose interactions range from transient GEF/GAP-mediated regulatory contacts to sustained effector engagements involving well-defined structural interfaces. Distinguishing between these interaction modalities necessitates a layered interpretative strategy that extends beyond network topology.

Accordingly, the present work applies a hierarchical analytical approach comprising three complementary levels of evidence. At the first level, KRAS interaction partners are identified through integrated bioinformatics platforms using confidence-based filtering to establish a broad interaction landscape. At the second level, these associations are cross-validated across experimentally curated databases to reduce platform-specific bias and enhance reliability. At the third level, selected interaction partners are evaluated at the structural level through rigid-body protein–protein docking using the LightDock framework combined with the DFIRE statistical potential, followed by interface characterization in UCSF ChimeraX. This final layer assesses whether network-identified associations correspond to physically plausible molecular interfaces, thereby providing mechanistic depth to network-level observations.

By integrating topological connectivity, experimental evidence, and structural compatibility within a unified conceptual framework, this study aims to bridge descriptive network mapping with mechanistic interpretation. This approach allows KRAS to be evaluated not merely as an isolated oncogenic protein, but as a dynamic integrator within a multi-layered signaling system whose interaction partners can be stratified according to both functional relevance and structural feasibility.

METHODOLOGY

Study Design and Analytical Workflow

This study was structured as an integrative computational investigation aimed at clarifying the interaction landscape of KRAS and determining which network-derived associations are supported at the structural level. Rather than relying on a single analytical platform, a sequential and evidence-based workflow was adopted to progressively refine candidate interaction partners.

The analysis began with the construction of a KRAS-centered interaction network using STRING under strict species filtering (Homo sapiens) (Szklarczyk et al., 2023). This initial step provided a broad overview of the interaction landscape and allowed identification of proteins that frequently co-occur with KRAS in signaling contexts. To increase reliability and reduce background noise, high-confidence

interaction thresholds were applied, thereby narrowing the candidate list to interactions supported by stronger integrated evidence.

To avoid platform-dependent bias, the shortlisted interaction partners were subsequently evaluated using experimentally curated databases. Cross-database comparison enabled assessment of consistency and strengthened confidence in recurrent interaction partners reported across independent evidence sources.

Following interaction refinement, functional and pathway enrichment analyses were performed to interpret the biological context of the identified proteins. This step positioned the interaction partners within established oncogenic signaling frameworks, particularly MAPK, PI3K–AKT, and related pathways, thereby linking network topology to functional relevance.

Finally, structural evaluation was introduced through protein–protein docking analysis. Selected candidates were tested for their ability to form energetically plausible interfaces with KRAS, allowing comparison between network-level association and physical binding feasibility. This final layer of analysis provided a mechanistic dimension to the computational findings.

By integrating interaction mapping, cross-database validation, functional contextualization, and structural assessment within a unified workflow, the study establishes a coherent framework for distinguishing broad functional connectivity from structurally supported molecular interactions.

Sequence Retrieval

The canonical amino acid sequence of human KRAS (UniProt ID: P01116; RASK_HUMAN) was retrieved from the UniProt Knowledgebase. The reviewed Swiss-Prot entry corresponding to the canonical isoform was selected to ensure sequence integrity and manual curation quality. The FASTA sequence was used as the standardized input across all subsequent bioinformatics platforms to prevent isoform-related variability and ensure reproducibility. All analyses were restricted to Homo sapiens.

STRING-Based Interaction Network Construction

The KRAS-centered PPI network was constructed using the STRING database with the organism filter set to Homo sapiens. The full STRING network mode was selected to capture both functional associations and experimentally supported interactions. During initial exploration, lower confidence thresholds were examined to observe global interaction density. Subsequently, a high-confidence threshold (≥0.900) was applied in order to focus on interactions supported by stronger evidence integration.

STRING confidence scores incorporate experimental datasets, curated pathway databases, gene co-occurrence, and text-mining signals. In this study, emphasis was placed on experimentally supported evidence rather than solely predictive associations. As the confidence threshold increased, the number of interaction partners decreased, reflecting reduced false-positive probability. The PPI enrichment p-value was evaluated to assess whether the observed network clustering was statistically significant relative to random expectation.

Cross-Database Validation

To reduce database-specific bias, interaction partners identified through STRING were cross-validated using IntAct and MINT (del Toro et al., 2022; Licata et al., 2012). In IntAct, KRAS (RASK_HUMAN) was queried under species restriction, and interaction reliability was interpreted based on experimental detection methods and associated publication evidence. Detection approaches such as two-hybrid array screening and proximity-dependent biotin identification were examined to evaluate methodological robustness. Proteins that were identified consistently across STRING, IntAct, and MINT were considered more reliable interaction candidates, as their presence in multiple independent databases strengthened confidence in the interaction.

Functional and Pathway Enrichment Analysis

Functional characterization of KRAS interaction partners was performed using the PANTHER classification system under Homo sapiens selection (Mi et al., 2021). Molecular functions and biological processes enriched within the interaction network were evaluated, with particular attention to enzymatic regulation, ion binding, and signal transduction activities.

Pathway-level contextualization was conducted using KEGG (Kanehisa et al., 2023). KRAS-associated pathways, including MAPK signaling (hsa04014), PI3K–AKT signaling, and Wnt signaling pathways, were examined to interpret interaction partners within established oncogenic signaling architectures. These enrichment analyses provided biological context to network connectivity and supported interpretation beyond topological association.

Structural Context Assessment

To complement network-level and functional enrichment analyses, structural interaction data were examined using Interactome3D (Mosca et al., 2013). This database integrates experimentally resolved structures and high-confidence structural models to provide three-dimensional context for PPI. KRAS and its selected interaction partners were queried under Homo sapiens filtering to determine whether experimentally supported structural interfaces were available.

The availability of resolved or modeled interaction complexes was evaluated to identify proteins with prior structural evidence of binding to KRAS or related domains. This step enabled preliminary structural validation before docking analysis and helped distinguish interactions supported by experimental structural data from those derived solely from network association.

Structural Evaluation and Docking Protocol

To determine whether network-level associations corresponded to structurally plausible physical interfaces, selected interaction partners were subjected to protein–protein docking analysis using the LightDock framework (Jiménez-García et al., 2018). LightDock employs a Glowworm Swarm Optimization (GSO) algorithm combined with the DFIRE scoring function, which evaluates distance-dependent statistical potentials derived from known protein structures (Zhou et al., 2002). This approach enables unbiased global sampling of binding poses without requiring prior knowledge of the interface location.

Three-dimensional protein structures were retrieved from the Protein Data Bank (PDB) and the AlphaFold Protein Structure Database (Jumper et al., 2021; Varadi et al., 2022). KRAS (PDB ID: 2N9C) was used as the receptor structure; however, since 2N9C is a solution NMR structure containing 25 conformational models, only the first model was extracted to ensure a single representative conformation for docking simulations. Hydrogen atoms and OXT terminal atoms were removed prior to docking to ensure compatibility with the DFIRE scoring function, which supports only standard heavy atoms of canonical amino acids. Ligand structures included SOS1 (PDB ID: 1Q9C), CALML6 (UniProt: Q8TD86; AlphaFold model v6), and CALML4 (UniProt: Q96GE6; AlphaFold model v6). SOS1 was obtained as a multi-chain X-ray crystallographic structure resolved at 2.20 Å (Sondermann et al., 2003). AlphaFold-predicted structures were used for CALML6 and CALML4 as no experimentally resolved structures were available in the PDB at the time of analysis. All structures were cleaned by retaining only ATOM records corresponding to standard amino acid residues.

Protein–protein docking simulations were performed using LightDock v0.9.4 under default rigid-body conditions with the DFIRE scoring function. For each protein pair, the simulation was configured with 25 swarms and 50 glowworms per swarm, generating a total of 1,250 initial docking poses per simulation. Each simulation was run for 100 optimization steps. Following docking simulations, predicted poses were ranked using the LightDock scoring function (lgd_rank.py), which integrates DFIRE statistical potentials. For each protein pair, top-ranked conformations were generated using lgd_generate_conformations.py, and the highest-scoring complex was selected for structural inspection. The receptor chain was designated as Chain A (KRAS) and the ligand chain as Chain B for all complexes.

Structural visualization and interaction interface analysis were performed using UCSF ChimeraX v1.10.1 (Pettersen et al., 2021). For each predicted docking complex, the receptor and ligand chains were displayed in cartoon representation and colored distinctly. Interface residues were identified using a distance cutoff of 4.0 Å between chains. Hydrogen bonds between receptor and ligand chains were computed and displayed as dashed lines to visualize polar interactions at the predicted interface.

RESULTS

STRING-Based Network Analysis

Construction of the KRAS-centered interaction network using STRING under Homo sapiens filtering revealed a statistically enriched PPI landscape. Application of a high-confidence threshold (≥0.900) reduced network complexity and prioritized robust interaction partners supported by integrated evidence channels. KRAS maintained a central network position, interacting with multiple signaling regulators associated with canonical oncogenic pathways (Figure 1).

Functional enrichment analysis using PANTHER demonstrated that KRAS-associated proteins were significantly enriched in molecular functions related to enzymatic regulation, ion binding, and signal transduction processes (Figure 3). KEGG pathway analysis further positioned these interaction partners within established oncogenic signaling cascades, including MAPK (hsa04014), PI3K–AKT, and Wnt signaling pathways, supporting the biological relevance of the constructed interaction network (Figure 2).

Structural Docking Results

Protein–protein docking simulations using LightDock with the DFIRE scoring function were performed for three selected KRAS interaction partners: SOS1, CALML4, and CALML6. Among the three complexes evaluated, KRAS–SOS1 yielded the highest DFIRE score (17.125), followed by KRAS–CALML4 (14.637) and KRAS–CALML6 (13.922) (Table 2). All top-ranked poses exhibited zero steric clashes, indicating sterically acceptable binding conformations across all three docking simulations.

The KRAS–SOS1 complex demonstrated the most extensive interaction interface, with 18 KRAS residues spanning the entire N-terminal segment from Met1 to Trp20 participating in intermolecular contacts. This broad engagement surface is consistent with the established biological function of SOS1 as a guanine nucleotide exchange factor that requires extensive surface complementarity to catalyze GDP-to-GTP exchange on KRAS (Sondermann et al., 2004). On the SOS1 side, interface residues were distributed across two chains (G and H), including Tyr148, Ile152, His154, and Gln160 from chain G, and Asp89, Arg99, Tyr136, and Lys143 from chain H, suggesting a bipartite recognition mode involving multiple SOS1 domains.

The KRAS–CALML4 complex exhibited a more focused interaction interface centered on the P-loop region of KRAS, with Val7, Val8, Ala11, Val14, and Lys16 constituting the receptor-side contacts. The CALML4 interface residues—Cys59, Leu62, Tyr63, Arg81, and Cys82—included two cysteine residues, suggesting potential redox-sensitive interaction dynamics. The mixed hydrophobic–polar character of this interface, combining aliphatic contacts (Val7, Val8, Leu62) with charged interactions (Lys16, Arg81), indicates a moderately specific binding mode.

The KRAS–CALML6 complex displayed the smallest interface among the three complexes, involving five KRAS residues (Tyr4, Leu6, Val7, Val8, Trp20) and three CALML6 residues (Glu43, Met44, Leu64). The predominance of hydrophobic and aromatic residues at this interface—particularly the contributions of Tyr4, Trp20, Met44, and Leu64—suggests a predominantly hydrophobic binding mode with limited electrostatic contribution from Glu43. Despite the smaller interface area, the involvement of bulky aromatic residues (Tyr4, Trp20) may provide sufficient binding specificity through shape complementarity.

Notably, a conserved set of KRAS residues appeared across multiple docking interfaces. Val7 and Val8 were present in all three complexes, while Val14 was shared between the SOS1 and CALML4 interfaces, and Leu6 was common to both SOS1 and CALML6 interfaces. This convergence on the KRAS N-terminal and P-loop region across independent docking simulations suggests that this segment constitutes a structurally accessible and energetically favorable binding surface for diverse interaction partners (Figure 4).

Table 1. Structural data sources and preparation details for proteins used in docking simulations.

Protein	Role	Source	ID	Resolution / Method	Organism	Atoms (clean)
KRAS	Receptor	PDB	2N9C	Solution NMR (Model 1 of 25)	*Homo sapiens*	148
SOS1	Ligand	PDB	1Q9C	X-ray Diffraction (2.20 Å)	*Homo sapiens*	12,267
CALML6	Ligand	AlphaFold DB	Q8TD86	AF Monomer v2.0 (v6)	*Homo sapiens*	1,445
CALML4	Ligand	AlphaFold DB	Q96GE6	AF Monomer v2.0 (v6)	*Homo sapiens*	1,532

Table 2. LightDock/DFIRE docking scores and interface residues for KRAS interaction partners. Interface residues were identified using a 4.0 Å distance cutoff in UCSF ChimeraX v1.10.1.

Complex	DFIRE Score	KRAS Interface Residues	Ligand Interface Residues
KRAS–SOS1	17.125	Met1, Thr2, Lys5, Leu6, Val7, Val8, Val9, Gly10, Ala11, Gly12, Gly13, Val14, Gly15, Lys16, Ser17, His18, Val19, Trp20	Tyr148(G), Ile152(G), His154(G), Gln160(G), Gln33(H), Asp89(H), Ser92(H), Arg99(H), Tyr136(H), Lys143(H)
KRAS–CALML4	14.637	Val7, Val8, Ala11, Val14, Lys16	Cys59, Leu62, Tyr63, Arg81, Cys82
KRAS–CALML6	13.922	Tyr4, Leu6, Val7, Val8, Trp20	Glu43, Met44, Leu64

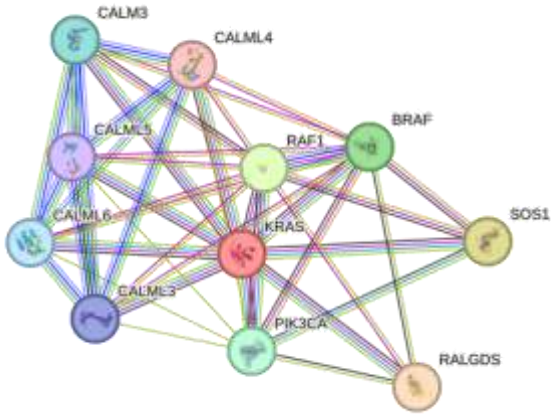

Figure 1. High-confidence KRAS-centered protein–protein interaction network generated using STRING (confidence ≥0.900, Homo sapiens). Nodes represent KRAS and its interaction partners including calmodulin-like proteins (CALML3, CALML4, CALML5, CALML6), kinases (RAF1, BRAF, PIK3CA), the guanine nucleotide exchange factor SOS1, and the effector protein RALGDS.

Colored edges represent different evidence channels, including experimental data, curated databases, co-expression, and text-mining.

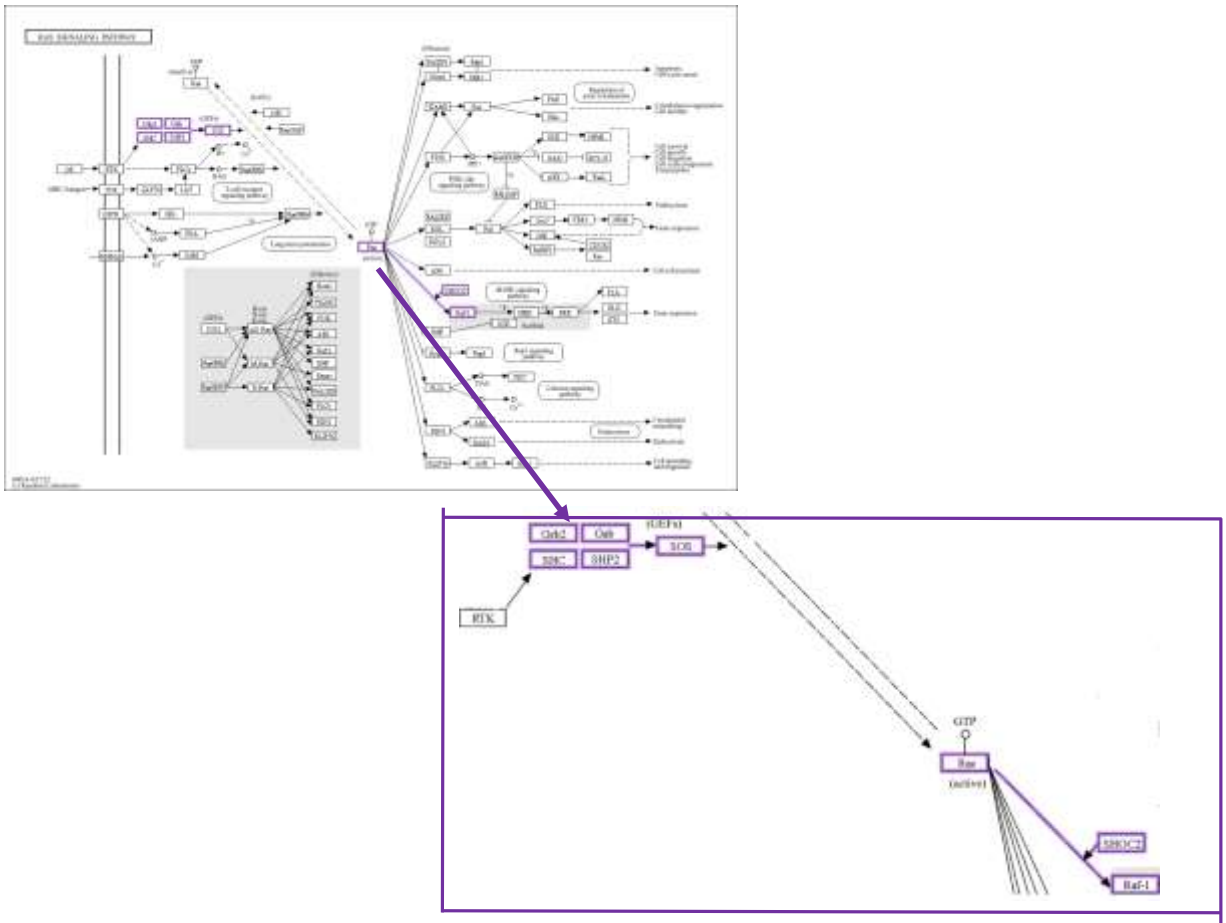

Figure 2. RAS signaling pathway map adapted from KEGG (hsa04010). The pathway illustrates the activation cycle of KRAS through upstream receptor tyrosine kinases (RTKs), G-protein coupled receptors (GPCRs), and guanine nucleotide exchange factors (GEFs, e.g., SOS1). Upon GTP loading, active KRAS engages multiple downstream effectors including RAF1, PI3K, RALGDS, TIAM1, and PLCε, initiating parallel signaling cascades governing cell proliferation (MAPK/ERK), survival (PI3K–AKT), cytoskeletal remodeling, endocytosis, and gene expression. GTPase-activating proteins (GAPs) facilitate signal termination by promoting GTP hydrolysis. Purple-highlighted nodes indicate proteins identified within the KRAS interaction network constructed in this study.

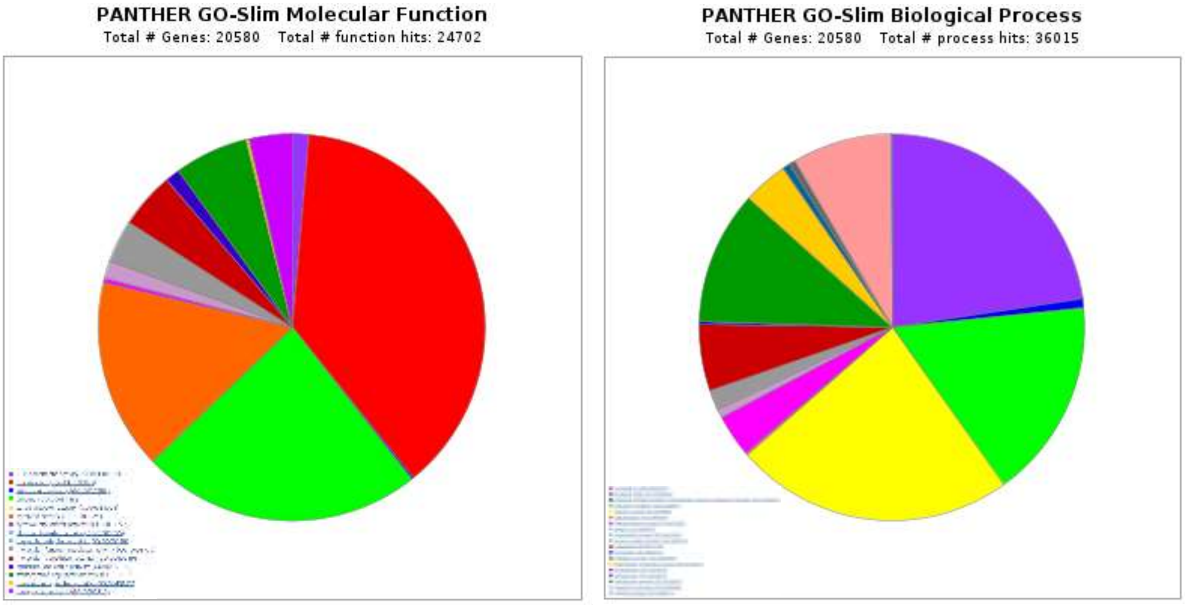

Figure 3. GO-Slim–based functional enrichment analysis of KRAS-centered interaction partners generated using the PANTHER classification system (Homo sapiens). The results indicate predominant enrichment in binding and catalytic activities, along with significant representation of biological regulation and signaling-related processes, underscoring the regulatory and signaling-oriented nature of the KRAS interaction network.

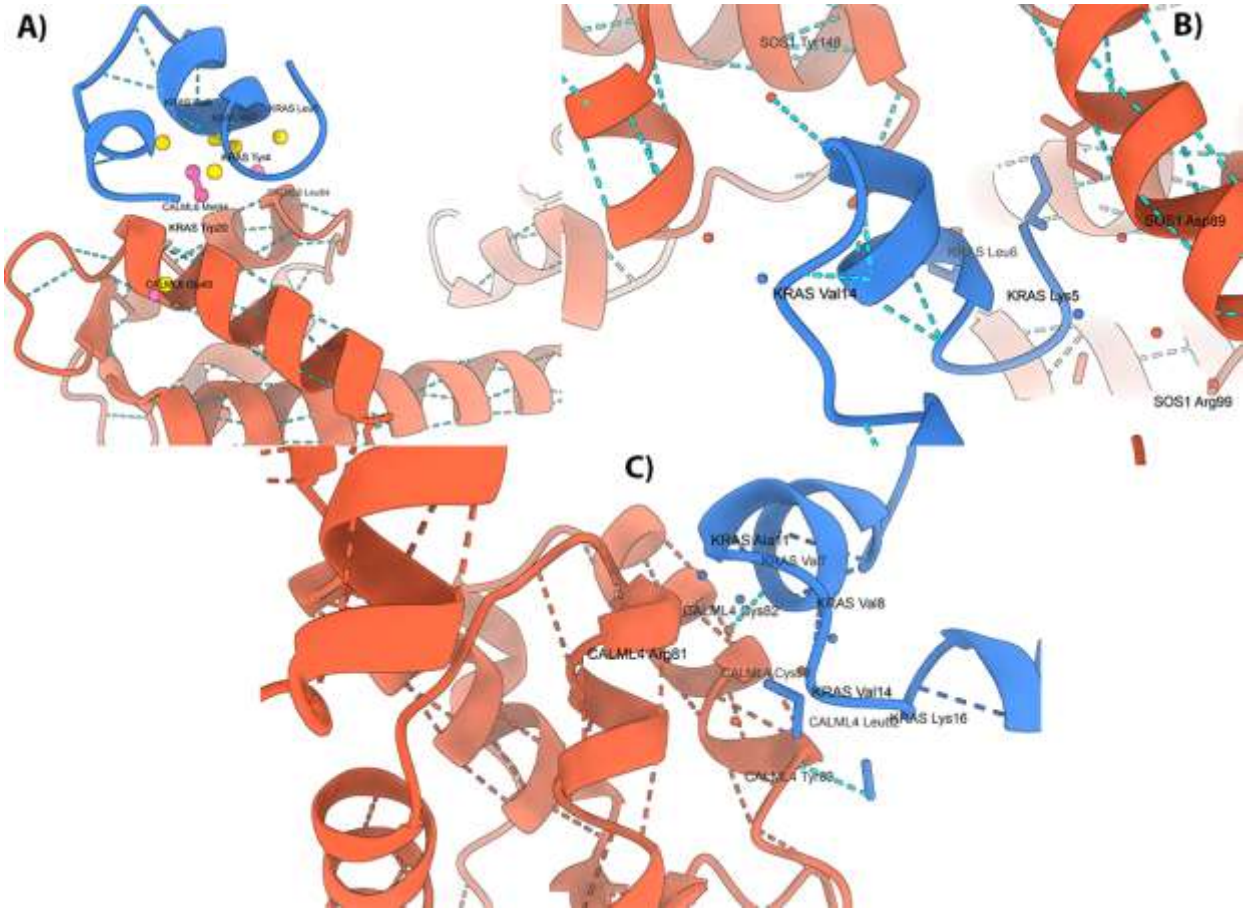

Figure 4. Structural visualization of KRAS docking complexes predicted by LightDock rigid-body docking analysis. (A) KRAS (blue)–CALML6 (orange) complex showing interface residues KRAS

Tyr4, Leu6, Val7, Val8, Trp20 and CALML6 Glu43, Met44, Leu64. (B) KRAS (blue)–SOS1 (orange) complex showing the extensive N-terminal KRAS interface (Met1–Trp20) engaging SOS1 chains G and H. (C) KRAS (blue)–CALML4 (orange) complex showing interface residues KRAS Val7, Val8, Ala11, Val14, Lys16 and CALML4 Cys59, Leu62, Tyr63, Arg81, Cys82. Hydrogen bonds between chains are displayed as dashed cyan lines. Interface residues were identified within a 4.0 Å distance cutoff using UCSF ChimeraX v1.10.1.

CONCLUSION AND DISCUSSION

The present study employed a multi-layered computational framework to evaluate the KRAS interaction landscape, integrating network-based PPI analysis with cross-database validation, functional enrichment, and structural docking assessment. This hierarchical approach enabled systematic differentiation between broadly reported functional associations and structurally plausible molecular interfaces, addressing a fundamental limitation inherent to single-platform PPI analyses. The STRING-based interaction network identified KRAS as a central hub protein with high-confidence connections to calmodulin-like proteins, kinases, the guanine nucleotide exchange factor SOS1, and the effector protein RALGDS, and the persistence of these interactions at the highest confidence threshold (≥0.900) indicates robust evidence integration across experimental, curated, and text-mining channels. Cross-validation through IntAct and MINT confirmed the reproducibility of key interaction partners across independent databases, thereby reducing the probability of database-specific artifacts, as previously emphasized in comparative PPI assessments (von Mering et al., 2002).

Rigid-body protein–protein docking using LightDock with the DFIRE scoring function revealed that all three selected interaction partners formed sterically acceptable complexes with KRAS, with zero-clash top-ranked poses observed for each pair. Among the three complexes, KRAS–SOS1 yielded the highest DFIRE score (17.125) and the most extensive interaction interface, engaging 18 KRAS residues spanning the entire N-terminal segment from Met1 to Trp20, while SOS1 contributed interface residues distributed across two chains including Tyr148, Ile152, His154, Gln160, Asp89, Arg99, Tyr136, and Lys143. This extensive binding surface is consistent with the established biological function of SOS1 as a guanine nucleotide exchange factor that requires broad surface complementarity to catalyze GDP-to-GTP exchange on KRAS (Sondermann et al., 2004), and the KRAS–SOS1 interaction has been characterized in the literature as a challenging PPI with a large contact surface area and high affinity, to the extent that even single atoms placed between key interface residues such as Y884 of SOS1 and A73 of KRAS have been shown to modulate binding and convert SOS1 activators into inhibitors (Hofmann et al., 2021). The KRAS–CALML4 complex yielded a DFIRE score of 14.637 with a more focused interaction interface centered on the P-loop region of KRAS (Val7, Val8, Ala11, Val14, Lys16), while the CALML4 side contributed Cys59, Leu62, Tyr63, Arg81, and Cys82 to the predicted interface; the presence of two cysteine residues at the CALML4 interface is noteworthy as it suggests potential redox-sensitive interaction dynamics that may modulate binding affinity under the oxidative stress conditions commonly observed in tumor microenvironments. The KRAS–CALML6 complex displayed the smallest interface (DFIRE: 13.922), involving five KRAS residues (Tyr4, Leu6, Val7, Val8, Trp20) and three CALML6 residues (Glu43, Met44, Leu64), with a predominantly hydrophobic binding mode characterized by aromatic contacts from Tyr4 and Trp20 and limited electrostatic contribution from Glu43.

A notable finding of the present study is the convergence of interface residues across all three docking complexes on the KRAS N-terminal and P-loop region, with Val7 and Val8 present in all three interfaces, Val14 shared between SOS1 and CALML4, and Leu6 common to both SOS1 and CALML6. The P-loop, spanning residues 10–17, is one of the four main regions bordering the nucleotide-binding pocket of KRAS alongside Switch I, Switch II, and the base-binding loops (Ostrem & Shokat, 2016), and it serves as a critical mutation hotspot in cancer with residues 12 and 13 being the most frequently mutated positions leading to oncogenic variants such as G12C, G12D, and G12V (Wang et al., 2024). The observation that diverse interaction partners converge on this region across independent docking simulations suggests that the P-loop and adjacent N-terminal residues constitute a structurally accessible and energetically favorable binding surface, which is consistent with recent motif-guided KRAS interaction studies demonstrating that partner proteins frequently recognize the interface formed by the P-loop and switch regions (Wu et al., 2024). Furthermore, molecular dynamics studies of KRAS P-loop

mutants have demonstrated that mutations at positions 12 and 13 induce allosteric structural changes in distant regions of the protein through hydrogen bond and hydrophobic signaling networks (Jani et al., 2024), suggesting that the interface residues identified in the present study may be functionally sensitive to oncogenic mutations.

The identification of CALML6 and CALML4 as KRAS interaction partners through both network analysis and structural docking provides computational support for the broader KRAS–calmodulin interaction paradigm. Previous computational modeling of the KRAS–Calmodulin interaction using conventional and scaled molecular dynamics simulations suggested that Calmodulin interacts with both the hypervariable region and the globular domain of KRAS, with the α4–α5 interface of the globular domain being particularly relevant for interaction with one lobe of Calmodulin (Garrido et al., 2018). Additionally, long-timescale molecular dynamics simulations totaling 20 microseconds have demonstrated that the KRAS–Calmodulin interaction is not static but rather dynamic, displaying various conformational ensembles (Pantsar, 2020), which suggests that the rigid-body docking poses presented herein represent snapshots of what is likely a conformationally heterogeneous interaction. The experimental validation of KRAS–Calmodulin binding through surface plasmon resonance has confirmed that mutations at the α4–α5 interface diminish this interaction (Garrido et al., 2018) providing experimental support for the computational prediction of calmodulin-like proteins as KRAS interaction partners. Notably, while the calmodulin-like proteins CALML6 and CALML4 share structural homology with canonical calmodulin, their specific interface residues differ, with CALML6 presenting a hydrophobic interface dominated by Met44 and Leu64 and CALML4 contributing a redox-sensitive interface featuring Cys59 and Cys82, suggesting that despite a shared general binding preference for the KRAS N-terminal region, the distinct physicochemical character of each interface may confer specific regulatory functions in different cellular contexts.

Several methodological considerations should be noted when interpreting these results. The KRAS structure used in this study (PDB: 2N9C) is a solution NMR structure from which only the first conformational model was extracted, resulting in a receptor comprising 148 atoms corresponding to 20 residues of the visible N-terminal segment, and this limited structural coverage may have biased the docking toward N-terminal interactions; future studies employing full-length KRAS structures including the complete G-domain and the hypervariable region may reveal additional binding interfaces. LightDock performs rigid-body docking without accounting for conformational flexibility or induced-fit effects, and the DFIRE scoring function provides a statistical potential-based ranking that reflects geometric complementarity rather than quantitative binding free energies, so the reported scores should be interpreted as relative rankings rather than absolute affinity predictions. Despite these limitations, the present study demonstrates that integrating network-level PPI data with structural docking analysis provides a more comprehensive evaluation of protein interactions than either approach alone, and the identification of shared interface residues across independent docking simulations strengthens confidence in the biological relevance of the predicted binding surfaces. The structural insights obtained herein—particularly the conserved involvement of Val7, Val8, and Val14—may serve as targets for the rational design of peptide-based or small-molecule PPI inhibitors, and extending the docking analysis to oncogenic KRAS mutants (G12C, G12D, G12V) would enable evaluation of how cancer-associated mutations alter the interaction landscape given the proximity of these mutations to the identified binding interfaces. Experimental validation through biolayer interferometry, surface plasmon resonance, or cross-linking mass spectrometry, combined with molecular dynamics refinement of the predicted poses, would further strengthen the computational predictions presented in this study and advance the development of KRAS-targeted therapeutic strategies.

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COMPREHENSIVE PROTEIN–PROTEIN INTERACTION ANALYSIS OF FRATAXIN (FXN) IN FRIEDREICH'S ATAXIA

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ABSTRACT

Friedreich's ataxia (FA) is an autosomal recessive neurodegenerative disorder resulting from decreased expression of the mitochondrial frataxin (FXN) protein, leading to impaired iron–sulfur (Fe–S) cluster biogenesis, mitochondrial dysfunction, and increased oxidative stress. Although previous studies have extensively investigated the structural features and evolutionary conservation of FXN, the broader protein–protein interaction (PPI) landscape of this protein has not been sufficiently explored through integrative bioinformatics approaches. This study aims to characterize the FXN-centered interaction network by combining computational PPI prediction, experimental database validation, functional enrichment analysis, and structural docking simulations.

The PPI network was constructed using the STRING database (version 12.0) with a high-confidence score threshold (≥ 0.900) for Homo sapiens. The reliability of the predicted interactions was assessed through cross-validation with experimentally curated data from the IntAct molecular interaction database. Functional interpretation was performed using Gene Ontology (GO) and KEGG pathway enrichment analyses. Structural compatibility of selected high-confidence interaction pairs was evaluated through rigid-body docking simulations using the ZDOCK algorithm, and the resulting complexes were analyzed using Discovery Studio Visualizer.

Network topology analysis revealed a densely connected interaction module comprising 11 protein nodes and 39 edges, with a PPI enrichment p-value of 6.46×10^{-10}. The primary interaction partners of FXN, including ISCU, NFS1, LYRM4, and FECH, are predominantly involved in mitochondrial iron metabolism, Fe–S cluster assembly, and oxidative stress response. Docking analyses demonstrated structurally stable complexes, with the FXN–ISCU pair exhibiting the highest docking score, consistent with the central role of this interaction in Fe–S cluster biogenesis. Functional enrichment results further highlighted the association of the FXN network with iron homeostasis, porphyrin metabolism, and energy metabolism pathways.

Overall, this integrative systems biology framework provides a broader perspective on FXN-associated cellular interaction networks and contributes to a clearer understanding of the molecular basis of Friedreich's ataxia. These findings may support future experimental validation studies and the development of potential therapeutic strategies targeting FXN-associated protein interaction surfaces.

Keywords: Friedreich's Ataxia; Protein–Protein Interaction; Bioinformatics; Network Analysis; Iron–Sulfur Cluster; ZDOCK

1.INTRODUCTION

Friedreich's ataxia (FA) is the most common autosomal recessive hereditary ataxia, with an estimated prevalence of approximately 1 in 50,000 individuals in Caucasian populations (Delatycki & Corben, 2012). The disease is characterized by progressive spinocerebellar and sensory ataxia, hypertrophic

cardiomyopathy, and impaired glucose metabolism, ultimately leading to significant disability and reduced life expectancy (Keita et al., 2022). The molecular basis of FA lies in a homozygous GAA trinucleotide repeat expansion within the first intron of the FXN gene, which results in transcriptional silencing and markedly reduced expression of the mitochondrial protein frataxin (FXN) (Campuzano et al., 1996). FXN plays a central role in iron–sulfur (Fe–S) cluster biogenesis, mitochondrial iron homeostasis, and the regulation of oxidative stress, and its deficiency triggers a cascade of mitochondrial dysfunction, iron accumulation, and reactive oxygen species (ROS) overproduction (Bencze et al., 2006; Rötig et al., 1997).

At the molecular level, FXN functions as an allosteric activator of the mitochondrial iron–sulfur cluster (ISC) assembly complex, a multi-protein machinery composed of the cysteine desulfurase NFS1, its accessory protein ISD11 (LYRM4), the acyl carrier protein ACP, and the scaffold protein ISCU2 (Fox et al., 2019). Structural studies, including cryo-electron microscopy at 3.2 Å resolution, have revealed that FXN binds at the interface between two NFS1 subunits and one ISCU subunit, where it stabilizes key loop conformations and modifies the local environment of a zinc ion that would otherwise inhibit NFS1 catalytic activity (Fox et al., 2019). More recently, it has been demonstrated that FXN accelerates persulfide transfer from NFS1 to ISCU2, thereby coordinating sulfur mobilization with iron availability during de novo [2Fe–2S] cluster synthesis (Bridwell-Rabb et al., 2014; Parent et al., 2015). Furthermore, recent evidence suggests that efficient Fe–S cluster assembly requires a finely balanced stoichiometric ratio between FXN and ferredoxin-2 (FDX2), highlighting the complexity of the regulatory mechanisms governing this essential biosynthetic pathway (Want et al., 2025).

Beyond its role in the ISC assembly complex, FXN has been implicated in broader mitochondrial functions (Doni et al., 2023) demonstrated that human frataxin interacts with components of the mitochondrial respiratory chain, suggesting a previously underappreciated role in cellular energy metabolism. Additionally, the sideroflexin family of mitochondrial iron transporters has been shown to exhibit functional connections with FXN-dependent pathways, underscoring the extensive complexity of mitochondrial iron homeostasis networks (Mon et al., 2019). These findings collectively indicate that the functional scope of FXN extends well beyond Fe–S cluster biosynthesis, encompassing multiple interconnected mitochondrial pathways.

The clinical significance of understanding FXN-associated molecular networks has been further emphasized by recent therapeutic developments. In 2023, omaveloxolone (Skyclarys), a potent activator of the Nrf2 antioxidant signaling pathway, became the first FDA-approved drug for the treatment of Friedreich's ataxia (Lynch et al., 2023). While omaveloxolone addresses downstream oxidative stress consequences of FXN deficiency, a comprehensive understanding of the upstream protein–protein interaction landscape of FXN remains essential for identifying additional therapeutic targets that may address the primary molecular deficits of the disease. In this context, computational approaches such as AI-based small molecule screening have shown promising results in identifying potential modulators targeting FXN-associated protein interaction surfaces (Kırboğa et al., 2023).

Recent advances in bioinformatics and systems biology have greatly facilitated the systematic analysis of protein–protein interaction (PPI) networks, enabling researchers to identify central regulatory nodes, functional modules, and enriched biological pathways within complex cellular systems (Szklarczyk et al., 2023). High-accuracy protein structure prediction methods, particularly AlphaFold, have further expanded the capacity to model and predict protein interactions where experimental structural data remain limited (Jumper et al., 2021). Despite these technological advances, the comprehensive PPI network of FXN and its functional implications in Friedreich's ataxia pathogenesis have not been systematically investigated using an integrative multi-database approach (Pastore & Puccio, 2013).

Therefore, the present study aims to construct and analyze a comprehensive FXN-centered protein–protein interaction network by integrating data from the STRING and IntAct databases. The biological significance of the identified interactions was evaluated through Gene Ontology and KEGG pathway enrichment analyses, while the structural compatibility of selected high-confidence interaction pairs was assessed through ZDOCK-based protein–protein docking simulations. This integrative systems biology approach is intended to provide a broader perspective on FXN-associated cellular networks and to contribute to the identification of potential therapeutic targets for Friedreich's ataxia.

2.METHODOLOGY

This study employed a multi-stage bioinformatics workflow to comprehensively analyze the protein–protein interaction (PPI) network of frataxin (FXN) in the context of Friedreich's ataxia. The methodology comprised four sequential stages: (i) PPI network construction, (ii) functional enrichment analysis, (iii) experimental validation through database comparison, and (iv) structural docking analysis.

2.1. Construction of the Protein–Protein Interaction Network

The FXN-centered PPI network was constructed using the STRING database (version 12.0; https://string-db.org), which integrates functional associations derived from experimental data, text mining, co-expression analysis, and curated pathway databases (Szklarczyk et al., 2023). The organism was set to *Homo sapiens* (taxonomy ID: 9606), and a high-confidence interaction score threshold (combined score ≥ 0.900) was applied to minimize false-positive interactions. Network topology parameters, including the number of nodes, number of edges, average node degree, clustering coefficient, and PPI enrichment p-value, were directly obtained from the STRING platform to assess the overall structure and statistical significance of the interaction network.

2.2. Functional Enrichment Analysis

Functional enrichment analyses were performed using the built-in enrichment tools provided by STRING. Gene Ontology (GO) annotations were examined across three categories—biological process (BP), molecular function (MF), and cellular component (CC)—to characterize the functional landscape of the FXN interaction network. In addition, Kyoto Encyclopedia of Genes and Genomes (KEGG) pathway analysis was conducted to evaluate the involvement of FXN-associated proteins in metabolic and signaling pathways, with particular emphasis on pathways related to iron metabolism, porphyrin biosynthesis, and Fe–S cluster assembly. Statistical significance was determined using a false discovery rate (FDR) threshold of < 0.05.

2.3. Comparison with Experimental Interaction Data

To assess the reliability of computationally predicted interactions, the STRING-derived PPI data were cross-validated against experimentally curated interaction records from the IntAct molecular interaction database (https://www.ebi.ac.uk/intact) (Del Toro et al., 2022). The FXN protein (UniProt ID: Q16595) was queried in IntAct, and direct binary interactions supported by experimental evidence were identified. The MI (Molecular Interaction) confidence scores associated with each interaction were examined to evaluate the strength of experimental support. Interactions that appeared in both STRING and IntAct were considered to have higher biological reliability.

2.4. Protein–Protein Docking Analysis

To investigate the structural basis of selected high-confidence interactions, protein–protein docking simulations were performed using the ZDOCK server (version 3.0.2; http://zdock.wenglab.org), a rigid-body docking algorithm that employs a fast Fourier transform (FFT)-based search strategy combined with shape complementarity, electrostatics, and desolvation scoring (Pierce et al., 2014). Four FXN interaction pairs were selected for docking analysis based on their STRING confidence scores and biological relevance: FXN–NFS1, FXN–ISCU, FXN–LYRM4, and FXN–FECH. Three-dimensional protein structures were obtained from the RCSB Protein Data Bank (PDB) where available; in cases where experimental structures were unavailable, AlphaFold-predicted models (Jumper et al., 2021) were used as input. The top-ranked docking poses were visualized and analyzed using BIOVIA Discovery Studio Visualizer (Dassault Systèmes). Docking scores, predicted contact residues, and interaction types (hydrogen bonding, hydrophobic, and electrostatic interactions) were evaluated to assess structural compatibility between FXN and its interaction partners. The stereochemical quality of the resulting docking complexes was further examined through Ramachandran plot analysis, and hydrophobicity surface profiles were generated to characterize the physicochemical properties of the predicted binding interfaces.

3.RESEARCH AND FINDINGS

3.1. STRING-Based Protein–Protein Interaction Network

The FXN-centered protein–protein interaction network was constructed using the STRING database with a high-confidence score threshold (≥ 0.900) for Homo sapiens. The analysis identified ten primary interaction partners of FXN: ISCU, NFS1, LYRM4, FECH, ACO1, ACO2, SCLY, HSPA9, CP, and HMOX1 (Figure 1). The majority of these proteins are functionally associated with mitochondrial iron metabolism, iron–sulfur (Fe–S) cluster biogenesis, and cellular energy metabolism, supporting the central role of FXN in mitochondrial processes (Bencze et al., 2006; Prischi et al., 2010).

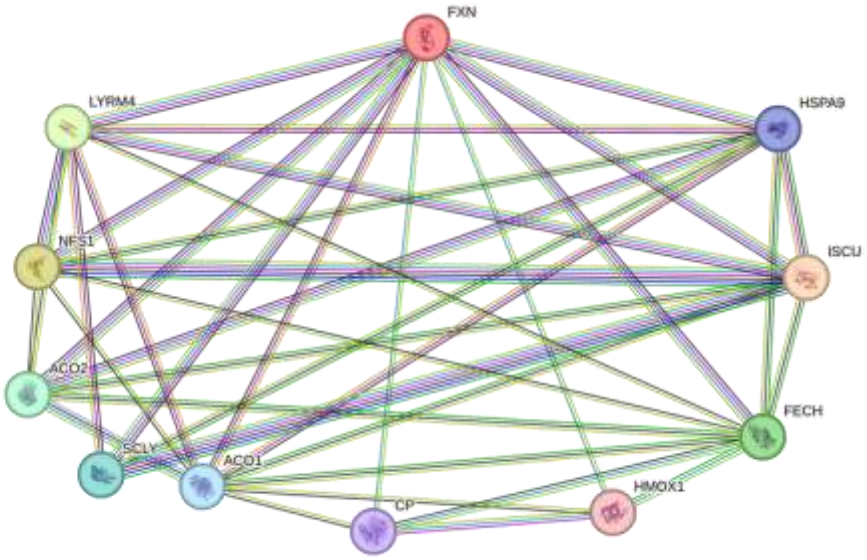

Figure 1. Protein–protein interaction network of the FXN protein constructed using the STRING database. Nodes represent interacting proteins, and edges indicate functional and biological associations between proteins.

Network topology analysis revealed that the PPI network comprises 11 protein nodes and 39 interaction edges. The average node degree of 7.09 indicates a densely connected interaction network surrounding FXN. The clustering coefficient of 0.878 further suggests that these proteins form a highly organized and functionally cohesive cluster. The PPI enrichment p-value of 6.46×10^{-10} confirms that the observed interaction network is not a product of random associations but rather represents a biologically significant functional module.

3.2. Experimental Validation via IntAct Database

To assess the consistency of the STRING-derived predictions with experimental evidence, a comparative analysis was conducted using the IntAct database. Direct experimental interaction partners of FXN identified in IntAct include NFS1, LYRM4, ACP6, ADCK2, MTRES1, and PRNP. The MI confidence scores associated with these interactions ranged from approximately 0.35 to 0.44, indicating that they are supported by in vitro experimental methods such as co-immunoprecipitation and affinity chromatography.

Notably, the overlap between STRING-predicted and IntAct-validated interactions, particularly for NFS1 and LYRM4, strengthens the biological reliability of the computational network. Previous structural studies have demonstrated that FXN directly binds to the NFS1–ISCU complex interface and functions as an allosteric activator of the Fe–S cluster biosynthesis machinery (Fox et al., 2019; Prischi et al., 2010). Similarly, LYRM4 (also known as ISD11) has been shown to stabilize the NFS1 desulfurase within the Fe–S assembly complex, and its functional association with FXN has been documented in both biochemical and structural investigations (Wiedemann et al., 2006).

However, certain IntAct-specific interactors, such as PRNP and ADCK2, were not identified in the STRING network at the applied confidence threshold. These proteins may represent context-dependent or transient interactions that require further experimental characterization.

3.3. Functional Enrichment Analysis

Functional enrichment analyses revealed that the FXN interaction network is predominantly associated with biological processes related to iron–sulfur cluster assembly (GO:0016226), cellular iron ion homeostasis (GO:0006879), oxidative stress response, and mitochondrial energy metabolism. KEGG pathway analysis further highlighted the involvement of FXN-associated proteins in porphyrin metabolism and ferroptosis-related pathways.

The enrichment of Fe–S cluster assembly and iron homeostasis processes is consistent with the established pathogenic mechanism of Friedreich's ataxia, in which FXN deficiency leads to mitochondrial iron accumulation, impaired Fe–S protein maturation, and elevated reactive oxygen species (ROS) production (Pastore & Puccio, 2013; Rötig et al., 1997).

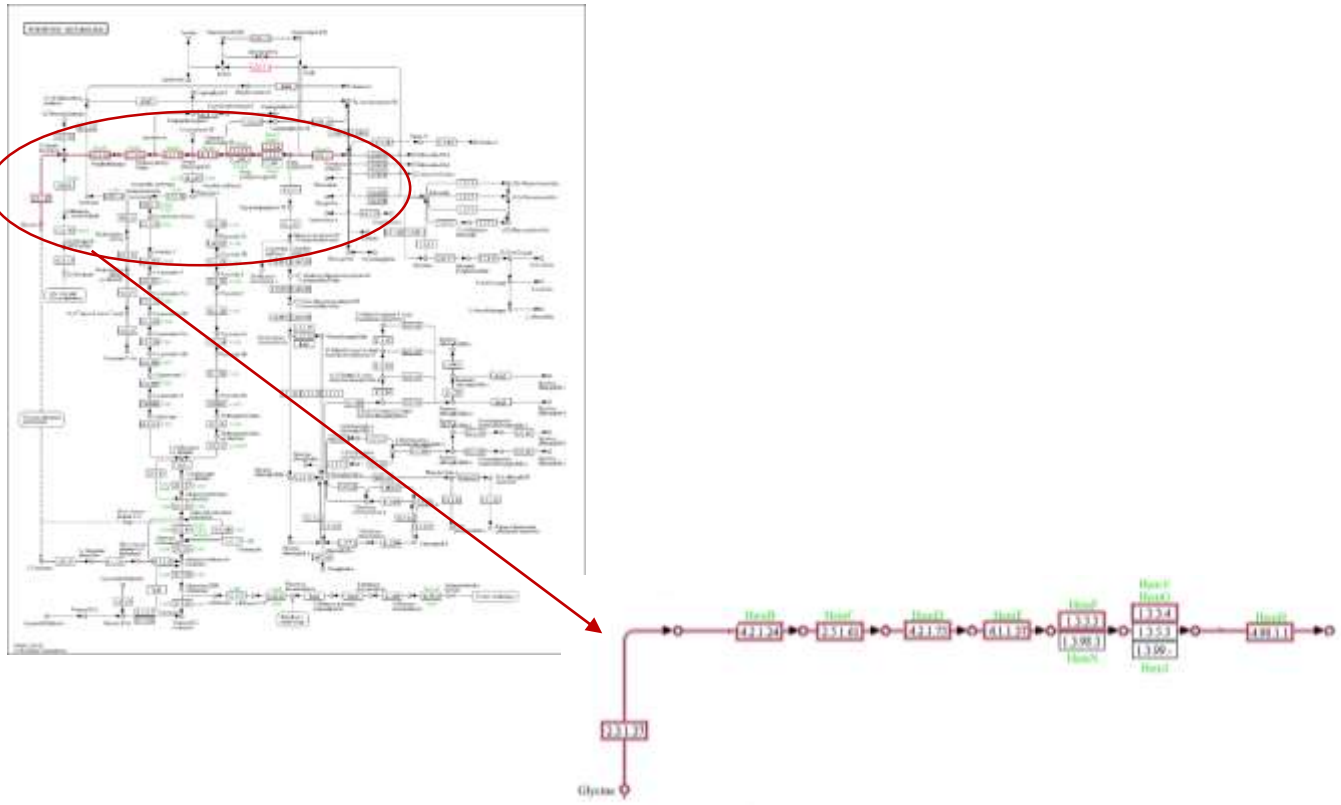

Figure 3. KEGG pathway map highlighting the porphyrin and heme biosynthesis region associated with FXN-related mitochondrial iron metabolism. The highlighted enzymatic steps represent metabolic processes functionally connected to iron–sulfur (Fe–S) cluster biogenesis and cellular iron homeostasis. Frataxin (FXN) plays a regulatory role in mitochondrial iron handling and Fe–S cluster assembly, which are essential for the activity of several enzymes involved in heme synthesis. Disruption of FXN function, as observed in Friedreich's ataxia, can impair Fe–S protein maturation, promote mitochondrial iron accumulation, and consequently affect heme biosynthesis pathways. This integrative pathway view illustrates the broader metabolic context of FXN interactions and supports its involvement in mitochondrial energy metabolism, oxidative stress regulation, and iron-dependent cellular processes.

3.4. Protein–Protein Docking Analysis

To evaluate the structural basis of the identified interactions, ZDOCK-based rigid-body docking simulations were performed for four selected FXN complexes: FXN–NFS1, FXN–ISCU, FXN–LYRM4, and FXN–FECH (Figure 2).

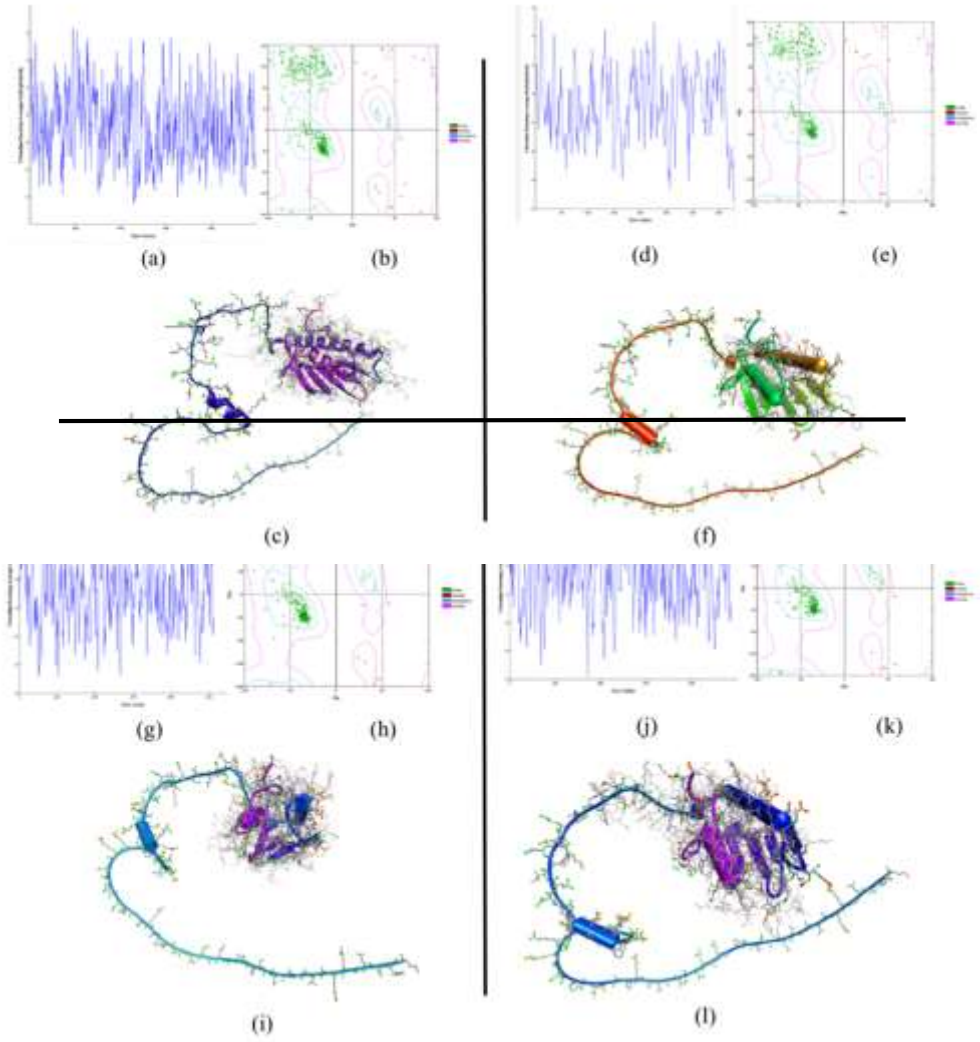

Figure 2. Structural interaction analyses of the FXN protein with mitochondrial proteins involved in Fe–S cluster biogenesis and iron metabolism. (a–c) NFS1–FXN complex, (d–f) LYRM4–FXN complex, (g–i) ISCU–FXN complex, and (j–l) FECH–FXN complex showing hydrophobicity profiles, Ramachandran plots, and protein–protein docking models, respectively. Hydrophobicity analyses indicate localized hydrophobic regions at the predicted FXN interaction interfaces, suggesting contributions to complex stability and sustained protein–protein association within the mitochondrial environment. Ramachandran plot distributions show that most residues fall within favored conformational regions, supporting the structural reliability of the predicted docking models.

Docking analyses reveal structurally compatible binding interfaces between FXN and key components of the iron–sulfur (Fe–S) cluster biosynthesis machinery, particularly NFS1, ISCU, and LYRM4. These interactions support the proposed role of frataxin as a regulatory factor that enhances the activity and stabilization of the Fe–S cluster assembly complex. The observed interaction with FECH further suggests a potential link between frataxin function and heme biosynthesis pathways, highlighting its broader involvement in mitochondrial iron homeostasis.

Collectively, these findings indicate that FXN functions not only as a structural participant in Fe–S cluster formation but also as a central regulator of mitochondrial iron metabolism, oxidative stress response, and cellular energy processes. This is consistent with the molecular pathology of Friedreich's ataxia, where frataxin deficiency leads to mitochondrial iron accumulation, impaired Fe–S protein synthesis, and increased oxidative stress. The identified interaction interfaces may therefore represent

promising targets for therapeutic strategies aimed at modulating protein–protein interactions in Friedreich's ataxia.

Among the analyzed complexes, FXN–ISCU exhibited the highest docking score (1495.930), suggesting the strongest predicted structural complementarity (Table 1). This finding is consistent with the known biological role of the FXN–ISCU interaction, in which frataxin facilitates iron delivery to the ISCU scaffold protein during Fe–S cluster assembly (Bridwell-Rabb et al., 2014). The FXN–LYRM4 complex (docking score: 1337.425) displayed predominantly hydrophobic interactions, supporting the proposed role of LYRM4 in stabilizing the quaternary structure of the Fe–S biosynthesis complex. The FXN–FECH interaction (docking score: 1295.990) suggests a potential functional link between Fe–S cluster biogenesis and heme biosynthesis, as ferrochelatase catalyzes the final step of heme synthesis and is itself an Fe–S cluster-containing enzyme (Rouault & Tong, 2008). The FXN–NFS1 complex (docking score: 1243.645) exhibited a combination of hydrogen bonding and hydrophobic contacts, consistent with the established regulatory role of FXN in modulating NFS1 cysteine desulfurase activity.

Table 1. Protein–protein docking scores of FXN interaction partners obtained from ZDOCK analysis.

Interacting Protein	Docking Score	Interaction Type	Structural Stability Interpretation
NFS1 – FXN	1243.645	Hydrogen bonding + hydrophobic interactions	Stable complex; consistent with Fe–S cluster biogenesis
ISCU – FXN	1495.930	Electrostatic + hydrogen bonding	Highest docking score, suggesting strong interaction stability
LYRM4–FXN	1337.425	Predominantly hydrophobic interactions	Likely supportive role in Fe–S assembly complex
FECH– FXN	1295.990	Mixed interaction profile	Potential association with heme biosynthesis pathway

Across all four complexes, the predicted binding interfaces were enriched in functionally conserved residues, suggesting that these interaction surfaces have been preserved under evolutionary selection pressure. However, it should be noted that the key residues listed in Table 1 were estimated based on docking predictions and literature evaluation; molecular dynamics simulations would be required to confirm precise binding interfaces and assess the dynamic stability of these complexes.

3.5. Integrative Assessment

Collectively, the comparison between STRING-based computational predictions and IntAct experimental data demonstrates a substantial level of concordance, indicating that FXN occupies a central position within a biologically meaningful interaction network. The functional enrichment results and docking analyses further support the notion that FXN serves as a regulatory hub in mitochondrial iron homeostasis, Fe–S cluster biogenesis, and oxidative stress response. These findings are consistent with the current understanding of Friedreich's ataxia pathogenesis and provide a systems-level perspective on the molecular interactions underlying this disorder.

4.CONCLUSION AND DISCUSSION

The present study employed an integrative bioinformatics approach to systematically characterize the protein–protein interaction (PPI) network centered on frataxin (FXN) in the context of Friedreich's ataxia pathogenesis. Through the combined use of the STRING and IntAct databases, functional enrichment analyses, and ZDOCK-based structural docking simulations, a comprehensive picture of FXN-associated molecular interactions was obtained.

STRING network analysis identified a densely connected interaction module comprising 11 protein nodes and 39 interaction edges, with a PPI enrichment p-value of 6.46×10^{-10}, confirming the non-random and biologically meaningful nature of the FXN interaction network. The primary interaction partners—ISCU, NFS1, LYRM4, FECH, ACO1, ACO2, SCLY, HSPA9, CP, and HMOX1—are predominantly associated with mitochondrial iron metabolism, Fe–S cluster biogenesis, and oxidative stress response. These findings are in strong agreement with the established molecular role of frataxin as an allosteric activator of the mitochondrial ISC assembly complex, where it binds at the NFS1–ISCU interface to stimulate cysteine desulfurase activity and promote Fe–S cluster synthesis (Fox et al., 2019; Bridwell-Rabb et al., 2014).

The cross-validation of computational predictions with experimentally curated interaction data from the IntAct database revealed a substantial degree of overlap, particularly for the NFS1 and LYRM4 interactions, both of which were supported by MI confidence scores in the range of 0.35–0.44. This concordance between bioinformatic predictions and experimental evidence strengthens the biological reliability of the identified network. However, certain IntAct-specific interactors, such as PRNP and ADCK2, were not captured by the STRING network at the applied confidence threshold (≥ 0.900), suggesting that these may represent context-dependent or transient interactions that merit further investigation. The identification of PRNP as an FXN interactor is particularly noteworthy, given the emerging evidence linking prion protein to mitochondrial function and iron metabolism, although the functional significance of this interaction in FA pathogenesis remains unclear (Singh et al., 2014).

Functional enrichment analyses provided further support for the central role of FXN in mitochondrial biology. The enrichment of Gene Ontology terms related to iron–sulfur cluster assembly (GO:0016226), cellular iron ion homeostasis (GO:0006879), and oxidative stress response aligns with the well-established pathogenic cascade of Friedreich's ataxia, in which FXN deficiency leads to mitochondrial iron accumulation, impaired Fe–S protein maturation, and elevated reactive oxygen species production (Pastore & Puccio, 2013; Rötig et al., 1997). KEGG pathway analysis further revealed the involvement of FXN-associated proteins in porphyrin metabolism and ferroptosis-related pathways (Figure 3), suggesting a functional link between Fe–S cluster biogenesis and heme biosynthesis. This connection is mechanistically supported by the fact that ferrochelatase (FECH), identified as an FXN interaction partner in both the STRING network and docking analyses, catalyzes the terminal step of heme synthesis and is itself an Fe–S cluster-dependent enzyme (Nguyen et al., 2023).

Protein–protein docking analyses provided structural-level evidence supporting the biological relevance of the identified interactions. Among the four analyzed complexes, the FXN–ISCU pair exhibited the highest ZDOCK docking score (1495.930), consistent with the critical role of this interaction in Fe–S cluster assembly. The FXN–NFS1 complex displayed hydrogen bonding and hydrophobic contacts compatible with the allosteric regulatory mechanism previously described through cryo-EM studies (Fox et al., 2019). The predominantly hydrophobic nature of the FXN–LYRM4 interaction is consistent with the stabilizing role of ISD11/LYRM4 within the quaternary ISC complex architecture (Wiedemann et al., 2006). These docking results, while computational in nature, provide valuable structural hypotheses that can guide future experimental studies, including site-directed mutagenesis and molecular dynamics simulations.

The broader significance of these findings should be considered in the context of recent therapeutic developments. Although omaveloxolone, the first FDA-approved drug for Friedreich's ataxia, addresses downstream oxidative stress through Nrf2 activation (Lynch et al., 2023), the upstream molecular deficits arising from FXN deficiency remain incompletely addressed. The identification of central regulatory nodes within the FXN interaction network—particularly ISCU, NFS1, and FECH—may inform the development of complementary therapeutic strategies aimed at stabilizing the ISC assembly complex or enhancing residual frataxin activity. In this regard, AI-based computational approaches have shown promising results in identifying small molecule modulators targeting FXN-associated protein interaction surfaces (Kırboğa et al., 2023), and the structural insights provided by the present docking analyses may facilitate the rational design of such modulators.

Several limitations of this study should be acknowledged. The PPI network was primarily constructed using the STRING database with a single confidence threshold, which may exclude weaker but

biologically relevant interactions. Moreover, the docking analyses were performed using rigid-body algorithms that do not account for conformational flexibility or post-translational modifications influencing binding affinity in vivo. The key residues reported in the docking results were estimated based on computational predictions and literature evaluation; molecular dynamics simulations and experimental validation through techniques such as cross-linking mass spectrometry or hydrogen-deuterium exchange would be required to confirm precise binding interfaces. It should also be noted that the present study focused on binary interactions and did not model the higher-order multi-protein assemblies, such as the complete NFS1–ISD11–ACP–ISCU2–FXN pentameric complex, that are more representative of the physiological ISC machinery.

In conclusion, this integrative systems biology analysis demonstrates that FXN occupies a central position within a functionally coherent protein interaction network associated with mitochondrial iron homeostasis, Fe–S cluster biogenesis, and oxidative stress response. The concordance between computational predictions and experimental interaction data supports the biological validity of the identified network, while docking analyses provide structural hypotheses for future investigation. These findings contribute to a systems-level understanding of Friedreich's ataxia pathogenesis and may serve as a foundation for the identification of novel therapeutic targets. Future studies incorporating experimental validation, molecular dynamics simulations, and expanded multi-database comparisons will be essential to further refine and extend the FXN-centered interaction landscape.

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AUGMENTED REALITY–BASED RTK-SUPPORTED HIGH-PRECISION UNDERGROUND CABLE MAPPING SYSTEM

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ABSTRACT

Underground infrastructure assets are physically invisible, which leads to positioning uncertainty in field operations, increased risk of accidental excavation, and higher operational costs. Supported under the Energy Market Regulatory Authority (EPDK) R&D program (Project No. 01/24/05-01), this study presents an integrated mobile system that localizes underground cable inventory with centimeter-level accuracy using Real-Time Kinematic (RTK) corrections and visualizes the assets in an Augmented Reality (AR) environment. The system architecture comprises dynamic acquisition of Geographic Information System (GIS) data via the Web Feature Service (WFS), metric-consistent transformation of global coordinates (WGS84) to a local tangent frame (ENU), and ARCore-based visualization. The developed application optimizes on-site data density through attribute-based filtering and layer management, while a georeferenced and visually annotated reporting module enables bidirectional data flow from the field to a central system.

Field trials conducted across Sivas province indicate that the custom mobile RTK solution achieves an accuracy profile comparable to reference devices. Measurements confirm that underground assets can be overlaid onto the real world with a horizontal error of 5–7 cm. Performance evaluations show stable frame rates on mid- and high-tier Android devices; however, RTK solution quality in dense urban environments is directly affected by surrounding geometry. Overall, the proposed system provides an end-to-end field decision-support solution that improves operational efficiency in underground infrastructure management and minimizes “blind excavation” risks.

Keywords: Augmented reality, GNSS, RTK, WFS, underground infrastructure, field reporting

NEUROBIOLOGICAL EFFECTS OF PROBIOTICS ON THE GUT–BRAIN AXIS

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ABSTRACT

The gut-brain axis refers to a complex bidirectional communication network between the gastrointestinal system and the central nervous system via neural, immune, endocrine, and metabolic pathways. Scientific evidence has revealed that the gut microbiota plays a key role in regulating brain function and behavior. Probiotics have emerged as a promising nutritional strategy that can influence neurobiological processes. Probiotics are defined as live microorganisms that, when consumed in sufficient quantities, provide health benefits to the host, and these benefits are reported to extend beyond the gastrointestinal system to include brain function.

The results of preclinical and clinical studies show that probiotics can modulate key neurobiological mechanisms involved in the gut-brain axis. These mechanisms include the regulation of neurotransmitter synthesis such as gamma-aminobutyric acid and serotonin, modulation of the hypothalamus-pituitary-adrenal (HPA) axis, reduction of systemic and neuroinflammation, and improvement of intestinal barrier integrity. It is thought that probiotics may exhibit neuroprotective effects through the suppression of inflammatory signaling and oxidative stress, and may contribute to the maintenance of cognitive and emotional homeostasis. Studies show that probiotic supplementation may be associated with improvements in cognitive function, stress response, anxiety, and depressive symptoms, particularly in individuals with chronic stress, metabolic disorders, or neuroinflammatory conditions. Some specific probiotic strains, referred to as “psychobiotics,” are reported to influence mood and cognitive outcomes via microbiota-mediated signaling pathways. It is emphasized that the magnitude of these effects varies depending on the strain used, dosage, duration of intervention, and individual factors.

In conclusion, probiotics play a significant role in modulating neurobiological pathways of the gut-brain axis and are considered a complementary approach to supporting brain health.

Key Words: Gut–brain axis, Probiotics, Cognitive function, Psychobiotics

NUTRITIONAL THERAPY AND CLINICAL IMPLICATIONS IN ACUTE KIDNEY INJURY

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ABSTRACT

Acute kidney injury (AKI) is a significant clinical condition characterized by sudden loss of renal function, associated with high morbidity and mortality, particularly in hospitalized and intensive care unit patients. Hemodynamic changes, inflammation, oxidative stress, and metabolic dysregulation play a key role in the development of acute kidney injury. The resulting hypercatabolic state, protein-energy loss, and micronutrient deficiencies can negatively impact the clinical course and prognosis of patients. Therefore, nutritional therapy is considered one of the fundamental supportive approaches in the management of acute kidney injury.

The primary goal of nutritional therapy in acute kidney injury is to reduce catabolism, maintain nutritional status, and support the recovery process by ensuring adequate energy and protein intake. Energy requirements vary depending on the patient's clinical condition, comorbidities, and renal replacement therapy. Protein requirements increase, especially in patients undergoing renal replacement therapy, and protein restriction should be avoided. In addition, electrolytes (sodium, potassium, phosphorus), fluid balance, and acid-base status should be carefully monitored and adjusted according to individual needs. Studies show that properly planned nutritional therapy can reduce the risk of infection, shorten the length of stay in the intensive care unit, and improve clinical outcomes. However, individualized approaches regarding the content and timing of nutritional therapy are of great importance.

In conclusion, nutritional therapy is an integral part of clinical management in acute kidney injury. Implementing patient-specific nutritional strategies planned with a multidisciplinary team approach can contribute to improving clinical outcomes in patients with acute kidney injury.

Key Words: Acute kidney injury, Nutritional therapy, Renal replacement therapy

EVALUATING THE EFFECTIVENESS OF YES-TR CERTIFICATION IN ENHANCING BUILDING ENERGY EFFICIENCY: A COMPARATIVE STUDY WITH LEED, BREEAM AND EU DIRECTIVES

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ABSTRACT

In response to the growing global demand for sustainable development, green building certifications have emerged as critical tools for promoting environmentally friendly practices in the construction industry. These certifications establish standards that address a wide range of sustainability aspects, including energy efficiency, water conservation, and indoor environmental quality, guiding building practices toward reduced environmental impact. Among the most recognized international certifications are LEED (Leadership in Energy and Environmental Design) and BREEAM (Building Research Establishment Environmental Assessment Method), both of which have demonstrated significant contributions to energy efficiency and overall sustainability in the built environment. However, in countries with unique climatic, cultural, and regulatory needs, there is an increasing push to develop region-specific certification systems that address local sustainability challenges more effectively.

In Türkiye, YES-Tr was introduced as a national green building certification system to align with Türkiye's specific environmental goals and regulatory frameworks. While YES-Tr aims to enhance energy efficiency and environmental performance in buildings, its effectiveness, particularly in comparison to international standards such as LEED and BREEAM, remains underexplored. This research aims to evaluate the effectiveness of YES-Tr in improving energy efficiency in Türkiye's residential buildings by conducting a comparative analysis with LEED and BREEAM, examining key differences, similarities, and unique features of each certification system. This study also aims to assess the extent to which YES-Tr aligns with international best practices and identify any areas where it may benefit from incorporating global standards to enhance its impact on energy performance.

Through a mixed-method approach, including document analysis, case studies, and expert insights, this paper offers analysis of the role of YES-Tr in Türkiye's green building sector. The study's findings provide valuable insights into the strengths and limitations of YES-Tr, highlighting potential improvements and recommending strategies for aligning Türkiye's national standards with international benchmarks. This research contributes to the ongoing efforts to optimize green building certifications for better energy efficiency outcomes, offering a framework for further exploration of national certification systems in the context of global sustainability goals.

Key Words: Energy Efficiency in Buildings; LEED; BREEAM; YES-Tr; Comparative analysis

INTRODUCTION

Regarding the increasing international demand for the sustainable green development, certification of the green buildings is erected as vital instruments for providing environmentally friendly applications regarding the building sector. Such certifications create standards which address a variety of sustainability specialties which include energy efficiency, water conservation, and indoor environmental quality, guiding building practices toward reduced environmental impact. Among the most recognized

international certifications are LEED (Leadership in Energy and Environmental Design) and BREEAM (Building Research Establishment Environmental Assessment Method), both of which have demonstrated significant contributions to energy efficiency and overall sustainability in the built environment (Vierra, 2016; Bernardi et al., 2017). However, in countries with unique climatic, cultural, and regulatory needs, there is an increasing push to develop region-specific certification systems that address local sustainability challenges more effectively.

In Türkiye, YES-Tr was introduced as a national green building certification system to align with Türkiye's specific environmental goals and regulatory frameworks (Republic of Türkiye Ministry of Treasury and Finance, 2021). While YES-Tr aims to enhance energy efficiency and environmental performance in buildings, its effectiveness, particularly in comparison to international standards such as LEED and BREEAM, remains underexplored. This research aims to evaluate the effectiveness of YES-Tr in improving energy efficiency in Türkiye's residential buildings by conducting a comparative analysis with LEED and BREEAM, examining key differences, similarities, and unique features of each certification system. This study also aims to assess the extent to which YES-Tr aligns with international best practices and identify any areas where it may benefit from incorporating global standards to enhance its impact on energy performance.

Through a mixed-method approach, including document analysis, case studies, and expert insights, this paper will offer a comprehensive analysis of the role of YES-Tr in Türkiye's green building sector. The study's findings provide valuable insights into the strengths and limitations of YES-Tr, highlighting potential improvements and recommending strategies for aligning Türkiye's national standards with international benchmarks. This research contributes to the ongoing efforts to optimize green building certifications for better energy efficiency outcomes, offering a framework for further exploration of national certification systems in the context of global sustainability goals.

CONCEPTUAL FRAMEWORK

Green Building Certifications and ISO Standards

In order to asses and intersect the different specialities of the sustainable design's impacts in buildings such as energy waste, energy usage, potential for savings, water conversation, green building certifications has become a major endeavour. These certifications are often supported by ISO standards. ISO 14024 (Type I) (International Organization for Standardization, 2018) defines voluntary, third-party certified programs like the EU Ecolabel. ISO 14021 (Type II) (International Organization for Standardization, 2016) governs self-declared environmental claims, while ISO 14025 (Type III) (International Organization for Standardization, 2022) covers Environmental Product Declarations (EPDs), which gives detailed quantitative information and dataset on the environmental impact of the product and are critical in regards to similar certifications such as LEED and BREEAM

International Certification Systems: LEED and BREEAM

Developed by the U.S. Green Building Council, The LEED certification system is one of the most well-known and widely accepted rating system internationally. The LEED certification concentrates on vital aspects such as Energy and Carbon footprint, emphasising great amount of weight on energy performance and Indoor Environmental Quality. The LEED rating system is first a performance-based system which enables flexibility in reaching the sustainability goals across categories.

The BREEAM is created in the United Kingdom which is the oldest standing method in the world. The BREEAM Certification grades the buildings based on performance aspects such as Energy, Health, Wellbeing and Materials. The BREEAM certification asserts local adaptability and has affected building regulations across Europe.

Table 1 Comparison of Green Building Certifications Granted (U.S. Green Building Council, n.d.), (BRE Group, n.d.).

Certification type	Amount of certification granted	Country amount	Amount of Certified building Türkiye
BREEAM	610,000	102	57
LEED	111,172	180	685

Turkish National Certification YES-Tr

The Turkish national green building certification system YES-Tr is specially designed to address the unique local environmental hardships, building applications and national regulations of Türkiye. The goal of this certification is to address the national landscape and priorities of energy conversation, water conservation and sustainable material usage while keeping a parallel profile with the Turkish regulatory framework such as Energy Efficiency Law. Even though YES-TR certification are given in at different levels such as Geçer (Pass), İyi (good), Çok İyi (very good) ve Ulusal Üstünlük (National superiority), the detailed grading systems are not generally accepted as global certifications such as LEED or BREEAM.

METHODOLOGY

This paper uses a mixed-method approach to evaluate the effectiveness of the YES-Tr certification in improving energy efficiency in Türkiye's residential and public buildings. The methodology encompasses document analysis, case studies and expert insights in order to create a comprehensive analysis of the place of YES-Tr in Türkiye's green building sector. By comparing with the LEED and BREEAM, this paper undermines important differences, similarities, and significant features of each certification system. The paper evaluates the content to which YES-Tr aligns with the international best practices and identifies areas where it could benefit from incorporating from the international standards and global practices. In order to conduct systematic evaluation, the three different criteria have been established:

1) Environmental Performance Categories (specifically focusing on energy efficiency, water conservation, indoor environmental quality, and materials);

2) System Structure and Methodology (comparing point-based scoring systems, prerequisites, and the fundamental differences between prescriptive compliance and performance-based outcomes); and

3) Regional Adaptability and Usability (assessing accordance with Turkish legislation, economic cost/feasibility, and responsiveness to local climatic conditions).

By using these criteria, we can decide to which extent YES-Tr aligns with these international green building certifications.

COMPARATIVE ANALYSIS AND DISCUSSION

Comparison of YES-Tr with International Standards

Even though YES-Tr shares a similar aim with the international grading standardising, there are sharp differences in the scope and application. Whereas YES-Tr concentrates specially on regarding the Türkiye's local geographical and climate conditions and regulatory needs, LEED presents an international perspective with predefined credits. Regarding the locality BREEAM is similar to YES-Tr nevertheless it benefits from wider international recognition as it longest standing standardising.

The major difference lies within the approach to certification. In contrast to LEED and BREEAM which are largely performance-based systems, YES-Tr is primarily prescriptive with a national focus, aligning with the Turkish national building codes. LEED and BREEAM certifications are largely performance-based systems in contrast to YES Tr. The difference is that the performance-based standardizations are asses the outcomes (e.g., energy use intensity) and pushes for the innovation while prescriptive codes

provide niche, step-by-step requirements which can limit flexibility. A summary of these fundamental differences is presented in Table 2.

Table 2 Comparison of YES-Tr, LEED, and BREEAM Certification Systems

Comparison Criteria	YES-Tr	LEED	BREEAM
Origin & Recognition	National (Türkiye)	International (USA origin)	International (UK origin); Longest-standing system
Scope & Focus	Tailored to Turkish national building codes, local climate, and regulatory needs.	Global perspective with predefined, standardized international credits.	Broad international recognition with strong emphasis on local adaptability.
Assessment Approach	**Prescriptive-based:** Provides specific, step-by-step requirements and technical codes.	**Performance-based:** Assesses final outcomes (e.g., energy use intensity).	**Performance-based:** Assesses final operational outcomes and lifecycle impacts.
Flexibility & Innovation	**Limited flexibility:** Focuses heavily on strict compliance with national codes.	**High flexibility:** Encourages and rewards innovative technologies and design.	**High flexibility:** Encourages innovation while adapting to local building regulations.

Energy Efficiency Performance

This paper shows that the international certification systems harbour significant operational benefits which currently performs better than the national prescriptive models. According to the studies done by the U.S. Green Building Council, LEED-certified buildings can achieve energy, carbon, water, and waste reductions ranging from 30% to 97%, alongside an 8-9% reduction in operating costs (Vierra, 2016; Bernardi et al., 2017). BREEAM certification also shows similar high-performance results by using comprehensive lifecycle evaluations and changing its criteria to the specific local climates, superstructure regulations and culture as well (Bernardi et al., 2017) (ASHRAE, 2022). There are a little information and documentation regarding performance of the YES-Tr certified buildings and it firstly focus on prescriptive compliance with the national energy codes such as TS 825 unlike the international best practices (Jahed Tunalı, 2025). While international standards increasingly drive the market toward "net-positive" outcomes—and specialized systems like the Passive House standard demonstrate up to an 86% reduction in heating energy—YES-Tr currently lacks the performance-based flexibility and stringency to mandate such deep energy reductions.

In order to understand the gap between YES-Tr's prescriptive modal and real performance-based results, the data from the Turkish retrofit initiatives provides a critical benchmark for what could be achieved. The World Bank-funded KABEV project (Energy Efficiency in Public Buildings) aims to reduce public building energy consumption by 30% by 2030, and has already achieved an average of 40% energy savings across over 370 retrofitted buildings (World Bank, 2025). Energy retrofitting project at the Bursa Yüksek İhtisas Hospital—which included trigeneration plants, solar PV, and advanced HVAC automation—resulted in realized primary energy savings of 17.4% (approximately 8.9 million kWh/year) (Ministry of Environment, Urbanization and Climate Change, n.d.). Other examples, such as the Kandıra State Hospital and Ortaköy High School, achieved 30% energy savings and up to 70% electricity reductions, respectively (World Bank, 2025).

In order to achieve these energy saving outcomes, detailed Measurement and Verification (M&V) works which are following the IPMVP framework is required. (Ministry of Environment, Urbanization and Climate Change, n.d.). YES-Tr framework generally function as a design phase regulation standard in the other hand continuous operational monitoring is an integral component of certifications like BREEAM In-Use and LEED O+M (Operations and Maintenance), it is critically underemphasized in the standard YES-Tr framework, which often functions more as a design-phase compliance tool. Which is why in IFI funded projects such as KABEV, KAYEP etc. are using LEED or BREEAM certifications in these initiatives.

Also, the difference of effectiveness increases of these certifications when it comes to the application to existing and heritage buildings. BREEAM gives more highly specialized tools for building refurbishments, while Restoration and retrofitting of Türkiye's huge stock of traditional old housing structures are difficult to work with for generic national certifications such as YES-Tr. Research on traditional *hımış* (timber-framed) houses in Güdül reveals that standard "unified" retrofit approaches (e.g., wrapping a building in external insulation, as often prescribed by basic codes) fail in hybrid structures due to high moisture entrapment risks in stone masonry (Jahed Tunalı, 2025). Conversely, a material-specific "partial retrofit" approach targeting only the timber-framed zones achieved heating energy savings of 30.5% while successfully maintaining hygrothermal safety (Jahed Tunalı, 2025).

This shows that there is an important amount of limitation in YES-Tr's application to different situations due to prescriptive regulation compared to the international certification systems. So, there is a need for more flexible approached for YES-Tr to be more effective in the vast categories of buildings and climate regions in Türkiye.

Finally, including the advanced and passive technologies to the YES-Tr regulations yet to be established unlike the international best practices. Studies in similar climatic contexts indicate that advanced active systems, such as smart window technologies, can reduce total building energy consumption by 14% (Khalifa et al., 2023). Similarly, building performance simulations for high-rise offices in moderate climates like Istanbul demonstrate that primary energy inputs can be reduced by 30% to 40% utilizing integrated passive cooling and natural ventilation strategies (Schulze, 2015). However, the widespread adoption of such high-performance interventions in Turkish projects is limited by a lack of specific rewards or incentives within national certification frameworks, which tend to prioritize basic insulation and thermal conductivity standards. Consequently, for YES-Tr to match the energy efficiency performance of LEED and BREEAM, evidence suggests it must evolve to incorporate the rigorous operational verification (M&V) and material-specific flexibility found in global best practices.

CONCLUSION AND DISCUSSION

DISCUSSION:

The main issue while making this comparison of the gaps and effectiveness difference between these various certification systems is, are there enough data and sources to dispute the effectiveness of the YES-Tr against its international pairs such as LEED, BREEAM, etc ? As we previously mentioned there are couple things regarding this issue. We can evaluate their approach since there are well enough materials regarding their established criteria, frameworks and regulations, etc. The framework and the manual of the YES-Tr clearly shows that it is aspired on the national energy efficiency law and other national regulations such as TS 825, In contrast LEED and BREEAM uses more flexible, performance-based metrics (Vierra, 2016; Said & Harputlugil, 2019).

Theoretically, it is possible to compare and identify methodological gaps in between YES-TR and other certifications and thus we can detect that whether is there are gaps which may cause ineffectiveness when it comes to the energy retrofitting and restoration of different building types such as heritage sites.

Nevertheless, the data regarding the quantitative measurements is absent, as there is no data base regarding the number of certified buildings and their savings in official website of the YES-Tr unlike the BREEAM and LEED certification. BREEAM and LEED owns their own data base and they are keeping the records of the certified building and their operational data which verifies the long-term impact of these certifications for example, USGBC studies track thousands of buildings and demonstrate measurable energy and water savings ranging from 30% to 97% for LEED-certified projects (Vierra, 2016).

Contrary, YES-Tr is still under its inception phase, and the empirical data on the long-term operational energy performance of YES-Tr-certified buildings is highly limited.

Even though there are some databases regarding the IFI funded projects such as KABEV and KAYEP, these databases mostly consist of public buildings thus this and national reports indicate that Türkiye currently lacks comprehensive databases regarding the energy and emission performance of its existing building stock, and post-occupancy monitoring systems remain insufficient (Ministry of Environment, Urbanization, and Climate Change, 2023).

Thus, we can say that there is an approach gap between these green building certifications, measuring the real-world performance gap between YES-Tr and LEED, BREEAM are hard to assess until more relevant data becomes available.

CONCLUSION

With this paper it is indicated that YES-Tr is a very important asset regarding the creating a locally relevant sustainability framework for Türkiye. It has its own benefits regarding mentioning the need for a system tailored to national regulation regarding the buildings and localized priorities. However, this paper indicates that there is gap between YES-Tr and its international peers, especially that this gap consist of its reliance on prescriptive design rather than proven operational outcomes. The results show of the strengths and limitations of YES-Tr, and includes suggestions for strategies for aligning the Türkiye's national YES-Tr standard with the global benchmarks.

Due to the fact that there is a very limited data regarding the performance of the buildings and type of structures certified, especially regarding the long-term effectiveness of buildings certified with the YES-Tr, there is a need for a strict monitoring of these buildings after usage. Thus, it can be determined that whether the criteria used in YES-Tr translate into comparable energy savings to those acquired via international certification such as LEED and BREEAM and how well YES-Tr address the geographical challenges and potential of Türkiye such as Earthquake danger, and the six different climate conditions. Finally, by considering the knowledge gained through national and internationally funded project's outcomes and measurement and verification protocols, as well as performance based operational assessments found in LEED and BREEAM, we could improve the potential and the impact of the YES-Tr on Türkiye's sustainable energy outcomes.

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DEVELOPING A SYSTEM FOR EVALUATING LEARNING OUTCOMES IN HIGHER EDUCATION WITHIN THE SCOPE OF EDUCATIONAL INNOVATION

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ABSTRACT

Educational innovation in higher education processes can occur at multiple levels, including instructional design, assessment, curriculum development, academic workflows, and student experience. Especially in today's world, where digital transformation in education is prominent, innovative practices within the quality assurance system, frequently discussed in educational processes, are gaining increasing importance.

Based on this approach, this study aims to develop an information system within the scope of educational innovation. This system, called the Course Learning Outcomes Management System (COLMS), includes a multi-layered structure allowing access to multiple users, including guests, academic staff, department heads, unit managers, and system administrators (admin). Statistical analyses are executed in the background of the system based on information obtained from the related studies in literature. Based on these analyses, detailed course outcomes reports are generated for users at the course, program, and unit levels.

The analysis of course outcome data in the developed system is collected within a centralized information architecture that includes multi-layered reporting modules. In this context, it is possible to compare the critical outputs obtained. Furthermore, the system's reporting architecture enhances traceability within the scope of quality assurance management in higher education organizations. This advantage reduces the burden of manual report generation, which is frequently used in academic workflows, and enables stakeholders to access consistent, accurate, and up-to-date outputs.

Key Words: Educational Innovation; Information System Development; Evaluation of Learning Outcomes; Quality Assurance; Higher Education

PETROL DEPOLAMA FAALİYETLERİ İÇİN LOJİSTİK SERVİS SAĞLAYICI SEÇİM KRİTERLERİ

SELECTION CRITERIA OF LOGISTICS SERVICE PROVIDERS FOR PETROLEUM STORAGE OPERATIONS

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ÖZET

Bu çalışma, küresel enerji arzının birincil bileşeni olan petrolün jeokimyasal oluşumundan nihai depolama terminallerine uzanan operasyonel döngüsünü ve bu süreçteki stratejik yönetim gerekliliklerini analiz etmektedir. Hidrokarbon değer zinciri; jeolojik prospeksiyon, ekstraksiyon, ön işleme ve boru hattı lojistiği gibi teknik evrelerin yanı sıra ekonomik politika belirsizlikleri (EPU) ve jeopolitik dinamiklerin simbiyotik etkileşimi altında şekillenmektedir. Özellikle enerji ithalatına bağımlı ekonomilerde, petrol fiyatlarındaki volatilite ve makroekonomik kırılganlıklar, lojistik ve depolama süreçlerinin ekonometrik modellerle sürekli monitorize edilmesini zorunlu kılmaktadır.

Depolama olgusu, emtianın lojistik akış içerisinde statik faza geçtiği bir süreç olmanın ötesinde, "zaman faydası" (time utility) yaratan dinamik bir risk yönetimi alanıdır. Petrol depolama sistemlerinin temel bileşeni olan tankların (yer üstü ve yer altı) tasarımı; ürünün parlama ve kaynama noktaları gibi fizikokimyasal karakteristiklerine göre belirlenmektedir. Evaporasyon kayıplarını minimize eden yüzer tavan teknolojileri ve çevresel kontaminasyonu engelleyen çift cidarlı taban yapıları, modern depolama mühendisliğinin sürdürülebilirlik odaklı temel çıktılarıdır.

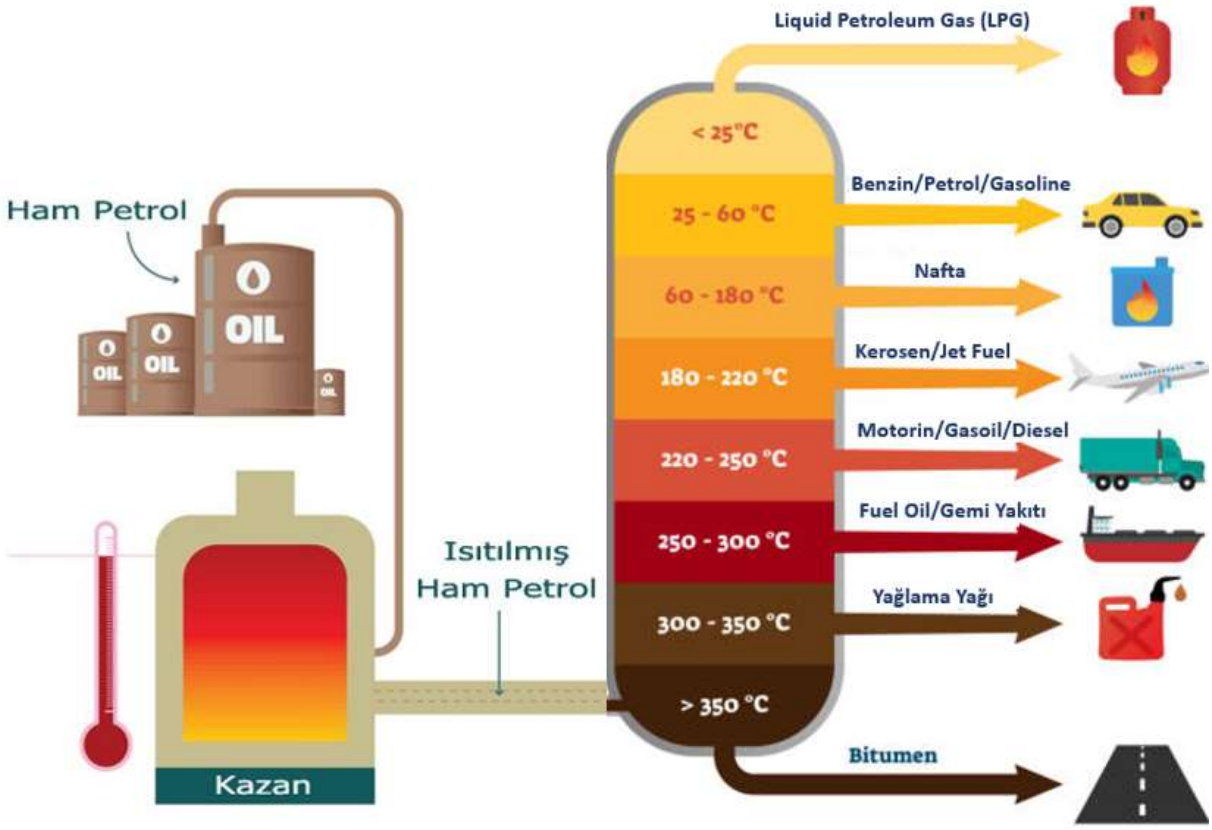
Çalışmanın merkezini oluşturan Lojistik Hizmet Sağlayıcılarının (LHS) seçimi, operasyonel başarıyı doğrudan etkileyen çok boyutlu bir karar verme problemidir. Literatürde yer alan Analitik Hiyerarşi Süreci (AHP) ve Analitik Ağ Süreci (AAS) gibi Çok Kriterli Karar Verme (ÇKKV) yöntemleri; seçimin salt maliyet odaklı bir yaklaşımdan ziyade; operasyonel yeterlilik, bilgi teknolojileri yetkinliği, hizmet inovasyonu, İSG (HSE) standartlarına uyum, sektörel itibar ve sürdürülebilirlik parametreleri üzerinden yapılması gerektiğini ortaya koymaktadır. Özellikle tehlikeli madde depolamasında, güvenlik ve emniyet kriterlerinin karardaki ağırlığı, maliyet avantajının önüne geçmektedir. Sonuç olarak, petrol depolama faaliyetlerinde etkin bir yönetişim; teknik altyapı, dijital izlenebilirlik ve stratejik iş birliği yetkinliklerinin entegrasyonuna bağlıdır.

Anahtar Kelimeler: Petrol Depolama, Lojistik Hizmet Sağlayıcı Seçimi, Çok Kriterli Karar Verme (ÇKKV), Enerji Tedarik Zinciri, Operasyonel Güvenlik, Sürdürülebilirlik.

1. GİRİŞ

Küresel enerji arzının temel bileşeni olan petrol, organik sedimentlerin jeolojik zaman ölçeklerinde yüksek basınç ve termal gradyanlara maruz kalarak biyokimyasal bozunmaya uğramasıyla oluşmaktadır. Fauna ve flora kalıntılarından türeyen bu materyalin kimyasal matrisi, baskın olarak hidrokarbon zincirlerinden oluşmakla birlikte; bünyesinde eser miktarda azot, oksijen ve kükürt gibi heteroatomları barındırmaktadır. Rezervuarlardan sondaj operasyonları ile ekstrakte edilen ham petrolün, rafineri ve depolama terminallerine uzanan lojistik sevk süreci, sektörün operasyonel

verimliliği açısından stratejik bir öneme sahiptir. Bu bağlamda, ham maddenin rafinaj öncesi ve sonrası süreçlerde ticari değeri yüksek türevlere dönüştürülmesi, yalnızca teknik bir işlem değil, aynı zamanda optimize edilmesi gereken karmaşık bir depolama ve lojistik yönetim döngüsüdür.

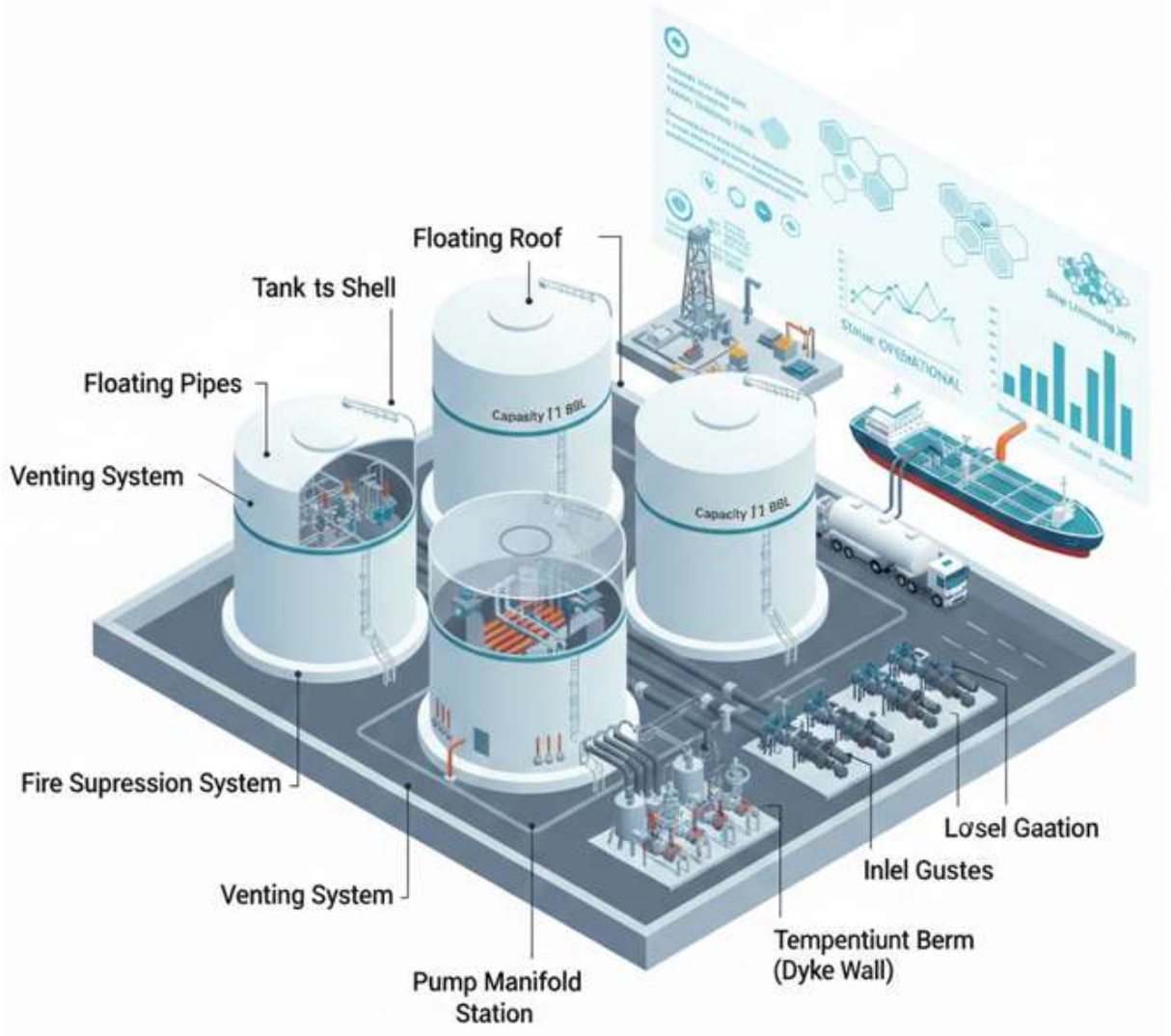


Resim-1. Ham Petrol Distilasyon Şeması

2. ARAŞTIRMA VE BULGULAR

Modern endüstriyel paradigmada petrol, yalnızca birincil bir enerji kaynağı değil, aynı zamanda küresel imalat ve ticari faaliyetlerin sürdürülebilirliği için vazgeçilmez bir stratejik hammadde niteliğindedir. Petrolün bu denli baskın bir rol oynamasının temelinde, küresel ölçekte tesis edilmiş olan sofistike tüketim ve lojistik ağları yatmaktadır. Günümüzde hidrokarbon türevleri, elektrik üretiminden mobilite çözümlerine kadar geniş bir spektrumda temel girdi teşkil etmektedir. Enerji üretiminin yanı sıra; polimer teknolojileri, petro-kimya endüstrisi, yağlama sistemleri ve ileri malzeme bilimi (çelik-seramik kompozitleri) gibi sektörlerde de temel yapı taşı olarak kullanılmakta, bu durum petrolü küresel ekonominin en çok boyutlu emtiası haline getirmektedir.

Kuyubaşından depolama terminallerine uzanan hidrokarbon transfer süreci, enerji değer zincirinin en kompleks ve multidisipliner aşamalarından birini temsil etmektedir. Söz konusu süreç; jeolojik prospeksiyondan başlayarak sondaj, ekstraksiyon, ön işleme, boru hattı lojistiği ve çevresel yönetişim gibi teknik, finansal ve ekolojik boyutları olan entegre bir evreler bütününü kapsamaktadır. Her bir faz; mühendislik çözümleri, ekonometrik analizler, çevre bilimleri ve jeopolitik dinamiklerin simbiyotik etkileşimini zorunlu kılmaktadır.



Resim-2. Petrol Yolculuğu ve Depolama

Hidrokarbon değer zinciri, yeraltı rezervuarlarının prospeksiyonu ve tanımlanmasıyla başlayan çok katmanlı bir süreçtir. Rezervuar potansiyelinin ve ekonomik üretilebilirliğinin saptanmasında, konvansiyonel jeokimyasal analizlerin yanı sıra ileri düzey jeofiziksel etütler belirleyici rol oynamaktadır. Özellikle deniz aşırı (offshore) arama faaliyetlerinde, sismik verilerin işlenmesi ve gravimetrik ölçümler gibi öncü teknikler, yüksek sermaye yoğunluklu yatırımların risk optimizasyonu için elzemdir.

Ekstraksiyon aşamasını takiben, kuyubaşında (wellhead) gerçekleştirilen faz ayrıştırma işlemleri; ham petrolün bünyesindeki formasyon suyu, gaz ve katı partiküllerden arındırılarak stabilize edilmesini sağlar. Bu ön tasfiye süreci, ürünün lojistik ağlara entegrasyonu ve depolama terminallerindeki bütünlüğünün korunması açısından teknik bir zorunluluktur. Petrolün iletiminde merkezi bir rol oynayan boru hattı altyapıları, yalnızca mühendislik çözümleri değil, aynı zamanda devlet politikaları ve jeopolitik stratejilerle şekillenen makro-ekonomik yatırımlardır. Sürecin bütünü ele alındığında; kaynaktan terminale uzanan bu operasyonel döngü, teknik ve ekonomik parametrelerin ötesinde, çevresel yönetişim ve proaktif risk yönetimi disiplinlerinin simbiyotik bir etkileşimini gerekli kılmaktadır. Taşıma ve depolama safhalarındaki ekolojik risklerin minimize edilmesi, sürecin sürdürülebilirlik performansının temel göstergesidir.

Hidrokarbon lojistiği ve depolama süreçlerinin yönetimi, operasyonel zorlukların yanı sıra küresel enerji piyasalarındaki yüksek volatilite ve makroekonomik belirsizliklerin etkisi altındadır. Ham petrolün ekstraksiyonundan terminal operasyonlarına kadar olan tüm fazlar; arz-talep projeksiyonları, fiyat dalgalanmaları ve ekonomik politika belirsizlikleri (EPU) tarafından doğrudan domine edilmektedir.

Literatürde, küresel ekonomik politika belirsizliği ile ham petrol fiyat dinamikleri arasında uzun vadeli ve belirgin bir nedensellik ilişkisi olduğu saptanmıştır; bu durum, stratejik karar vericilerin ve yatırımcıların riskten korunma (hedging) mekanizmalarında politika belirsizliği endekslerini temel bir parametre olarak kabul etmelerini zorunlu kılmaktadır (Gulcan, 2022). Özellikle enerji ithalatına bağımlı ekonomilerde, petrol fiyatlarındaki volatilite doğrudan maliyet enflasyonuna ve makro-finansal kırılganlıklara yol açtığından, lojistik ve depolama döngülerinin ekonometrik modellerle sürekli monitorize edilmesi kritik bir gerekliliktir (Solmaz & Bayraktutan, 2019).

Depolama olgusu, tarihsel süreç içerisinde insanoğlunun temel gereksinimlerini çevresel ve iklimsel faktörlerden koruma güdüsüyle ortaya çıkmış, medeniyetin gelişimiyle paralel olarak stratejik bir disipline dönüşmüştür. Teknik anlamda depolama, emtianın lojistik akış içerisinde statik faza geçtiği bir mekânsal süreci temsil ederken; depo, ürünlerin fonksiyonel amaçlar doğrultusunda giriş ve çıkış operasyonları arasında muhafaza edildiği teknik altyapıyı ifade etmektedir.

Küresel ekonominin ve üretim paradigmalarının evrildiği günümüz konjonktüründe, depolama faaliyetleri zaman faydası (time utility) yaratma noktasında her geçen gün daha fazla önem kazanmaktadır. Çağdaş endüstriyel stratejilerin temel odağı; üretim ve tedarik zinciri süreçlerindeki arz-talep uyumsuzluklarını minimize etmek, operasyonel darboğazları gidermek ve marjinal faydayı maksimize etmektir. Bu bağlamda, hammadde aşamasından nihai ürün fazına kadar olan süreçte, emtianın fiziksel bütünlüğünün korunması ve lojistik kayıpların en aza indirilmesi; kurumsal hafıza, teknik uzmanlık ve sistematik yönetim modelleriyle doğrudan ilişkilidir. Dolayısıyla depolama, sadece statik bir bekletme eylemi değil, işletme verimliliğini ve karlılığını doğrudan etkileyen dinamik bir risk ve süreç yönetimi alanıdır.

Petrol depolama, modern endüstriyel toplumların enerji ihtiyacının karşılanmasında merkezi bir rol oynamaktadır. Ham petrol ve türevlerinin güvenli, verimli ve sürdürülebilir bir şekilde depolanması, enerji arz güvenliğinin sağlanması, ekonomik dalgalanmaların yönetilmesi ve çevresel risklerin azaltılması açısından kritik öneme sahiptir.

Hidrokarbonların büyük ölçekli ve emniyetli muhafazası için kurgulanan depolama sistemlerinin merkezinde tank birimleri yer almaktadır. Bu yapılar genel olarak yeraltı ve yerüstü depolama tankları şeklinde iki temel kategoride sınıflandırılmaktadır. Rafineri operasyonlarında, atmosferik koşullarda kaynama noktasının altında kalan ürünlerin depolanması sürecinde; maliyet avantajı, bakım-onarım süreçlerindeki erişilebilirlik gibi faktörler nedeniyle yerüstü atmosferik tanklar öncelikli olarak tercih edilmektedir.

Depolama tanklarının konfigürasyonu; evaporasyon (buharlaşma) kayıplarını asgari düzeye indirmek, ekonomik verimliliği artırmak ve operasyonel güvenliği tesis etmek amacıyla belirli fiziksel kriterlere göre tayin edilir.

- **Basınçlı Depolama:** Atmosferik basınç altında kaynama noktası 0°C'nin üzerinde olan petrol türevleri, genellikle küresel veya silindirik basınçlı kaplarda muhafaza edilir.
- **Yüzer Tavanlı Tanklar:** Parlama noktası 55°C'den düşük olan uçucu hidrokarbonlar (ham petrol, benzin, nafta vb.) ile normal şartlarda yanıcı buhar-hava karışımı oluşturma potansiyeli yüksek ürünler için kullanılır. Bu tasarımda temel amaç, sıvı yüzeyi ile hava temasını keserek parlayabilir atmosfer oluşumunu engellemek, emisyonları azaltmak ve yangın anında koruma sağlamaktır.
- **Sabit Tavanlı Tanklar:** Parlama noktası 55°C eşiğinin üzerinde olan ve düşük uçuculuk sergileyen fuel-oil veya bitümen gibi ağır ürünlerin depolanmasında tercih edilmektedir.

Mekanik dayanıklılığın yüksek olması, yüzey alanının hacme oranla küçük kalması ve üretim kolaylığı gibi teknik gerekçelerle tanklar silindirik geometride inşa edilirler. Tank gövdesi, dikdörtgen sac levhaların hedeflenen çapa göre bükülmesi ve üst üste kaynaklanmasıyla oluşturulur. Statik yük dağılımı nedeniyle sac kalınlıkları tabandan yukarıya doğru gidildikçe kademeli olarak azaltılmaktadır; yan sac kalınlıkları toplam yüksekliğe bağlı olarak 25-35 mm aralığında değişebilmektedir. Çevresel sızıntı risklerine karşı bir önlem olarak tank tabanları, özellikle ekolojik koruma standartları gereği çift cidarlı olarak da üretilmektedir.

Depolama terminallerinin yerleşim planlaması; rutin işletme, acil durum müdahale ve yangınla mücadele stratejileriyle entegre şekilde yürütülür. Güvenlik protokolleri gereği:

- **Mesafe Kriteri:** Tanklar arası mesafe, komşu tank çapının en az yarısı kadar () olacak şekilde kurgulanır.
- **Konumlandırma:** Üniteler, olası ateşleme kaynaklarından maksimum uzaklıkta konumlandırılır.
- **İkincil Muhafaza:** Sızıntı veya taşma durumlarında çevreye yayılımı engellemek amacıyla tank sahaları sedde (bund/dyke) yapılarıyla çevrelenir. Bu set yapılarının drenaj sistemleri, tahliye kontrolünün dışarıdan yönetilebilmesine imkan tanıyacak şekilde tasarlanmaktadır.

Petrol ve türevlerinin depolanmasında kullanılan tankların yönetimi, yalnızca operasyonel süreçlerle sınırlı değildir; aynı zamanda çevresel düzenlemeler ve yasal mevzuat da önemli bir rol oynar. Tankların kurulumu, bakımı, izlenmesi ve olası sızıntıların önlenmesine yönelik düzenlemeler detaylı olarak açıklanmalıdır. Özellikle, tankların yerleştirileceği alanların seçimi, ikincil koruma sistemlerinin kullanımı ve düzenli denetimlerin yapılması gibi hususlar, çevresel risklerin minimize edilmesi açısından kritik öneme sahiptir. Bu tür düzenlemeler, petrol depolama tesislerinin sürdürülebilirliğini ve çevreyle uyumunu sağlamak için gereklidir (Olexa et al., 2006).

Petrol depolama sistemlerinin güvenliği, yalnızca tankların yapısal bütünlüğüyle değil, aynı zamanda operasyonel süreçlerdeki insan faktörüyle de yakından ilişkilidir. Özellikle, tankların dolum ve boşaltım işlemlerinde meydana gelebilecek hatalar, büyük ölçekli çevresel felaketlere yol açabilir. Bu nedenle, otomasyon sistemlerinin yanı sıra, personelin eğitimi ve operasyonel prosedürlerin standartlaştırılması da büyük önem taşır. Tank seviyesinin sürekli izlenmesi ve kritik seviyelere ulaşıldığında otomatik olarak müdahale edilmesi sağlanmalıdır. Ayrıca, insan-makine arayüzlerinin ergonomik olarak tasarlanması, operatörlerin hata yapma olasılığını azaltmakta ve süreçlerin daha güvenli bir şekilde yürütülmesine katkı sağlamaktadır (Montenegro & Salazar, 2012).

Petrol depolama faaliyetleri, yüksek hacimli ve tehlikeli maddelerin güvenli, verimli ve sürdürülebilir bir şekilde yönetilmesini gerektirir. Bu faaliyetlerin başarısı, yalnızca teknik altyapı ve operasyonel süreçlerle sınırlı kalmayıp, aynı zamanda lojistik servis sağlayıcılarının (LSS) seçimine de doğrudan bağlıdır. Lojistik servis sağlayıcılarının seçimi, petrol depolama operasyonlarının etkinliği, güvenliği ve maliyet etkinliği üzerinde belirleyici bir rol oynamaktadır. Bu nedenle, petrol depolama faaliyetleri için uygun lojistik servis sağlayıcı seçim kriterlerinin belirlenmesi, hem sektörel rekabet gücünün artırılması hem de operasyonel risklerin minimize edilmesi açısından kritik öneme sahiptir.

Lojistik hizmet sağlayıcılarının seçiminde işin finansal boyutu da önem arz etmektedir. Finansal olarak önemli unsur maliyet yönetimidir. Bokor'un çalışmasında, lojistik maliyetlerinin doğru ve şeffaf bir şekilde hesaplanmasının, kaynak tahsisi ve planlama açısından kritik olduğu belirtilmektedir. Geleneksel maliyetlendirme yaklaşımlarının, karmaşık ve heterojen lojistik hizmet yapılarında yetersiz kalabildiği, bu nedenle çok seviyeli tam maliyet tahsis tekniklerinin uygulanmasının maliyetlerin daha doğru ve şeffaf bir şekilde belirlenmesine katkı sağladığı vurgulanmaktadır (Bokor, 1970). Petrol depolama gibi yüksek hacimli ve uzun vadeli operasyonlarda, maliyet şeffaflığı ve etkin maliyet kontrolü sağlayıcı seçiminde belirleyici olmaktadır. Özellikle dış kaynak kullanımının temel motivasyonlarından biri olan maliyet avantajı, lojistik servis sağlayıcılarının seçiminde ana kriterlerden biri olarak öne çıkmaktadır. İthalat ve ihracat sektöründe yapılan bir çalışmada, üçüncü parti lojistik şirketlerinin seçiminde toplam 16 kriter belirlenmiş ve bu kriterler arasında maliyetin en önemli ana kriter olduğu tespit edilmiştir. Analitik Hiyerarşi Süreci (AHP) yöntemiyle yapılan bu çalışmada, maliyetin yanı sıra hizmet kalitesi, zamanında teslimat ve esneklik gibi kriterler de değerlendirilmiştir (Çetinkaya et al., 2020). Petrol depolama faaliyetlerinde, yüksek sabit maliyetler ve operasyonel giderler göz önüne alındığında, maliyet etkinliği sağlayan lojistik servis sağlayıcılarının tercih edilmesi, işletmelerin rekabet gücünü artırmaktadır.

Lojistik hizmet sağlayıcılarının yenilikçilik ve hizmet inovasyonu yetenekleri de seçim kriterleri arasında yer almaktadır. Hou ve arkadaşlarının Tayland'daki lojistik hizmet sağlayıcılarıyla yaptığı çalışmada, hizmet inovasyonunun lojistik yetkinlik ve maliyet avantajı üzerinde doğrudan etkisi olduğu, ayrıca lojistik yetkinlik aracılığıyla dolaylı olarak da maliyet avantajı sağladığı ortaya konmuştur. Bu nedenle, lojistik hizmet sağlayıcılarının kendi özgün hizmet inovasyonlarını geliştirmeleri ve lojistik

yetkinliklerini artırmaları, maliyet avantajı elde etmeleri açısından kritik öneme sahiptir (Mian et al., 2025). Petrol depolama gibi rekabetin yoğun olduğu sektörlerde, yenilikçi hizmet sunabilen sağlayıcıların tercih edilmesi, operasyonel verimlilik ve maliyet etkinliği açısından avantaj sağlamaktadır. Hizmet kalitesi ve zamanında teslimat kriterleri de önemli bir yer tutmaktadır. Çok Kriterli Karar Verme (ÇKKV) yöntemleriyle yapılan bir çalışmada, maliyet, hizmet kalitesi ve zamanında teslimatın, üçüncü parti lojistik sağlayıcılarının seçiminde en büyük etkiye sahip üç kriter olduğu tespit edilmiştir. Bu çalışmada, Pisagor Bulanık Analitik Hiyerarşi Süreci (PFAHP) ve Gri İdeal Çözüme Benzerliğe Göre Sipariş Tercihi Tekniği (GTOPSIS) yöntemleri entegre edilerek, gıda endüstrisinde müşteri siparişlerinin tesliminde en uygun lojistik servis sağlayıcısı belirlenmiştir (Çalık et al., 2024). Petrol depolama faaliyetlerinde de, hizmet kalitesinin sürekliliği, teslimatların zamanında ve eksiksiz yapılması, operasyonel süreçlerin aksamadan yürütülmesi açısından kritik öneme sahiptir.

Tedarik zinciri şeffaflığı ve verimliliği arasındaki ilişki de sağlayıcı seçiminde göz önünde bulundurulması gereken bir diğer faktördür. Petrol depolama faaliyetlerinde, şeffaflık ve izlenebilirlik sağlayan lojistik hizmet sağlayıcılarının seçilmesi, operasyonel risklerin azaltılması ve mevzuata uyum açısından önemlidir.

Lojistik hizmet sağlayıcılarının seçiminde, hizmet kalitesinin sürdürülebilirliği ve bölgesel farklılıklara uygunluk düzeyidir. Petrol depolama faaliyetlerinde, hizmet sağlayıcılarının sürdürülebilirlik hedeflerine ve bölgesel düzenlemelere uyum düzeyi, seçim kriterleri arasında yer almalıdır. Tuljak-Suban'ın çalışmasında, yeşil tedarik zinciri yönetimine geçişte lojistik hizmet sağlayıcılarının çevresel performansının genellikle göz ardı edildiği, ancak lojistik sağlayıcılarının çevresel sürdürülebilirliğe önemli katkılar sunabileceği belirtilmektedir. Çalışmada, lojistik hizmet sağlayıcılarının seçiminde en sık uygulanan çevresel kriterler arasında katma değerli tersine lojistik hizmetleri, çevresel harcamalar, salınan kirleticiler, enerji tüketimi ve temiz enerji kullanımı yer almaktadır (Tuljak-suban, 2016). Petrol depolama faaliyetlerinde, çevresel risklerin yüksek olması nedeniyle, çevresel sürdürülebilirlik sağlayıcı seçiminde temel bir kriter olarak değerlendirilmelidir.

Petrol depolama faaliyetlerinde lojistik hizmet sağlayıcılarının seçiminde, tedarik zinciri entegrasyonu ve iş birliği düzeyi de kritik bir rol oynamaktadır. Petrol depolama gibi çok aktörlü ve karmaşık süreçlerin yönetildiği alanlarda, entegrasyon yeteneği yüksek sağlayıcıların tercih edilmesi, operasyonel uyum ve verimlilik açısından önem taşımaktadır.

Petrol depolama faaliyetlerinde, liderlik ve insan kaynakları yönetimi güçlü olan sağlayıcıların seçilmesi, hizmet kalitesinin sürdürülebilirliği ve operasyonel risklerin azaltılması açısından avantaj sağlamaktadır. Sektöre özgü yasal ve güvenlik gerekliliklerine uyum düzeyidir. Yüksek riskli sektörlerde, mevzuata uyum, güvenlik standartlarının karşılanması ve acil durum yönetimi sağlayıcı seçiminde vazgeçilmez kriterlerdir.

Günümüzde lojistik sektöründe yaşanan hızlı değişim ve artan rekabet, firmaların lojistik süreçlerini dış kaynak kullanımı yoluyla optimize etme eğilimini güçlendirmiştir. Özellikle petrol gibi yüksek riskli ve değerli ürünlerin depolanmasında, doğru lojistik servis sağlayıcısının seçilmesi, operasyonel başarıyı doğrudan etkileyen bir faktör olarak öne çıkmaktadır. Lojistik servis sağlayıcılarının seçiminde dikkate alınması gereken kriterler, sektörün kendine özgü dinamikleri, operasyonel gereksinimleri ve güvenlik standartları doğrultusunda şekillenmektedir.

Lojistik servis sağlayıcılarının seçiminde kullanılan kriterlerin belirlenmesi ve önceliklendirilmesi, literatürde farklı sektörler ve uygulama alanları için çeşitli yöntemlerle incelenmiştir. Özellikle depolama faaliyetleri için yapılan çalışmalarda, operasyonel yeterlilik, maliyet, hizmet kalitesi, güvenlik ve bilgi teknolojileri yetkinliği gibi kriterlerin öne çıktığı görülmektedir. Örneğin, depolama faaliyetleri özelinde yapılan bir araştırmada, üçüncü parti lojistik servis sağlayıcılarının değerlendirilmesinde "operasyonel yeterlilik" kriterinin en önemli değerlendirme kriteri olduğu vurgulanmıştır. Bu çalışmada, Analitik Ağ Süreci (AAS) yöntemi kullanılarak, karar verme probleminin yapısı analiz edilmiş ve gıda perakendeciliği sektöründe bir uygulama örneği sunulmuştur. Sonuç olarak, operasyonel yeterliliğin, depolama lojistiği servis sağlayıcılarının seçiminde öncelikli olarak dikkate alınması gerektiği ortaya konmuştur (Görener, 2014). Bu bulgu, petrol depolama gibi yüksek riskli ve karmaşık operasyonlarda da benzer bir önemin söz konusu olabileceğini göstermektedir.

Değişen ve yenilenen bilgi çağında doğru veri akışı ve izlenebilirlik açısından seçiminde hizmet sağlayıcıların bilgi teknolojileri yetkinliği önem arz etmektedir. Günümüzde lojistik süreçlerin dijitalleşmesi ve otomasyonun artmasıyla birlikte, bilgi teknolojilerinin etkin kullanımı, operasyonel verimlilik ve izlenebilirlik açısından kritik bir rol oynamaktadır. Lojistik servis sağlayıcılarının seçim kriterleri üzerine yapılan bir çalışmada, bilgi teknolojisi kullanım yeteneğinin en önemli seçim kriterlerinden biri olduğu belirlenmiştir. Bu çalışmada, şirketlerle yapılan görüşmeler sonucunda elde edilen verilerin içerik analiziyle değerlendirilmiş ve bilgi teknolojisi yetkinliğinin, özellikle karmaşık ve yüksek hacimli operasyonlarda öne çıktığı vurgulanmıştır (Aydin & Koseoglu, 2016). Petrol depolama faaliyetlerinde, özellikle stok yönetimi, izlenebilirlik ve güvenlik açısından bilgi teknolojilerinin etkin kullanımı, operasyonel risklerin azaltılması ve süreçlerin optimize edilmesi açısından büyük önem taşımaktadır.

Petrol depolama faaliyetlerinde güvenlik ve emniyet kriterleri, diğer sektörlere kıyasla çok daha yüksek bir öneme sahiptir. Lojistik 4.0 uygulamaları kapsamında yapılan bir çalışmada, lojistik hizmet sağlayıcılarının seçiminde emniyet ve güvenlik kriterlerinin en önemli iki kriter olduğu belirlenmiştir. Analitik Hiyerarşi Süreci (AHP) ve bulanık yaklaşım kullanılarak yapılan bu çalışmada, güvenlik kriterinin AHP'de 0,568 değerle en önemli kriter olduğu, bulanık yaklaşımda ise güvenlik ve emniyet kriterlerinin %83,7 ile en önemli iki kriter olarak öne çıktığı vurgulanmıştır. Bu bulgu, özellikle tehlikeli madde taşımacılığı ve depolamasında, güvenlik standartlarının ve risk yönetiminin öncelikli olarak ele alınması gerektiğini göstermektedir (Göçmen, 2020). Petrol depolama faaliyetlerinde, yangın, patlama ve çevresel kirlilik gibi yüksek riskler söz konusu olduğundan, lojistik servis sağlayıcılarının güvenlik altyapısı, acil durum yönetimi ve risk azaltma yetkinlikleri seçimde belirleyici olmaktadır.

Lojistik servis sağlayıcılarının seçiminde sektörel deneyim ve itibar önem arz etmektedir. Şirketlerin sektördeki tanınırlığı, geçmişteki performansları ve müşteri memnuniyeti düzeyleri, seçim sürecinde belirleyici olabilmektedir. Petrol depolama faaliyetlerinde, özellikle uzun vadeli iş birlikleri ve yüksek hacimli operasyonlar söz konusu olduğunda, sağlayıcıların sektörel deneyimi ve güvenilirliği, operasyonel risklerin azaltılması ve sürdürülebilir iş ilişkilerinin kurulması açısından kritik öneme sahiptir.

Son olarak, lojistik servis sağlayıcılarının seçiminde sürdürülebilirlik ve çevresel etki kriterleri de giderek daha fazla önem kazanmaktadır. Özellikle enerji sektöründe, çevresel regülasyonlar ve toplumsal beklentiler doğrultusunda, lojistik operasyonların çevreye olan etkisinin minimize edilmesi gerekmektedir. Petrol depolama faaliyetlerinde de, karbon emisyonlarının azaltılması, enerji verimliliğinin artırılması ve çevre dostu uygulamaların benimsenmesi, lojistik servis sağlayıcılarının seçiminde göz önünde bulundurulması gereken önemli kriterler arasında yer almaktadır.

Akademik Literatürde Öne Çıkan Temel Kriter Grupları

Petrol depolama gibi tehlikeli madde sınıfları için kriterlerin şu şekilde kümelendiği görülmektedir:

- **Güvenlik ve Risk Yönetimi (En Yüksek Ağırlık):** Yangın emniyeti, acil durum müdahale kapasitesi, sızıntı tespit sistemleri ve HSE (Sağlık, Emniyet, Çevre) standartlarına uyum.
- **Operasyonel Yetkinlik:** Depolama kapasitesi, terminalin iskele/boru hattı bağlantıları, yükleme/boşaltma hızı ve operasyonel doğruluk.
- **Maliyet ve Finansal Yapı:** Depolama birim ücretleri, sigorta maliyetleri, finansal stabilite ve şeffaf maliyetlendirme modelleri.
- **Bilgi Teknolojileri ve İzlenebilirlik:** Gerçek zamanlı stok takibi, SCADA entegrasyonu ve ERP sistemleriyle uyumluluk.
- **Sürdürülebilirlik:** Emisyon yönetimi, atık su tasfiyesi ve "yeşil terminal" uygulamaları.

3. SONUÇ

Araştırma kapsamında elde edilen ampirik ve teorik bulgular bütünsel bir perspektifle değerlendirildiğinde; petrol depolama ekosisteminde lojistik servis sağlayıcılarının seçim sürecinin, salt finansal parametrelerin ötesinde multidisipliner bir mahiyet arz ettiği saptanmıştır. Sektörün yüksek riskli doğası ve stratejik önemi, seçim matrisinde; operasyonel yeterlilik, maliyet etkinliği, hizmet

kalitesi, zamanında teslimat (dakiklik), bütünleşik güvenlik protokolleri, bilgi teknolojileri yetkinliği, sektörel deneyim ile çevresel sürdürülebilirlik kriterlerinin birincil derecede belirleyici olduğunu ortaya koymaktadır.

Söz konusu kriterlerin, Çok Kriterli Karar Verme (ÇKKV) metodolojileri aracılığıyla sistematik bir analize tabi tutulması, karar vericilerin subjektif yargılardan arınarak rasyonel ve optimize edilmiş sonuçlara ulaşmasını sağlayacaktır. Sonuç olarak, bu parametrelerin hiyerarşik bir modelle ağırlıklandırılması ve titizlikle yönetilmesi; petrol depolama operasyonlarının operasyonel mükemmellik düzeyinde, yüksek güvenlik standartlarında ve çevresel sürdürülebilirlik ilkeleriyle uyumlu bir biçimde yürütülmesine stratejik bir zemin hazırlayacaktır. Bu yaklaşım, sadece kurumsal verimliliği artırmakla kalmayacak, aynı zamanda enerji değer zincirinin genel direncinin (resilience) güçlendirilmesine de kritik bir katkı sunacaktır.

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SİNİFDAXİLİ QARŞILIQLI ƏLAQƏ VƏ MƏDƏNİYYƏTLƏRARASI KOMMUNİKASİYA: UNİVERSİTETDƏ ALMAN DİLİ TƏDRİSİ KONTEKSTİNDƏ

IN-CLASS INTERACTION AND INTERCULTURAL COMMUNICATION: IN THE CONTEXT OF TEACHING GERMAN AT UNIVERSITY

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XÜLASƏ

Bu məqalədə universitet səviyyəsində Alman dili tədrisi prosesində sinifdaxili qarşılıqlı əlaqənin və mədəniyyətlərarası kommunikasiyanın rolu ətraflı şəkildə araşdırılır. Tədqiqatın əsas məqsədi müəllim–tələbə və tələbə–tələbə arasında qurulan qarşılıqlı əlaqələrin tələbələrin dil bacarıqlarının inkişafına, ünsiyyət səriştələrinin formalaşmasına və mədəni şüurun yüksəlməsinə təsirini müəyyənləşdirməkdir. Araşdırma çərçivəsində keyfiyyət və kəmiyyət tədqiqat metodlarının birgə tətbiqi həyata keçirilmiş, müşahidə, sorğu və təhlil üsullarından istifadə olunmuşdur. Əldə olunan nəticələr göstərir ki, dərs prosesində mədəniyyətlərarası kommunikasiya elementlərinin məqsədyönlü şəkildə inteqrasiyası tələbələrin öyrənmə motivasiyasını artırır, aktiv iştirakını təşviq edir və onların real ünsiyyət mühitinə uyğun dil bacarıqları qazanmasına şərait yaradır. Nəticə etibarilə, bu yanaşma xarici dil təliminin effektivliyinin yüksəldilməsinə, inklüziv və interaktiv tədris mühitinin formalaşmasına mühüm töhfə verir.

Açar sözlər: sinifdaxili qarşılıqlı əlaqə, mədəniyyətlərarası kommunikasiya, Alman dili tədrisi, xarici dil təlimi, inklüziv təhsil

ÖZET

Bu makalede üniversite düzeyinde Almanca öğretimi sürecinde sınıf içi etkileşim ve kültürlerarası iletişimin rolü ayrıntılı olarak incelenmektedir. Çalışmanın temel amacı, öğretmen–öğrenci ve öğrenci–öğrenci arasındaki etkileşimlerin öğrencilerin dil becerilerinin gelişimine, iletişim yeterliklerinin oluşmasına ve kültürel farkındalığın artmasına olan etkisini belirlemektir. Araştırmada nitel ve nicel araştırma yöntemlerinin bir arada kullanıldığı, gözlem, anket ve analiz tekniklerinden yararlanıldığı görülmektedir. Elde edilen bulgular, ders sürecine kültürlerarası iletişim unsurlarının bilinçli bir şekilde entegre edilmesinin öğrencilerin öğrenme motivasyonunu artırdığını, aktif katılımı teşvik ettiğini ve onların gerçek iletişim ortamlarına uygun dil becerileri kazanmalarına katkı sağladığını göstermektedir. Sonuç olarak, bu yaklaşım yabancı dil öğretiminin etkinliğini artırmaya, kapsayıcı ve etkileşimli bir öğrenme ortamının oluşmasına önemli katkı sunmaktadır.

Anahtar kelimeler: sınıf içi etkileşim, kültürlerarası iletişim, Almanca öğretimi, yabancı dil eğitimi, kapsayıcı eğitim

ABSTRACT

This article examines the role of classroom interaction and intercultural communication in the process of German language teaching at the university level. The primary aim of the study is to identify how teacher–student and student–student interactions influence the development of students' language skills, the formation of communicative competence, and the enhancement of intercultural awareness. The research employs a mixed-methods approach, combining qualitative and quantitative techniques such as observations, surveys, and data analysis. The findings indicate that the purposeful integration of intercultural communication elements into classroom instruction increases learners' motivation, encourages active participation, and supports the acquisition of language skills that are applicable to real communicative contexts. Consequently, this approach significantly contributes to improving the

effectiveness of foreign language education and fostering an inclusive and interactive learning environment.

Keywords: classroom interaction, intercultural communication, German language teaching, foreign language education, inclusive education

GİRİŞ

Qloballaşma prosesinin sürətlənməsi, beynəlxalq akademik əlaqələrin genişlənməsi və əmək bazarının tələblərinin dəyişməsi xarici dillərin öyrənilməsini müasir ali təhsilin prioritet istiqamətlərindən birinə çevirmişdir. Bu şəraitdə xarici dil tədrisi yalnız linqvistik biliklərin ötürülməsi ilə məhdudlaşmır, eyni zamanda tələbələrin mədəniyyətlərarası kommunikasiya bacarıqlarının formalaşdırılmasına yönəlir (Byram, 1997).

Alman dili Avropa və beynəlxalq akademik mühitdə mühüm yer tutduğuna görə onun tədrisi zamanı mədəni aspektlərin nəzərə alınması xüsusi aktuallıq kəsb edir. Dil və mədəniyyətin qarşılıqlı vəhdətdə öyrədilməsi tələbələrin dili sosial və mədəni kontekst daxilində mənimsəməsinə imkan yaradır (Kramsch, 1993). Bu baxımdan sinifdaxili qarşılıqlı əlaqə effektiv dil tədrisinin əsas mexanizmlərindən biri hesab olunur.

Azərbaycan dilçiliyində də xarici dil tədrisi və kommunikativ yanaşma məsələləri geniş şəkildə araşdırılmışdır. Yerli tədqiqatçılar sinifdaxili qarşılıqlı əlaqənin tələbələrin fəallığının artırılmasında və dil bacarıqlarının inkişafında mühüm rol oynadığını vurğulayırlar (Əliyev, 2015; Abdullayeva, 2018). Bu məqalədə universitet səviyyəsində Alman dili tədrisi kontekstində sinifdaxili qarşılıqlı əlaqə və mədəniyyətlərarası kommunikasiya məsələləri kompleks şəkildə təhlil edilir.

1. Sinifdaxili Qarşılıqlı Əlaqənin Nəzəri Əsasları

Sinifdaxili qarşılıqlı əlaqə müəllim və tələbələr arasında, eləcə də tələbələrin öz aralarında baş verən kommunikativ proseslərin məcmusudur. Kommunikativ yanaşmaya əsaslanan xarici dil tədrisində bu qarşılıqlı əlaqə mərkəzi rol oynayır. Bu yanaşma tələbələrin dili real ünsiyyət vasitəsi kimi istifadə etməsinə şərait yaradır (Richards & Rodgers, 2014).

Əliyev (2015) qeyd edir ki, tələbəyönümlü tədris modeli tələbələrin dil öyrənməyə marağını artırır və onların ünsiyyətə daxil olmasını asanlaşdırır. Sinifdə yaradılan açıq və təhlükəsiz mühit tələbələrin səhv etmək qorxusunu azaldır və dil öyrənmə prosesini daha effektiv edir.

2. Alman Dili Tədrisində Mədəniyyətlərarası Kommunikasiya

Mədəniyyətlərarası kommunikasiya fərqli mədəniyyətlərə məxsus şəxslər arasında qarşılıqlı anlaşmanı təmin edən bacarıqlar sistemidir. Xarici dil tədrisində bu anlayış dilin mədəni kontekstlə birlikdə öyrədilməsini nəzərdə tutur (Byram & Wagner, 2018).

Alman dili dərslərində Almaniya, Avstriya və İsveçrənin sosial dəyərləri, davranış normaları və gündəlik həyat tərzinə dair mövzuların müzakirəsi tələbələrin mədəni şüurunu inkişaf etdirir. Abdullayeva (2018) vurğulayır ki, mədəni komponentlərin dərs prosesinə inteqrasiyası tələbələrin dili daha dərindən mənimsəməsinə və mədəni empatiya bacarıqlarının formalaşmasına kömək edir.

3. Tədris Metodları və Sinif Təcrübəsi

Universitet səviyyəsində Alman dili tədrisində rol oyunları, qrup və cütlərlə iş, situativ tapşırıqlar, təqdimatlar və autentik mətnlərdən geniş istifadə olunur. Bu metodlar tələbələrin dərsdə fəal iştirakını təmin edir və onların dil bacarıqlarını praktik kontekstdə inkişaf etdirir (Littlewood, 2004).

Müəllimin fasilitator rolunda çıxış etməsi və tələbələri sərbəst fikir bildirməyə təşviq etməsi sinifdaxili qarşılıqlı əlaqənin intensivliyini artırır. Bu yanaşma xüsusilə müxtəlif mədəni fonlardan gələn tələbələrin dərsə adaptasiyasını asanlaşdırır.

4. Tədqiqat Metodologiyası və Nəticələrin Təhlili

Tədqiqat keyfiyyət və kəmiyyət metodlarının birgə tətbiqi əsasında aparılmışdır. Müşahidələr, sorğular və yarı-strukturlaşdırılmış müsahibələr vasitəsilə toplanan məlumatlar göstərir ki,

mədəniyyətlərarası kommunikasiya elementlərinin tətbiq olunduğu dərslərdə tələbələrin motivasiyası və ünsiyyət bacarıqları daha yüksək səviyyədə inkişaf edir.

Eyni zamanda, intensiv sinifdaxili qarşılıqlı əlaqə tələbələrin Alman dilində sərbəst danışmaq bacarığını artırır və onların mədəni biliklərinin zənginləşməsinə şərait yaradır.

Nəticə və Təkliflər

Aparılan təhlil göstərir ki, universitet səviyyəsində Alman dili tədrisində sinifdaxili qarşılıqlı əlaqə və mədəniyyətlərarası kommunikasiya dil öyrənmənin effektivliyini artıran əsas amillərdəndir. Bu baxımdan aşağıdakı təkliflər irəli sürülür:

- xarici dil müəllimləri üçün mədəniyyətlərarası kommunikasiya üzrə ixtisasartırma proqramlarının təşkili;
- kommunikativ və tələbəyönümlü tədris metodlarının sistemli tətbiqi;
- mədəni cəhətdən həssas və autentik tədris materiallarından istifadənin genişləndirilməsi;
- bu sahədə empirik tədqiqatların artırılması.

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EVALUATION OF THE ACTIVITY OF NISIN IN COMBINATION WITH ANTIBACTERIAL AND ANTIPARASITIC AGENTS AGAINST BACTERIA AND PARASITES

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ABSTRACT

This study evaluated the antimicrobial and antiparasitic activity of nisin A alone and in combination with different antibacterial and antiparasitic agents against various bacterial and parasitic species. Clinical isolates of *Staphylococcus aureus*, *Enterococcus faecalis*, *Enterococcus faecium*, *Escherichia coli*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa* and *Acinetobacter baumannii*, as well as *Leishmania tropica* and *Trichomonas vaginalis*, were included in the study.

The minimum inhibitory concentrations (MIC/IC_{50}) of nisin and the selected antimicrobial agents were determined using the microdilution method. Combination studies were performed by the checkerboard assay, and the interactions were evaluated based on the Fractional Inhibitory Concentration Index (FICI).

According to the results, the nisin–tigecycline combination exhibited a synergistic effect particularly against *Enterococcus faecalis* and some *Pseudomonas aeruginosa* clinical isolates. Partial synergistic interactions were predominantly observed in *Escherichia coli* and *Klebsiella pneumoniae* isolates, whereas limited interaction was detected in *Staphylococcus aureus*. In contrast, no significant synergistic effect was observed in *Acinetobacter baumannii* and *Enterococcus faecium* isolates. The nisin–gentamicin combination did not demonstrate synergistic activity in most of the tested isolates; however, synergistic effects were detected in some *Pseudomonas aeruginosa* isolates and partial synergy was observed in *Klebsiella pneumoniae*.

In antiparasitic evaluations, no activity was observed against *Leishmania tropica*. In contrast, assays conducted on *Trichomonas vaginalis* revealed that the antiparasitic activities of nisin and metronidazole increased in a time-dependent manner, with a significant reduction in IC_{50} and MPC values after 48 hours of incubation.

In conclusion, nisin may enhance antimicrobial activity against certain microorganisms when used in combination with specific antibiotics; however, this effect varies depending on the microorganism and the antimicrobial agent used. Although nisin shows potential as an adjunctive agent against multidrug-resistant pathogens, its synergistic activity cannot be generalized and should be evaluated individually for each microorganism–drug combination.

Key Words: Antimicrobial, Antiparasitic, bacteriocin, synergy

EVALUATION OF THE PHENOLIC CONTENT AND ANTIOXIDANT ACTIVITY OF ULTRASONIC BATH-ASSISTED 70% ETHANOLIC EXTRACT OF *Phlomis russeliana* Lag. ex Benth.

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ABSTRACT

Plants widely used in traditional medicine constitute important natural resources for the development of novel pharmaceutical agents. It is estimated that more than 15,000 plant species are utilized worldwide for therapeutic purposes, and their bioactive constituents represent a valuable potential for modern drug discovery (Atanasov et al., 2015). The genus *Phlomis* L. (Lamiaceae) comprises over 105 species distributed across Europe, Asia, and North Africa (Kondeva-Burdina et al., 2024). Previous studies have reported that *Phlomis russeliana* Lag. ex Benth. exhibits wound-healing, antibacterial, and anticancer activities (Okur et al., 2020; Alpay et al., 2019). In addition, its aerial parts are traditionally consumed as infusions to alleviate gastrointestinal disorders and to promote digestion. In the present study, the antioxidant capacity and phenolic composition of a 70% ethanolic extract obtained from the aerial parts of *P. russeliana* collected in Tokat Province (Türkiye) were investigated using ultrasonic bath-assisted extraction (UBAE). Total phenolic content (TPC) and total flavonoid content (TFC) were determined using the Folin–Ciocalteu (Singleton & Rossi, 1965) and aluminum chloride colorimetric methods (Zhishen et al., 1999), respectively. Antioxidant activity was evaluated by DPPH free radical scavenging (Blois, 1958) and ferric reducing antioxidant power (FRAP) assays (Thaipong et al., 2006). The extract exhibited a TPC of 69.57 mg GAE/g and a TFC of 45.30 mg QE/g extract. In the DPPH assay, the IC_{50} value was determined as 0.0344 mg/mL, while the FRAP value reached 345,33 mg TE/g extract. These findings indicate that *P. russeliana* is rich in phenolic and flavonoid compounds and displays considerable antioxidant capacity. Overall, ultrasonic bath-assisted extraction appears to be a suitable and efficient approach for the recovery of antioxidant-related bioactive compounds from *P. russeliana*.

Keywords: *Phlomis russeliana*, ultrasonic bath-assisted extraction, phenolic compounds, antioxidant activity

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WAR CORRESPONDENCE TRAINING AND JOURNALIST SAFETY IN TÜRKİYE
TÜRKİYE'DE SAVAŞ MUHABİRLİĞİ EĞİTİMİ VE GAZETECİ GÜVENLİĞİ

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ABSTRACT

Dünyada The recent intensification of conflicts and war environments worldwide has increased the physical, psychological, ethical, and digital risks faced by journalists, transforming war correspondence into a specialized field of journalism that requires specific expertise and structured training. In today's media environment, war correspondence stands out not only as a form of news production but also as a domain of professional practice grounded in competencies related to physical security, psychological resilience, ethical decision-making, and digital risk management. Despite this, academic studies focusing on war correspondence training in Türkiye remain limited. Aiming to address this gap and to examine the relationship between training and field practice, this study investigates the War Correspondence Courses organized by the Anadolu Agency News Academy since 2012 as an institutional example of war journalism training in Türkiye.

In the existing literature, war journalism training is predominantly examined through the lenses of journalist safety, trauma awareness, and ethical responsibility, with HEFAT-based training models and international journalist safety guidelines receiving particular attention. However, the ways in which this normative framework is translated into national-level institutional training programs have not been sufficiently explored.

This study adopts a qualitative research design and is based on in-depth interviews conducted with nine journalists who participated in the Anadolu Agency News Academy War Correspondence Courses and subsequently worked in conflict zones. The data were analyzed using thematic analysis. The findings indicate that participants were able to directly apply training related to personal safety, movement along frontlines, the use of ballistic protective equipment, water survival techniques, and basic first aid in the field. In contrast, topics such as coping with psychological trauma, long-term stress management, communication with local communities, cultural sensitivity, gender-based risks, and digital security received limited attention within the training program. Some participants also noted that editorial guidance was insufficient when addressing ethical dilemmas encountered in the field and decision-making processes related to visual content production.

Overall, the findings demonstrate that the Anadolu Agency News Academy War Correspondence Courses offer a practice-oriented, functional model that is largely aligned with international standards. Nevertheless, the results suggest that, in response to evolving warfare dynamics and increasingly digitalized conflict environments, the curriculum should be further developed to incorporate a stronger psychological dimension, greater gender sensitivity, and a more comprehensive approach to digital risks.

Key Words: War Reporting; Journalist Safety; Media Training; Anadolu Agency

ÖZET

Dünyada son dönemde yoğunlaşan çatışma ve savaş ortamlarında gazetecilerin karşı karşıya kaldığı fiziksel, psikolojik, etik ve dijital risklerin artması, savaş muhabirliğini özel uzmanlık ve yapılandırılmış eğitim gerektiren bir gazetecilik alanı haline getirmiştir. Savaş muhabirliği, günümüz medya ortamında, yalnızca haber üretimine değil, fiziksel güvenlik, psikolojik dayanıklılık, etik karar alma ve dijital risk yönetimine ilişkin özel yeterliliklere dayanan bir uzmanlık alanı olarak öne çıkmaktadır. Buna karşın, Türkiye'de savaş muhabirliği eğitimine odaklanan akademik çalışmaların sınırlı olduğu görülmektedir. Söz konusu boşluğu doldurmayı ve eğitim ile saha pratiği arasındaki ilişkiyi ortaya koymayı amaçlayan bu çalışma, Türkiye'de savaş muhabirliği eğitiminin kurumsal bir örneği olarak Anadolu Ajansı Haber Akademisi tarafından 2012 yılından itibaren düzenlenen Savaş Muhabirliği Kurslarını incelemektedir.

Literatürde savaş muhabirliği eğitimi çoğunlukla gazeteci güvenliği, travma farkındalığı ve etik sorumluluklar ekseninde ele alınmakta, uluslararası alanda HEFAT temelli eğitim modelleri ve gazeteci güvenliğine ilişkin kılavuzlar öne çıkmaktadır. Ancak bu normatif çerçevenin ulusal düzeydeki kurumsal eğitim programlarına nasıl yansıdığı yeterince tartışılmamıştır.

Araştırma, nitel araştırma yaklaşımıyla tasarlanmış, Anadolu Ajansı Haber Akademisi Savaş Muhabirliği Kurslarına katılmış ve çatışma bölgelerinde görev yapmış dokuz gazeteciyle derinlemesine görüşmeler gerçekleştirilmiştir. Veriler tematik analiz yöntemiyle çözümlenmiştir. Bulgular, katılımcıların özellikle kişisel güvenlik, çatışma hattında hareket etme, kurşun geçirmez ekipman kullanımı, suda hayatta kalma ve temel ilk yardım eğitimlerini sahada doğrudan uygulayabildiklerini ortaya koymaktadır. Buna karşılık, psikolojik travma ile baş etme, uzun süreli stres yönetimi, yerel halkla iletişim, kültürel hassasiyetler, cinsiyet temelli riskler ve dijital güvenlik başlıklarının eğitim programında sınırlı yer tuttuğu tespit edilmiştir. Bazı katılımcılar, sahada karşılaşılan etik ikilemler ve görsel içerik üretimine ilişkin karar süreçlerinde editoryal rehberliğin yetersiz kaldığını ifade etmiştir.

Araştırma bulguları, Anadolu Ajansı Haber Akademisi Savaş Muhabirliği Kurslarının uluslararası standartlarla büyük ölçüde uyumlu, uygulama ağırlıklı ve işlevsel bir model sunduğunu, ancak değişen savaş dinamikleri ve dijitalleşen çatışma ortamları karşısında müfredatın daha psikoloji temelli, cinsiyet duyarlı ve dijital riskleri kapsayan bir yapıya kavuşturulması gerektiğini göstermektedir.

Anahtar Kelimeler: Savaş Muhabirliği; Gazeteci Güvenliği; Medya Eğitimi; Anadolu Ajansı

STRUCTURAL OPTICAL AND PHOTOCATALYTIC PROPERTIES OF SNS THIN FILMS

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ABSTRACT

In this study, SnS thin films were deposited onto glass substrates at 350 °C using the sol–gel dip-coating method and subsequently annealed at 400 °C. The surface morphology and compositional properties of the resulting SnS thin films were systematically investigated using scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDS). SEM images of the SnS thin films annealed at 400 °C reveal pronounced grain growth with a partially compact morphology. The grains exhibit a heterogeneous size distribution ranging from sub micrometer to micrometer scales, with noticeable voids and surface roughness observed between the grains. The presence and uniform distribution of Sn and S elements were confirmed by EDS and elemental mapping analyses. UV–Vis measurements indicated an increase in absorbance intensity and optical band gap as the number of coatings increased from 3 to 7. Photocatalytic tests demonstrated that SnS is a promising candidate for the removal of textile wastewater. Overall, the results indicate the absence of secondary phase formation, improved chemical homogeneity, and a near-stoichiometric composition, highlighting the potential of SnS thin films for the remediation of textile wastewater.

Keywords: SnS thin film, Sol-gel dip-coating method, Surface morphology, Structural and compositional analysis, Photocatalytic analysis.

INTRODUCTION

The increasing discharge of untreated textile wastewater into natural water bodies has become a major environmental concern due to its high content of persistent dyes, toxic organic compounds, and heavy metals. These pollutants not only reduce light penetration and dissolved oxygen levels in aquatic ecosystems but also pose significant risks to human health (Yaseen & Scholz, 2019). Conventional treatment methods such as coagulation, adsorption, and biological processes often suffer from limited efficiency, high operational costs, or secondary pollution problems. Consequently, there is a growing interest in developing cost-effective, stable, and environmentally friendly semiconductor materials for photocatalytic wastewater remediation (Katheresan et al., 2018).

Tin(II) sulfide (SnS) has emerged as a promising candidate among metal chalcogenides due to its suitable band gap, high absorption coefficient in the visible region, low toxicity, and earth-abundant constituents. SnS is a p-type semiconductor with an optical band gap typically ranging between 1.3 and 1.7 eV, making it attractive for optoelectronic and photocatalytic applications (Sinsermsuksakul et al., 2015). In recent years, SnS thin films have been extensively investigated for solar cells, photodetectors, and environmental applications owing to their favorable electronic structure and chemical stability (Reddy et al., 2015). The photocatalytic performance of SnS is strongly influenced by its microstructure, surface morphology, crystallinity, and stoichiometry, which are, in turn, governed by the synthesis technique and post-deposition treatment conditions.

Among various fabrication techniques, the sol–gel dip-coating method offers several advantages, including low cost, compositional control, uniform coating over large areas, and precise thickness adjustment through repeated coating cycles (Brinker & Scherer, 1990). Post-deposition annealing plays a critical role in enhancing grain growth, improving crystallinity, and eliminating residual organic components, thereby directly affecting the optical and photocatalytic properties of the films. In

particular, annealing temperature significantly influences surface morphology, grain size distribution, and chemical homogeneity, which are essential parameters for efficient charge separation and light absorption (Salwa et al., 2021).

Characterization techniques such as SEM and EDS are widely used to evaluate surface morphology and elemental composition. A compact and homogeneous morphology with near-stoichiometric Sn and S distribution is crucial to prevent secondary phase formation and recombination centers that could deteriorate photocatalytic efficiency. In addition, UV–Vis spectroscopy provides valuable information about optical absorbance and band gap energy, both of which are key factors in determining photocatalytic activity under visible light irradiation (Yaseen & Scholz, 2019). In this context, the present study focuses on the deposition of SnS thin films on glass substrates via the sol–gel dip-coating method at 350 °C, followed by annealing at 400 °C. The surface morphology, compositional uniformity, optical properties, and photocatalytic performance of the films are systematically examined. By correlating structural and optical characteristics with photocatalytic activity, this work aims to evaluate the suitability of SnS thin films as an efficient and environmentally sustainable material for the remediation of textile wastewater.

CONCEPTUAL FRAMEWORK

Overview

This conceptual framework describes the relationships between fabrication parameters, structural characteristics, surface morphology, optical properties, and photocatalytic performance of SnS thin films produced by the sol–gel dip-coating method. It is based on established thin-film growth principles and aims to guide the systematic optimization of SnS layers for textile wastewater remediation using earth-abundant and environmentally friendly materials. In this framework, key fabrication parameters such as precursor concentration, number of coating cycles, deposition temperature, and annealing conditions directly influence crystallinity, grain growth, phase purity, and stoichiometry. Annealing promotes grain coalescence and improves chemical homogeneity, while the number of coatings controls film thickness and light absorption.

These structural and compositional features determine surface morphology, defect density, and optical band gap, which in turn affect charge carrier generation and separation under visible light. Improved crystallinity, near-stoichiometric composition, and controlled morphology enhance photocatalytic activity. Overall, the framework establishes a clear link between processing conditions and functional performance, supporting the rational design of efficient SnS-based photocatalysts.

Fabrication Parameters

The sol–gel dip-coating method forms the central fabrication route for SnS thin films, where precursor solution composition, withdrawal speed, and the number of coating cycles control the initial film thickness, surface coverage, and compositional uniformity. Increasing the number of coatings directly enhances film thickness and optical absorbance, influencing light-harvesting capability. Subsequent thermal treatment, particularly annealing at 400 °C, serves as the primary control parameter governing crystallization, grain growth, and chemical homogeneity. Annealing promotes atomic diffusion and grain coalescence, reduces residual organics, and supports the formation of single-phase SnS while minimizing secondary phases. At the same time, it influences defect density, stoichiometric balance (Sn/S ratio), and surface morphology, which collectively determine optical band gap, charge carrier behavior, and ultimately photocatalytic performance in textile wastewater treatment applications.

Structural Properties

The structural characteristics of SnS thin films are primarily governed by the crystallization process during annealing. Adequate thermal treatment, particularly at 400 °C, promotes the formation of single-phase orthorhombic SnS while suppressing undesirable secondary phases such as SnS_2 or Sn_2S_3. Enhanced crystallinity is typically associated with increased grain size, reduced lattice defects, and improved structural ordering. Improved structural quality directly supports more efficient charge transport by reducing grain boundary scattering and minimizing defect-related recombination, which is essential for enhanced optical absorption and photocatalytic performance.

Compositional Characteristics

The chemical composition of SnS thin films is controlled by precursor stoichiometry and annealing conditions. Maintaining a near-stoichiometric Sn/S ratio is essential for achieving phase-pure SnS with stable semiconductor behavior. Elemental homogeneity across the film surface and thickness prevents local band gap variations and secondary phase formation. Annealing at appropriate temperatures enhances elemental diffusion and improves chemical uniformity, whereas excessively high temperatures may lead to sulfur loss due to its volatile nature. Surface morphology develops through nucleation and grain growth during thermal treatment. Optimized annealing at 400 °C promotes grain coalescence, resulting in partially compact and interconnected grains with moderate surface roughness. Such morphological uniformity enhances light absorption and provides sufficient active surface sites for photocatalytic reactions. In contrast, excessive voids or highly irregular surfaces may increase defect density and hinder charge transport, negatively affecting photocatalytic efficiency in textile wastewater treatment applications.

Optical Properties

The optical properties of sol–gel-derived SnS thin films are closely related to their structural integrity and compositional uniformity. As a direct band gap semiconductor, SnS exhibits strong absorption in the visible region, making it suitable for photocatalytic applications. Improved crystallinity and near-stoichiometric Sn/S composition contribute to a well-defined optical band gap and enhanced absorbance intensity. Grain growth and reduced defect density minimize localized states within the band structure, leading to sharper absorption edges and reduced sub-band-gap absorption. Increasing film thickness through additional coating cycles further enhances light absorption capacity. Consequently, improved structural ordering and chemical homogeneity promote more efficient photon absorption and generation of charge carriers, which are critical for enhanced photocatalytic activity in textile wastewater treatment.

Interrelationships and Optimization Pathway

This framework emphasizes the interdependent nature of processing parameters and material properties. Annealing temperature acts as a central node influencing structure, composition, morphology, and electrical performance. Structural improvement enhances electrical transport, while compositional control ensures phase stability and defect regulation. Surface morphology serves as a bridge between bulk material quality and functional device integration.

Conceptual Outcome

This framework highlights the interdependent relationship between processing parameters and the resulting optical and functional properties of SnS thin films. Annealing temperature serves as the central control factor, influencing crystallinity, phase purity, compositional uniformity, and surface morphology. Structural improvement enhances light absorption and sharpens the optical band edge, while proper stoichiometric control ensures phase stability and minimizes defect-related absorption states. Surface morphology acts as a key link between bulk material quality and photocatalytic performance, as grain structure and surface uniformity directly affect photon interaction and the generation of charge carriers under visible light irradiation.

METHODOLOGY

Experimental

SnS thin films were deposited onto glass substrates using a computer-controlled sol–gel dip-coating system. All chemicals were of analytical grade and used without further purification. The precursor solution was prepared using 0.1 M tin(II) chloride dihydrate ($SnCl_2 \cdot 2H_2O$) as the tin source and 0.1 M thiourea ($CS(NH_2)_2$) as the sulfur source. An ethanol and glacial acetic acid (GAA) mixture was employed as the solvent, with a molar ratio of 1:10. The solution was magnetically stirred until a clear and homogeneous sol was obtained. Prior to deposition, glass substrates were ultrasonically cleaned in deionized water and acetone, dried in air, and further treated by heating in ambient atmosphere to remove residual contaminants. The precursor solution was deposited onto the heated glass substrates at 350 °C under ambient conditions using the dip-coating technique. The number of coating cycles was varied (3–

7 cycles) to control film thickness. After deposition, the films were annealed at 400 °C for 1 hour to promote crystallization, enhance grain growth, and improve chemical homogeneity.

Characterization Tools

The crystalline structure and possible secondary phases of the SnS thin films were analyzed by X-ray diffraction (XRD) using a Rigaku Ultima III diffractometer operated at 40 kV and 40 mA with Cu Kα radiation (λ = 1.54 Å). Surface morphology and grain distribution were examined using scanning electron microscopy (SEM, Zeiss EVO 50). The elemental composition and spatial uniformity of Sn and S were further evaluated by energy-dispersive X-ray spectroscopy (EDS) combined with elemental mapping analysis. Optical properties and photocatalytic performance were investigated using a UV–Vis spectrophotometer (PerkinElmer Lambda 45).

CONCLUSION AND DISCUSSION

SEM and EDX measurements

The SEM image of the SnS thin film annealed at 400 °C reveals pronounced grain growth with a partially compact surface morphology. The film consists of agglomerated grains exhibiting a heterogeneous size distribution ranging from submicrometer to micrometer scales. The surface appears generally continuous and free of large cracks; however, localized voids and noticeable surface roughness are observed between adjacent grains. These observations indicate that annealing effectively promotes crystallization and grain coalescence, although complete densification of the film has not been fully achieved. The SEM micrograph obtained at high magnification (5,00 KX) confirms the polycrystalline nature of the SnS layer, composed of irregularly shaped grain clusters forming a relatively compact network. Grain sizes extending from several hundred nanometers to the micrometer range are consistent with SnS thin films prepared by solution-based deposition methods. The presence of loosely packed regions and void-like structures may result from incomplete grain fusion during annealing. Such morphological imperfections can introduce defect sites that influence light absorption behavior and charge carrier dynamics, potentially affecting the overall photocatalytic efficiency of the SnS thin films.

The EDX spectrum presented in Figure 2(a) shows well-defined characteristic X-ray peaks corresponding to Sn and S, confirming the formation of an SnS-based thin film. Quantitative analysis obtained from the selected region indicates that the film composition is close to the expected Sn/S (52.81/47.19) ratio, suggesting near-stoichiometric SnS formation. The absence of additional elemental peaks supports the purity of the deposited layer and indicates no detectable secondary phases within the measurement limits.

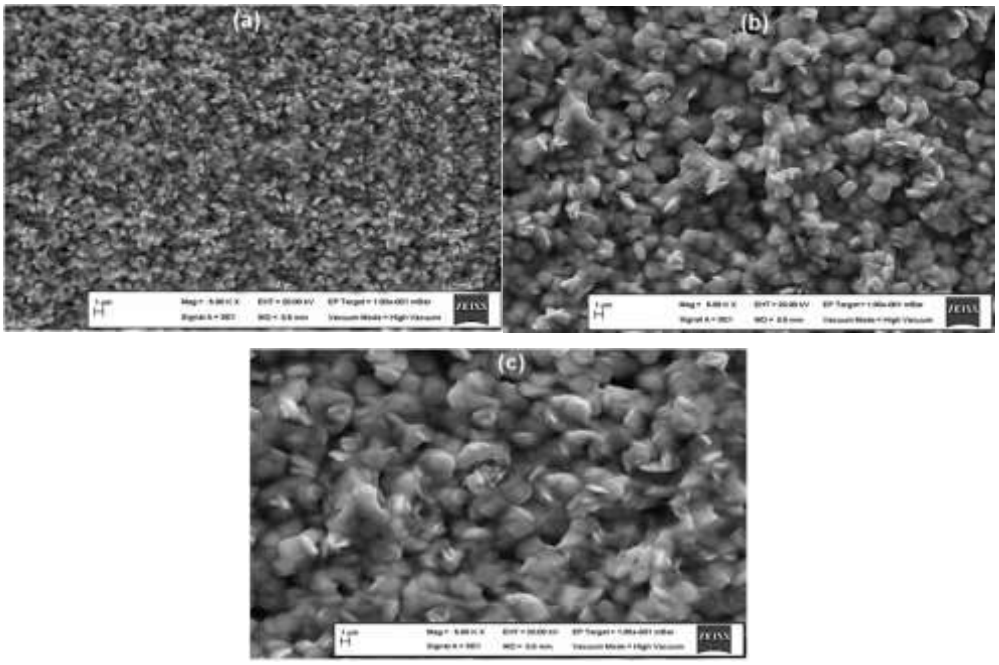


Figure 1: SEM image of the SnS thin film prepared for different coating cycles: (a) 3, (b) 5 and (c) 7.

It should be noted that EDS results are inherently semi-quantitative and must be interpreted carefully. The relatively high accelerating voltage used during measurement increases the electron–material interaction volume, meaning that the detected signal represents an average composition over a certain depth rather than a purely surface-sensitive analysis. Furthermore, light elements such as sulfur may be underestimated due to X-ray absorption effects and lower detector sensitivity at low energies. Despite these limitations, the EDS results confirm the presence and uniform distribution of Sn and S elements, consistent with the formation of chemically homogeneous SnS thin films.

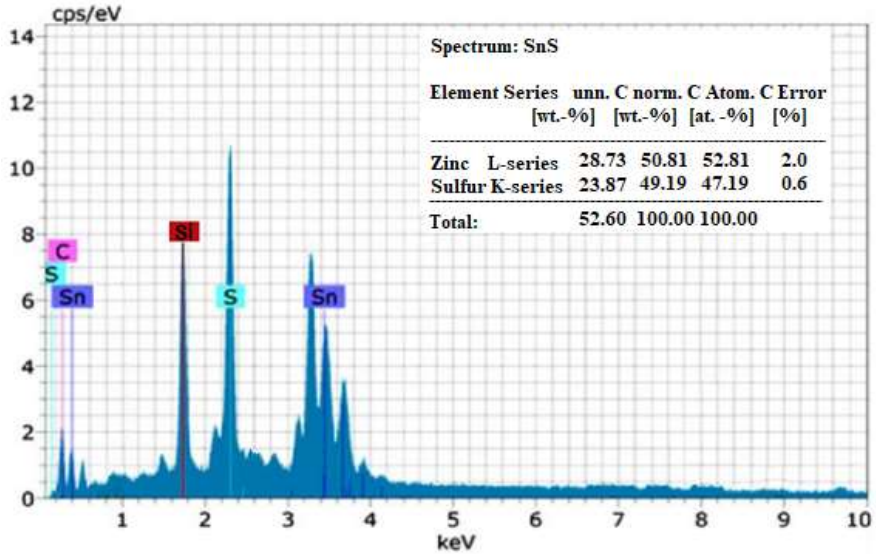


Figure 2: EDX elemental analysis of the SnS thin film.

XRD analyses

The structural properties of the SnS thin film were examined by X-ray diffraction (XRD) analysis over a 2θ range of 10°–70°. The XRD pattern shows distinct diffraction peaks corresponding to the orthorhombic SnS phase, consistent with standard reference data. In Figure 3, the diffraction planes of the (021), (101), (040), (041), and (160), can be indexed for the orthorhombic of SnS crystalline (JCPDS card no: 00-039-0354) have observed. In addition, no trace of the Zn, ZnS, or any secondary phases/impurities can be found in the XRD analysis. The dominant reflections can be indexed to characteristic crystallographic planes of SnS, confirming the formation of a single-phase structure without detectable secondary phases such as SnS_2 or Sn_2S_3. Slight shifts in peak positions may be attributed to lattice strain, grain growth effects, or residual stress induced during annealing at 400 °C.

The relatively strong diffraction peak intensities indicate improved crystallization under the applied deposition and annealing conditions. The enhancement in peak sharpness suggests increased grain size and reduced structural disorder, which are typical outcomes of effective thermal treatment in sol–gel-derived films. No significant impurity-related peaks were observed within the detection limits of the measurement, supporting the compositional uniformity of the SnS thin films. These structural findings are consistent with the SEM and EDX results, confirming that annealing promotes phase purity, crystallinity, and overall structural quality.

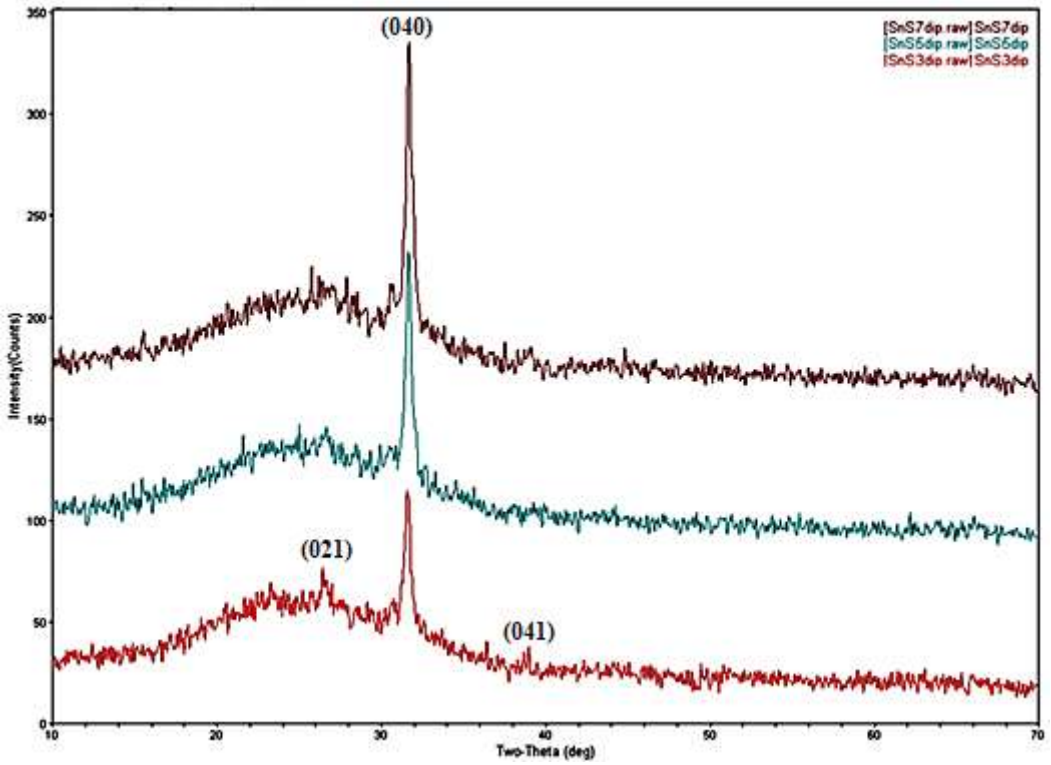


Figure 3: XRD analysis of the SnS thin film prepared for different coating cycles (3-7).

UV-Vis Measurements

The UV–Vis absorption spectra of the SnS thin films coated three, five, and seven times demonstrate a clear dependence of optical behavior on the number of coating cycles (Figure. All samples exhibit strong absorption in the ultraviolet region (around 300–350 nm), followed by a gradual decrease in intensity toward the visible and near-infrared regions (400–900 nm). This trend is consistent with the characteristic optical response of SnS, a direct band gap semiconductor with strong absorption in the visible region due to its high absorption coefficient (Goktas et al., 2022). A systematic increase in absorbance intensity is observed as the number of coating cycles increases from three to seven. The film coated seven times exhibits the highest absorbance across the entire measured wavelength range, while the three-times-coated film shows the lowest intensity. This behavior can be directly attributed to the increase in film thickness with additional coating cycles. Thicker films provide a longer optical path length and enhanced photon–matter interaction, resulting in greater light absorption (Arslan, 2019). The relatively stable absorbance profile in the visible region suggests uniform film formation without abrupt optical scattering losses, which supports the SEM observations of a largely continuous morphology.

Importantly, the absence of irregular fluctuations or unexpected absorption features indicates good compositional homogeneity and minimal secondary phase formation. The gradual absorption edge behavior is typical for polycrystalline SnS thin films prepared by solution-based techniques, where slight band tailing may occur due to localized defect states (Aslan et al., 2022). Overall, the results confirm that increasing the number of coating cycles effectively enhances light-harvesting capability, which is a critical factor for improving photocatalytic performance in textile wastewater treatment applications.

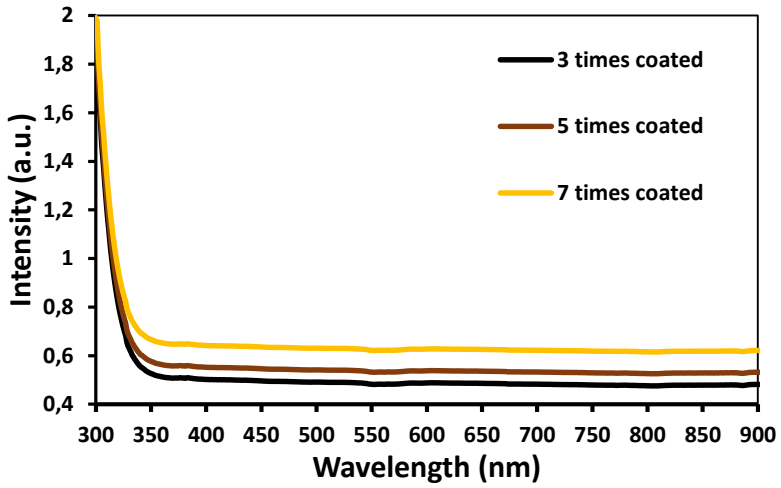


Figure 4: UV-Vis absorbance of the SnS thin film prepared for different coating cycles (3-7).

The Tauc plots presented for the SnS thin films coated three, five, and seven times illustrate the variation of the optical band gap with increasing coating cycles (Figure 5). The graphs were constructed by plotting $(\alpha h\nu)^2$ versus photon energy ($h\nu$), consistent with the assumption of a direct allowed transition, which is widely reported for SnS thin films (Arslan et al., 2019). The linear regions observed near the absorption edge confirm the direct band gap nature of the deposited films. Extrapolation of the linear portion of each curve to the energy axis indicates a slight increase in the optical band gap as the number of coating cycles increases. The three-times-coated film exhibits the lowest band gap value, while the seven-times-coated film shows the highest. This trend may be attributed to improvements in crystallinity and compositional homogeneity with additional coating and subsequent annealing. Enhanced structural ordering can reduce defect-related band tailing and localized states near the band edges, resulting in a sharper absorption edge and a marginal widening of the apparent optical band gap (Voznyi et al., 2018). Furthermore, increased film thickness can influence light absorption behavior and optical transition probability, contributing to the observed differences in the Tauc plots. The relatively smooth and well-defined linear regions suggest minimal secondary phase contribution, supporting the XRD and EDS findings of phase-pure SnS. Overall, the results demonstrate that the number of coating cycles plays a significant role in tuning the optical band gap, which is a critical parameter for optimizing light absorption and enhancing photocatalytic efficiency.

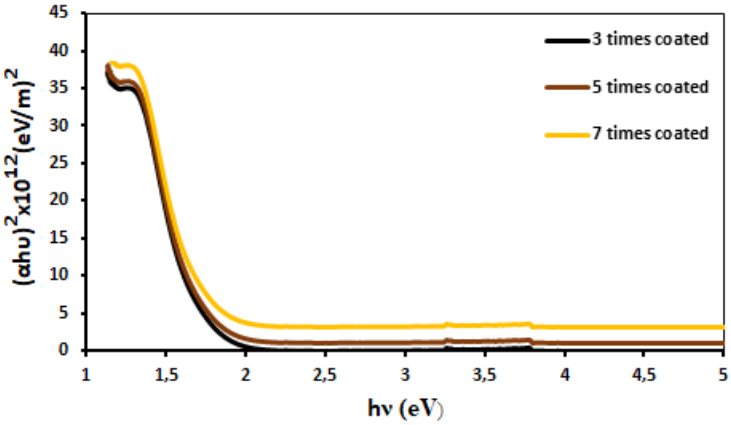
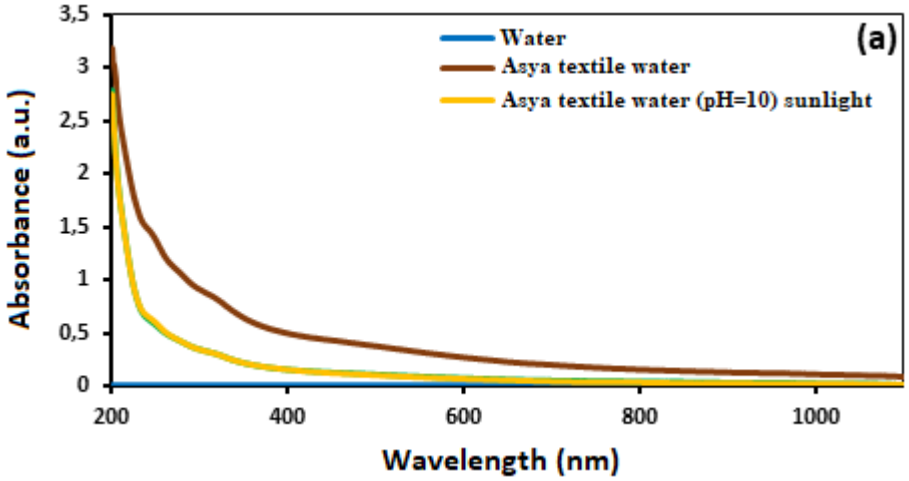


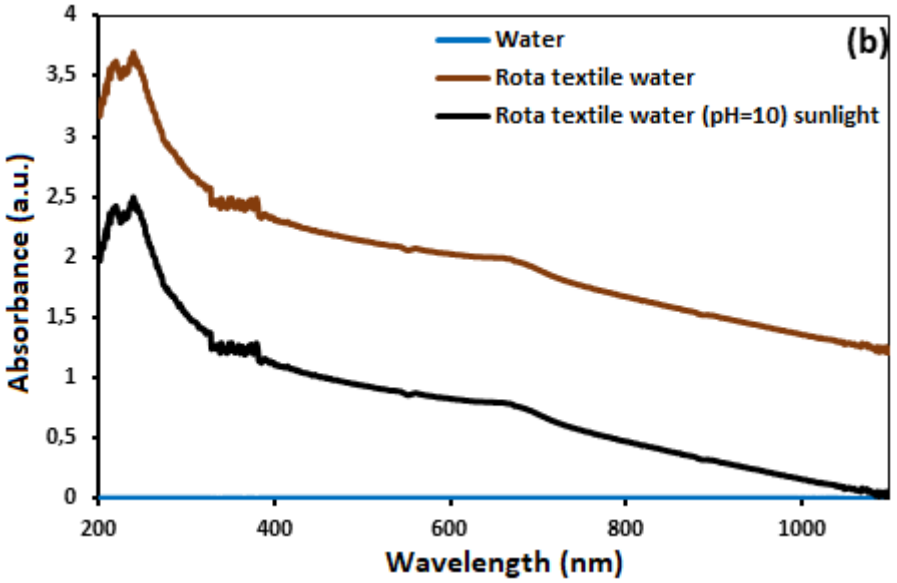
Figure 5: Tauc plots of (αhν)2 versus hν for SnS thin films coated three, five, and seven times and annealed at 400 °C.

Photocatalytic Measurements

To evaluate the photocatalytic performance of the SnS thin films for textile wastewater remediation, real textile wastewater was used as the target pollutant under natural solar irradiation. The experiments were carried out at pH 10, adjusted to provide alkaline conditions favorable for hydroxyl radical formation, which is known to enhance oxidative degradation processes in semiconductor-based

photocatalysis (Chong et al., 2010). The SnS photocatalysts were employed in immobilized thin-film form on glass substrates rather than as suspended powders, ensuring ease of recovery and practical applicability for wastewater treatment systems. Prior to solar exposure, the wastewater solution containing the SnS-coated substrates was kept in the dark for 30 minutes to establish adsorption–desorption equilibrium between the pollutant molecules and the catalyst surface. The photocatalytic experiments were conducted under direct sunlight for a total duration of 48 hours at ambient temperature.





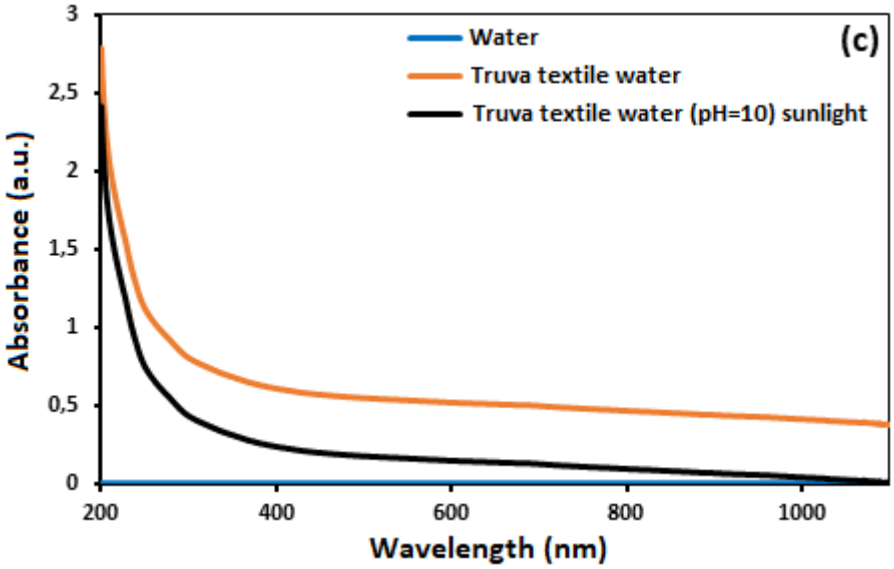


Figure 6: Absorbance spectra of the various textile wastewater (a) Asya, (b) Rota and (c) Truva after and before photocatalytic degradation by SnS photocatalysts under sunlight radiation.

The degradation efficiency was determined from the change in absorbance of the wastewater sample using:

$$Degradation\ efficiency=[(C-C_0/C_0)]\ x\ 100$$

where C_0 and C are the absorbance value of wastewater at the any characteristic wavelength, between 200 and 1100 nm, before and after exposure to sun light radiation, respectively (Goktas, 2022).

Under visible-light-rich solar irradiation, SnS being a narrow band gap semiconductor (≈1.3–1.5 eV) can efficiently absorb photons and generate electron–hole pairs (Andrade-Arvizu et al., 2015). The photogenerated electrons in the conduction band react with dissolved oxygen to form superoxide radicals ($\cdot O_2^-$), while the holes in the valence band oxidize surface hydroxide ions (OH^-) or water molecules to generate hydroxyl radicals (·OH). These reactive oxygen species (ROS) play a dominant role in the oxidative decomposition of complex organic compounds present in textile effluents, ultimately leading to their mineralization into simpler, less harmful products (Göktaş, 2024; Chong et al., 2010).

The observed degradation over 48 hours demonstrates that immobilized SnS thin films can effectively utilize solar energy for the treatment of real textile wastewater. The results highlight the potential of SnS as a cost-effective and environmentally sustainable photocatalyst, particularly due to its visible-light responsiveness and suitability for large-area thin-film configurations. Figs. 6 (a–c) present the UV–Vis absorption spectra of three different real textile wastewater samples (Asya, Rota, and Truva companies in Turkey) before and after photocatalytic treatment with SnS thin films under solar irradiation at pH = 10. In all cases, a clear decrease in absorbance intensity is observed across the UV–visible region after 48 hours of sunlight exposure, indicating the degradation of colored organic compounds present in the effluents.

For the Asya textile wastewater (Figure a), the absorbance in the 200–400 nm region decreases markedly after treatment. Based on the relative reduction in peak intensity (at 305 nm) the degradation efficiency is estimated to be approximately 60 at. %. The Rota company textile wastewater (Figure b) exhibits a more gradual but still significant decline in absorbance over the entire spectral range (200–1100 nm, especially at 668 nm), corresponding to an estimated degradation efficiency of about 72 at. %. In contrast, the Truva company textile wastewater (Figure c) shows the most pronounced reduction in absorbance, particularly in the UV region (at 731 nm) suggesting a higher degradation efficiency of roughly 80 at. %.

The observed decrease in absorbance can be attributed to the photocatalytic activity of SnS under solar irradiation. Due to its narrow band gap (≈1.6–1.75 eV), SnS can effectively utilize visible light to

generate electron–hole pairs (Andrade-Arvizu et al., 2015). The photogenerated electrons react with dissolved oxygen to produce superoxide radicals ($\cdot O_2^-$), while the holes oxidize hydroxide ions (OH^-) at alkaline pH to form hydroxyl radicals (·OH). These reactive oxygen species are primarily responsible for the oxidative breakdown of complex dye molecules and other organic contaminants in textile wastewater (Andrade-Arvizu et al. 2015). The alkaline condition (pH = 10) likely enhances hydroxyl radical formation, thereby improving overall degradation performance.

Although no control experiment was conducted, the consistent reduction in absorbance under solar exposure in the presence of SnS thin films strongly indicates photocatalytic-driven degradation rather than simple photolysis. The variation in efficiency among the three wastewater samples may be attributed to differences in initial dye composition, pollutant concentration, and chemical complexity.

Overall, the results demonstrate that immobilized SnS thin films can effectively harness solar energy for the treatment of real textile effluents, achieving estimated degradation efficiencies between approximately 60% and 85% after 48 hours of irradiation. These findings support the potential of SnS as a visible-light-active and environmentally sustainable photocatalyst.

Conclusions

In conclusions, SnS thin films were similarly prepared by the sol–gel dip-coating method and annealed at 400 °C, resulting in polycrystalline, phase-pure orthorhombic SnS with improved grain growth and near-stoichiometric composition. As demonstrated by UV–Vis measurements, increasing the number of coating cycles enhanced light absorption in the visible region, which is particularly advantageous for solar-driven photocatalysis given the narrow band gap of SnS (≈1.6–1.75 eV). Photocatalytic tests performed on three different real textile wastewater samples (Asya, Rota, and Truva) under natural sunlight at pH 10 revealed substantial reductions in absorbance intensity after 48 hours. Based on the characteristic absorbance decreases shown in Figure 6, the degradation efficiencies were estimated to be approximately 60% for Asya, 72% for Rota, and 80% for Truva company textile wastewater. These values are comparable to, and in some cases approach, the higher efficiencies reported for doped ZnS systems under UV irradiation. The enhanced degradation observed for certain samples may be associated with improved visible-light absorption of SnS and favorable surface morphology that facilitates interfacial redox reactions.

Mechanistically, upon solar illumination, SnS generates electron–hole pairs; conduction band electrons reduce dissolved oxygen to form superoxide radicals ($\cdot O_2^-$), while valence band holes oxidize hydroxide ions (OH^-) at alkaline pH to produce hydroxyl radicals (·OH). These reactive oxygen species are responsible for the oxidative breakdown of complex dye molecules and organic contaminants in textile effluents. The alkaline condition (pH=10) likely enhances ·OH formation, thereby contributing to the observed degradation efficiencies. Consistent with structure–activity relationships reported in the literature, photocatalytic performance in SnS thin films is strongly influenced by crystallinity, grain morphology, and optical absorption properties. While no control experiments were conducted, the systematic decrease in absorbance under solar irradiation in the presence of SnS films indicates effective photocatalytic degradation rather than mere photolysis.

Overall, the present SnS thin films demonstrate significant photocatalytic potential. Their strong visible-light response, phase purity, and thin-film configuration make them promising candidates for sustainable solar-driven textile wastewater remediation.

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PHOTOCATALYTIC PROPERTIES OF SNS THIN FILMS: ROLE OF OPERATIONAL PARAMETERS-A MINI REVIEW

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ABSTRACT

Tin(II) sulfide (SnS) thin films have attracted increasing attention as photocatalytic materials due to their narrow band gap, high optical absorption in the visible region, earth-abundant constituents, and low toxicity. This mini review summarizes recent studies on the photocatalytic properties of SnS thin films with a particular focus on the role of operational parameters influencing their performance. Key factors such as film thickness, crystallinity, surface morphology, light source characteristics, solution pH, catalyst loading, and initial pollutant concentration are critically discussed. The influence of deposition techniques and post-deposition treatments on structural and optoelectronic properties, which directly affect charge carrier generation and recombination, is also highlighted. In addition, the impact of operational conditions on photocatalytic efficiency and stability during degradation reactions is evaluated based on reported experimental trends. Understanding the interplay between material properties and operational parameters is essential for optimizing the photocatalytic activity of SnS thin films. This review aims to provide a concise and coherent overview that may guide future experimental design and support the development of efficient SnS-based photocatalytic systems for environmental and energy-related applications.

Keywords: SnS thin films; Photocatalysis; Operational parameters; Visible light activity; Thin film deposition; Environmental remediation.

INTRODUCTION

Tin(II) sulfide (SnS) is an emerging semiconductor material with significant potential in photocatalytic applications due to its narrow band gap and strong absorption in the visible range of the electromagnetic spectrum. In thin-film form, SnS exhibits an orthorhombic crystal structure and is typically p-type, characteristics that influence its optoelectronic and photocatalytic behavior (Aparna et al., 2023). The band gap of SnS thin films is reported to lie in the range of approximately 1.3–1.6 eV, making it capable of harvesting visible light efficiently for photocatalytic reactions, such as the degradation of organic contaminants (Ding et al., 2025). Photocatalysis with SnS thin films relies on the generation of electron–hole pairs upon light absorption and their subsequent participation in redox reactions at the catalyst surface. Under visible light, these charge carriers can interact with adsorbed species such as oxygen and water to produce reactive oxygen species (ROS), including hydroxyl radicals (•OH) and superoxide anions ($O2^{-}$•), which are responsible for degrading organic pollutants in aqueous environments. However, the efficiency of this process is strongly dependent on operational parameters such as film crystallinity, morphology, stoichiometry, and thickness. For instance, non-stoichiometric SnS films with optimized crystallinity show enhanced dye degradation performance due to improved charge separation and increased surface active sites. The method of deposition also plays a crucial role in determining film quality. SnS thin films have been successfully synthesized using various techniques including Successive Layer Adsorption and Reaction (SILAR) at room temperature, which yields uniform polycrystalline films with effective visible-light photocatalytic activity for methylene blue degradation following a Langmuir–Hinshelwood kinetic mechanism. Other physical vapor deposition methods such as magnetron sputtering allow precise control of film thickness and interface quality, especially when SnS is combined with materials like TiO_2 to form heterostructures. In such heterostructures, a type-II band alignment enhances charge carrier separation and significantly improves both photoelectrochemical performance and photocatalytic degradation rates compared to pure SnS films.

Operational conditions like light intensity, pH of the solution, and initial pollutant concentration further influence photocatalytic efficiency. The interaction between surface charge, dye molecule adsorption, and ROS formation can vary with pH, often leading to higher activity in basic conditions due to increased adsorption of cationic dyes on negatively charged catalyst surfaces. Moreover, film thickness affects visible-light absorption and charge transport; excessively thick films may suffer from recombination losses, whereas very thin films may not absorb sufficient light, indicating that there is an optimal thickness range for maximizing photocatalytic performance (Göktaş & Şahin, 2023). Understanding the interplay between deposition methods, structural properties, and operational parameters is therefore essential for optimizing SnS thin films as efficient photocatalysts. Continued research focusing on controlled synthesis, defect engineering, and operational optimization will contribute to the development of effective SnS-based systems for environmental remediation and sustainable energy applications (Göktaş et al., 2024).

CONCEPTUAL FRAMEWORK

Overview

This conceptual framework describes the interrelationships between fabrication conditions, structural features, surface characteristics, and operational parameters governing the photocatalytic performance of SnS thin films. The framework is based on established principles of semiconductor photocatalysis and thin-film growth, aiming to provide a systematic understanding of how processing and operational variables collectively influence photocatalytic efficiency. Emphasis is placed on optimizing SnS thin films as visible-light-responsive photocatalysts using earth-abundant and low-toxicity materials. Tin(II) sulfide (SnS) is a p-type semiconductor with a narrow and near-optimal band gap of approximately 1.3 eV, which enables strong absorption in the visible region and makes it a promising photocatalyst for environmental remediation applications (Vidal et al., 2012). Owing to its earth-abundant constituents and low toxicity, SnS has attracted increasing attention as an alternative to conventional wide-bandgap photocatalysts. The photodegradation mechanism in SnS-based systems involves a combination of photophysical and photochemical processes governed by the generation, separation, and transport of photogenerated charge carriers.

Fig. 1 illustrates the visible-light-driven photodegradation mechanism in SnS-based photocatalysts, where photon absorption excites electrons from the valence band to the conduction band, generating separated electrons and holes that migrate through the SnS structure due to its narrow band gap.

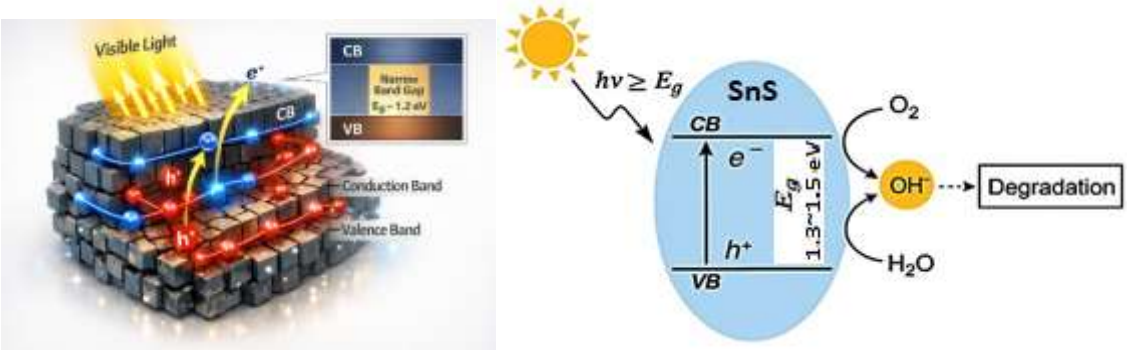

Figure 1: Photocatalytic degradation of SnS nanostructures under the sun light

The fundamental step in the photodegradation process is the excitation of electrons from the valence band (V_B) to the conduction band (C_B) of SnS upon absorption of visible-light photons. The narrow band gap of SnS allows this excitation to occur efficiently under solar or visible light irradiation, in contrast to wide-bandgap materials such as TiO_2, which are primarily active under ultraviolet illumination (Fujishima & Honda, 1972). Following photoexcitation, the photogenerated electrons and holes migrate to the surface of the SnS photocatalyst, where they participate in redox reactions with adsorbed species, leading to the formation of reactive oxygen species responsible for pollutant degradation.

Fabrication Parameters

The photocatalytic behavior of SnS thin films is strongly dependent on fabrication parameters, including the **deposition technique**, precursor chemistry, film thickness, and post-deposition thermal treatment. Chemical deposition methods such as SILAR, sol–gel, or chemical bath deposition enable controlled growth of SnS layers, while parameters such as solution concentration, deposition cycles, and growth temperature determine initial film uniformity and stoichiometry. **Annealing temperature and atmosphere** are critical factors influencing crystallization, phase purity, and defect formation. Thermal treatment serves as a primary control variable by regulating grain growth, sulfur incorporation, and the suppression of secondary phases that may adversely affect photocatalytic activity.

Structural Properties

Structural characteristics such as **crystal phase, crystallinity, grain size, and lattice defects** play a decisive role in charge carrier generation and transport during photocatalysis. Proper thermal processing promotes the formation of phase-pure orthorhombic SnS with improved crystallinity and enlarged grains. Enhanced structural ordering reduces grain boundary density and minimizes charge carrier recombination, thereby facilitating efficient electron–hole separation under visible-light irradiation. Conversely, poor crystallinity or the presence of secondary phases can act as recombination centers, limiting photocatalytic efficiency.

Compositional Characteristics

The chemical composition of SnS thin films is governed by precursor stoichiometry and post-deposition processing conditions. Near-stoichiometric Sn/S ratios are essential for maintaining a suitable band structure and stable p-type conductivity. Elemental homogeneity across the film surface and thickness is crucial to avoid localized band gap variations that hinder uniform charge transport. Excessive thermal treatment may lead to sulfur deficiency, increasing defect density and negatively affecting photocatalytic performance.

Surface Morphology

Surface morphology directly influences photocatalytic reactions by controlling light absorption, active surface area, and adsorption of reactant molecules. Optimized fabrication and annealing conditions yield compact, uniformly distributed grains with moderate surface roughness, enhancing photocatalyst–solution interactions. In contrast, porous structures or excessive roughness can reduce electrical continuity and promote recombination, despite increased surface area. Therefore, balanced morphological control is essential for achieving optimal photocatalytic activity

Role of Operational Parameters

Beyond the intrinsic material properties of SnS thin films, operational parameters play a decisive role in determining photocatalytic efficiency during dye degradation processes. Parameters such as light source characteristics, solution pH, catalyst loading, and initial dye concentration directly influence charge carrier generation, surface reactions, and overall degradation kinetics. Optimizing these parameters is therefore essential to fully utilize the visible-light-driven photocatalytic potential of SnS thin films.

Light Source

The characteristics of the light source, particularly light intensity and wavelength distribution, play a critical role in governing the photocatalytic performance of SnS-based materials. Owing to its narrow band gap of approximately 1.3 eV, SnS exhibits strong absorption in the visible region and can be efficiently activated under both visible light irradiation and natural sunlight, enabling effective generation of electron–hole pairs without the need for ultraviolet excitation (Vidal et al., 2012). This intrinsic property provides a significant advantage over wide-bandgap photocatalysts and underpins the growing interest in SnS for solar-driven photocatalytic applications.

Experimental studies reported over the past decade consistently show that increasing light intensity enhances photocatalytic activity by promoting higher charge carrier generation rates in SnS thin films and nanostructured SnS powders. Enhanced photon flux increases the population of excited electrons in the conduction band and holes in the valence band, thereby accelerating surface redox reactions involved in the degradation of organic pollutants (Kumar et al., 2018; Aparna et al., 2024). However, these studies also indicate that beyond an optimal intensity threshold, further increases in light intensity can lead to a higher probability of electron–hole recombination, ultimately reducing quantum efficiency and limiting photocatalytic performance.

The wavelength distribution of the light source is equally important, as effective photocatalysis requires spectral overlap between the incident light and the absorption edge of SnS. Visible-light-responsive behavior has been demonstrated for both SnS thin films and powder-based systems during the degradation of various organic pollutants, including dyes and other aromatic compounds (Fig. 2), confirming that SnS can efficiently utilize a broad portion of the solar spectrum (Venkatesh et al., 2019). In this context, sunlight-driven photocatalysis represents a particularly attractive approach, combining material efficiency with sustainability and reduced operational costs.

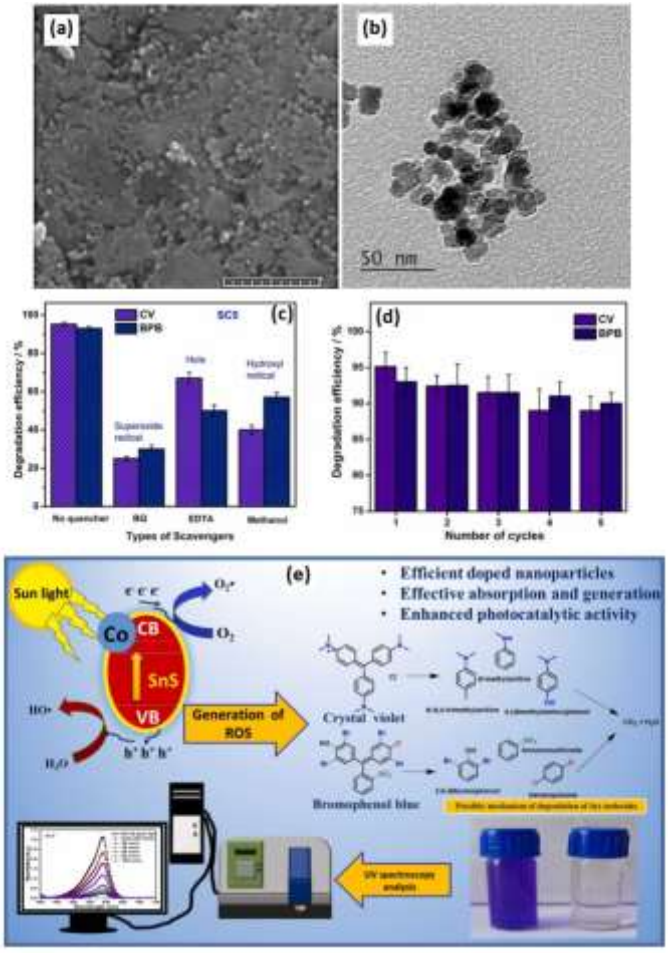

Figure 2: SEM (a), TEM (b), (c) Scavenger study and (d) reusability and (e) photocatalytic schematic representation of CV and BP pollutant for the SnS and Co-doped SnS nanoparticles. Reproduced with permission of Venkatesh et al. Copyright 2024 Elsevier.

From a mechanistic perspective, photoexcited electrons and holes generated under visible or solar irradiation migrate to the SnS surface, where they participate in the formation of reactive oxygen species such as superoxide radicals ($O_2^{\bullet-}$) and hydroxyl radicals (•OH). These species play a dominant role in the oxidative degradation and mineralization of organic contaminants. Several recent studies have emphasized that efficient light harvesting under visible illumination enhances charge carrier availability while suppressing recombination, especially in nanostructured SnS systems with increased surface area and shortened diffusion pathways (Gadore et al., 2020). Overall, the reported results demonstrate that careful control of light source characteristics is essential for maximizing the photocatalytic performance of SnS-based materials. The ability of SnS to operate effectively under visible light and natural sunlight not only highlights its suitability for laboratory-scale studies but also underscores its potential for large-scale, solar-driven treatment of organic pollutants in wastewater systems.

- **Solution pH**

Solution pH is a critical operational parameter that strongly influences the photocatalytic performance of SnS-based materials, as it governs both the surface charge characteristics of the photocatalyst and the ionization state of organic pollutants in solution. Variations in pH directly affect electrostatic interactions between the SnS surface and pollutant molecules, thereby controlling adsorption behavior, surface reaction kinetics, and overall degradation efficiency. This effect is particularly pronounced for SnS thin films and nanostructured SnS systems, where surface-mediated processes dominate photocatalytic activity.

Under acidic or alkaline conditions, changes in surface charge can either enhance or suppress the adsorption of organic contaminants depending on their molecular structure and charge state. At acidic pH values, protonation of the SnS surface may promote the adsorption of anionic pollutants, whereas alkaline conditions often favor the adsorption of cationic species. Such pH-dependent adsorption behavior has been reported to significantly influence photocatalytic reaction rates and degradation pathways in metal sulfide–based photocatalysts (Hoffmann et al., 1995; Wang et al., 2018). For SnS photocatalysts, an optimal pH range is often observed, where favorable surface interactions coincide with efficient charge transfer processes.

In addition to adsorption effects, solution pH plays a decisive role in the generation and stability of reactive oxygen species (ROS), which are the primary oxidizing agents responsible for the degradation and mineralization of organic pollutants. The formation of hydroxyl radicals (•OH), superoxide radicals ($O_2^{\bullet-}$), and photogenerated holes (h^+) is strongly pH-dependent, as proton availability and redox potentials vary with solution chemistry. Several recent studies have demonstrated that alkaline conditions can enhance the generation of $O_2^{\bullet-}$ species through improved electron transfer to dissolved oxygen, while acidic conditions may favor hole-driven oxidation pathways (Göktaş et al., 2023).

For nanostructured and powder SnS photocatalysts, the influence of pH is further amplified due to their higher surface area and increased density of active sites. In these systems, pH-induced changes in surface chemistry can significantly alter charge carrier recombination dynamics and ROS-mediated reaction pathways. Thin-film SnS photocatalysts, on the other hand, often exhibit greater structural stability over a wider pH range as seen in Fig. 3, making them attractive for practical wastewater treatment applications where pH conditions may fluctuate (Aparna et al., 2023).

Overall, the reported results indicate that careful control of solution pH is essential for optimizing the photocatalytic degradation of organic pollutants using SnS-based materials. By simultaneously regulating surface charge interactions, ROS generation, and charge carrier dynamics, pH optimization enables more efficient utilization of the intrinsic photocatalytic properties of SnS and enhances its applicability in solar-driven environmental remediation systems.

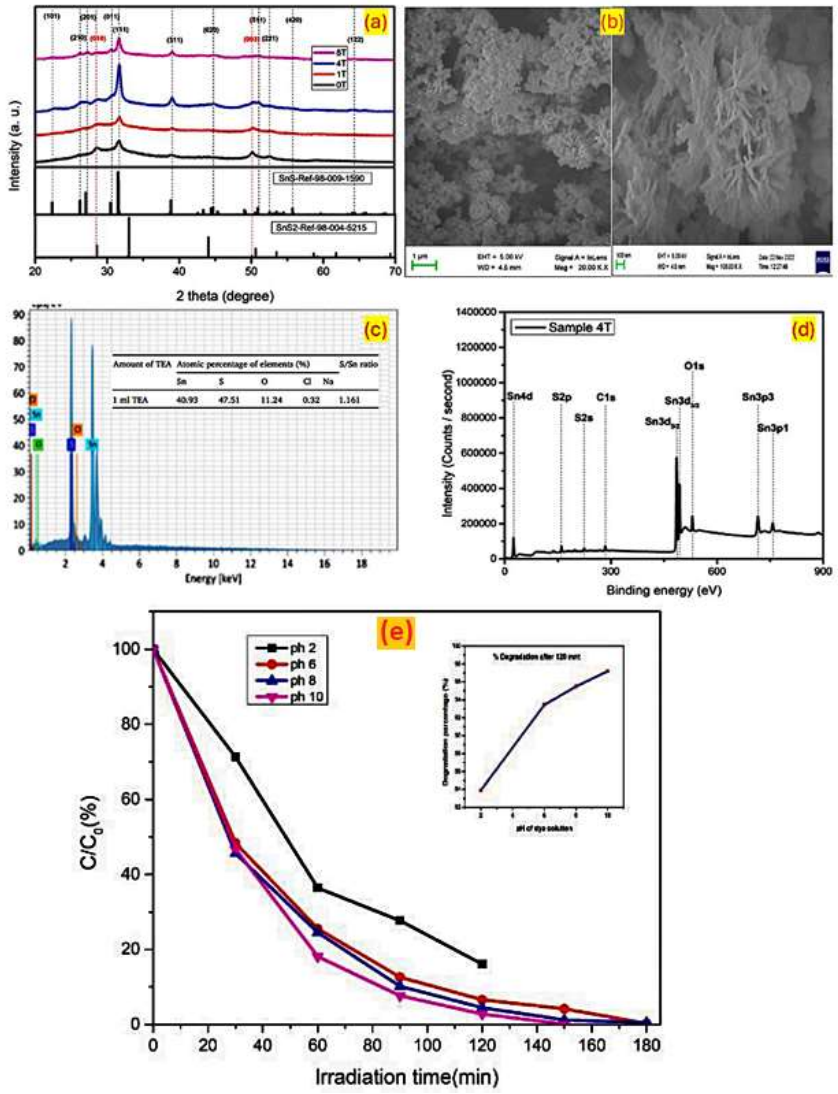

Figure 3: (a) XRD, (b) SEM, (c)EDX, (d) XPS, and (e) pH depended photocatalytic analysis of SnS thin films with 1T by SILAR. Reproduced with permission of Elsevier, Copyright (Aparna et al., 2024).

- **Catalyst loading**

Catalyst loading is a key operational parameter that strongly influences the photocatalytic performance of SnS-based systems. In the case of thin-film photocatalysts, catalyst loading is intrinsically linked to film thickness or the number of deposited layers, which directly affects light absorption, charge carrier generation, and surface reaction kinetics. An increase in film thickness generally enhances optical absorption in the visible region, enabling more efficient utilization of incident photons and providing a higher density of active sites for photocatalytic reactions.

Experimental studies on SnS thin films have demonstrated that moderate increases in catalyst loading can significantly improve photocatalytic degradation efficiency by promoting enhanced light harvesting and prolonged charge carrier lifetimes (Aparna et al., 2017). Moreover, thicker films can absorb a larger fraction of the visible spectrum, thereby increasing the generation rate of electron–hole pairs. This effect is particularly beneficial under low-intensity visible light or natural sunlight conditions, where efficient photon utilization is critical.

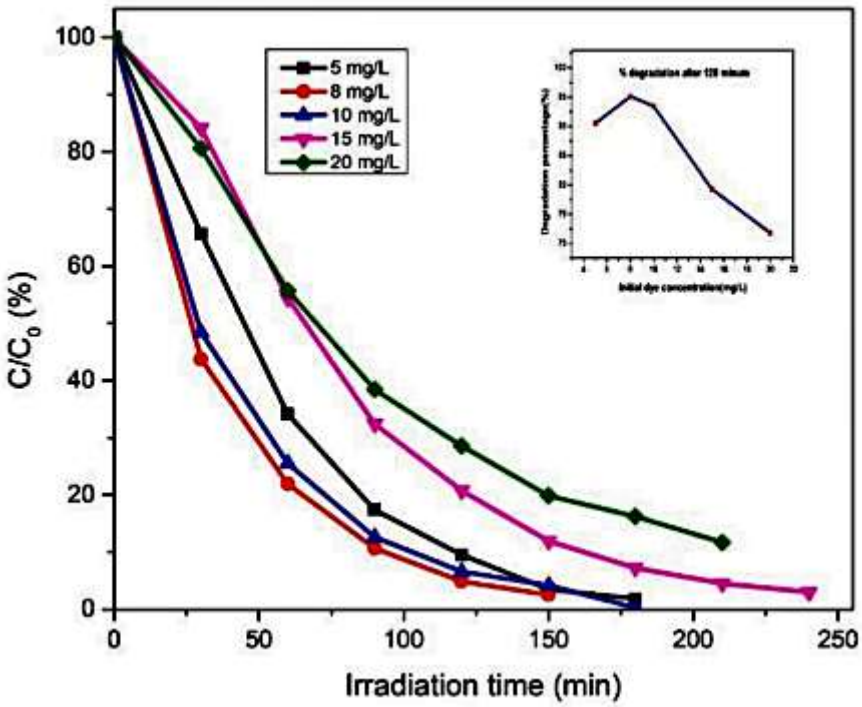

Figure 4: Photocatalyst loading depended photocatalytic analysis of SnS thin films by SILAR. Reproduced with permission of Elsevier, Copyright (Aparna et al., 2024).

However, excessive catalyst loading or overly thick SnS films can adversely affect photocatalytic performance (Fig. 4). As film thickness increases beyond an optimal threshold, light penetration into the inner layers becomes limited, resulting in inactive regions that do not effectively participate in photocatalysis. Moreover, increased thickness can hinder charge carrier transport to the film surface, leading to higher recombination losses within the bulk of the film (Alagarasan et al., 2019). These transport limitations reduce the availability of photogenerated electrons and holes for surface redox reactions, ultimately decreasing degradation efficiency.

A similar trade-off between catalyst loading and photocatalytic activity has also been reported for powder and nanostructured SnS systems. While higher catalyst dosages increase the number of available active sites, excessive loading can cause light scattering, shielding effects, and particle agglomeration, all of which negatively impact effective light absorption and charge transfer (Yadav et al., 2025). These observations highlight that both thin-film and powder SnS photocatalysts require careful optimization of catalyst loading to achieve maximum efficiency.

Overall, the results indicate that an optimal SnS film thickness or catalyst loading is essential to balance light harvesting efficiency and charge carrier transport. Achieving this balance minimizes recombination losses while maximizing surface-driven photocatalytic reactions. Rational control of film thickness, therefore, represents a critical design parameter for improving the performance and scalability of SnS thin-film photocatalysts in visible-light and solar-driven wastewater treatment applications.

The initial dye concentration

The initial dye concentration is another critical parameter that significantly influences the photocatalytic performance of SnS-based materials by affecting both light absorption in the reaction medium and surface coverage of the photocatalyst. At relatively low dye concentrations, pollutant molecules can be efficiently adsorbed onto the surface of SnS thin films or nanostructured SnS particles, allowing effective interaction with photogenerated charge carriers and reactive oxygen species. Under these conditions, photocatalytic degradation typically follows pseudo-first-order kinetics, resulting in high degradation efficiencies and reproducible reaction rates.

As the initial dye concentration increases, a gradual decline in photocatalytic performance is commonly observed. Higher dye concentrations can lead to excessive surface coverage, where active sites on the SnS surface become saturated and less accessible to photogenerated electrons and holes. In addition, strongly absorbing dye molecules may act as light filters, reducing the penetration of visible or solar light to the photocatalyst surface and thereby limiting charge carrier generation (Yadav et al., 2020). This screening effect is particularly pronounced in systems operating under low-intensity visible light or natural sunlight.

From a mechanistic perspective, elevated dye concentrations can also alter the balance between reactive oxygen species generation and consumption. When the number of pollutant molecules exceeds the available reactive species, incomplete degradation pathways may dominate, leading to slower mineralization rates and the accumulation of intermediate products. Similar trends have been reported for both thin-film and powder SnS photocatalysts, as well as other visible-light-responsive semiconductors, indicating that this behavior is a general characteristic of heterogeneous photocatalytic systems (Goktas et al., 2022).

For SnS thin films, the effect of initial dye concentration is further coupled with mass transfer limitations at the solid–liquid interface. While thin films offer advantages in terms of structural stability and reusability, their fixed surface area makes them particularly sensitive to surface saturation at high pollutant concentrations. In contrast, nanostructured or powder SnS systems with higher surface areas may tolerate slightly higher dye loadings, although excessive concentrations still result in light attenuation and recombination losses. Moreover, these results underscore the importance of carefully controlling the initial dye concentration to achieve reliable, efficient, and reproducible photocatalytic performance. Optimization of pollutant concentration is essential not only for maximizing degradation efficiency but also for ensuring meaningful comparison between different SnS-based photocatalytic systems and for facilitating the translation of laboratory-scale results to practical wastewater treatment applications (Das et al., 2015).

Overall, the photocatalytic degradation of dyes using SnS thin films is governed by a complex interplay between operational parameters and material properties. Systematic optimization of light conditions, solution chemistry, film thickness, and pollutant concentration is essential for maximizing photocatalytic efficiency and for advancing the practical application of SnS thin films in solar-driven wastewater treatment systems.

Interrelationships and Optimization Pathway

This framework underscores the inherently interdependent relationship between fabrication parameters, material properties, and operational conditions in determining the photocatalytic performance of SnS-based systems. Structural and compositional optimization achieved through controlled synthesis and post-deposition treatments directly influences crystallinity, defect density, and band structure, which in turn govern charge carrier generation, transport, and recombination behavior. Improved crystallinity and near-stoichiometric composition have been shown to facilitate more efficient charge transport in SnS thin films and nanostructures, thereby enhancing the availability of photogenerated electrons and holes for surface reactions.

Surface morphology plays an equally critical role by regulating interfacial interactions between the photocatalyst and the surrounding reaction medium. Parameters such as grain size, surface roughness, and porosity determine the density of accessible active sites and influence adsorption behavior of organic pollutants. In nanostructured and powder SnS systems, increased surface area and shortened diffusion pathways can promote interfacial charge transfer, while in thin-film configurations, well-controlled surface morphology contributes to improved stability and reproducibility during repeated photocatalytic cycles.

Operational parameters function as external modifiers that dynamically regulate photocatalytic reaction kinetics. Light source characteristics, solution pH, catalyst loading, and pollutant concentration collectively control photon absorption, surface charge interactions, and reactive oxygen species generation. Variations in these parameters can either enhance or suppress photocatalytic efficiency, even when material properties remain unchanged. Recent studies emphasize that suboptimal operational conditions can mask the intrinsic photocatalytic potential of SnS, leading to misleading performance assessments.

Importantly, experimental evidence consistently demonstrates that effective photocatalytic performance does not arise from the optimization of a single parameter in isolation. Instead, it emerges from a balanced and synergistic optimization of fabrication conditions, material characteristics, and operational variables. For example, increasing film thickness without considering light penetration or pH-dependent surface chemistry may result in limited performance gains. Similarly, favorable operational conditions cannot compensate for poor charge transport caused by structural defects or excessive recombination centers. Overall, these findings highlight the necessity of adopting a holistic design strategy when developing SnS-based photocatalytic systems. Understanding and controlling the complex interplay between synthesis parameters, material properties, and operating conditions is essential for achieving reliable, efficient, and scalable photocatalytic degradation of organic pollutants under visible light and solar irradiation.

Conceptual Outcome

By systematically tailoring fabrication conditions and operational parameters, SnS thin films with enhanced crystallinity, well-controlled surface morphology, favorable electronic properties, and high visible-light-driven photocatalytic efficiency can be achieved. Control over deposition parameters and post-deposition treatments enables optimization of crystal structure, defect density, and stoichiometry, which are critical factors governing charge carrier generation, transport, and recombination dynamics. Improved crystallinity and reduced structural defects have been shown to facilitate more efficient charge transport in SnS thin films, thereby increasing the availability of photogenerated electrons and holes for surface redox reactions. Simultaneously, controlled surface morphology—such as optimized grain size, surface roughness, and porosity—enhances interfacial interactions between the photocatalyst and organic pollutants, promoting adsorption and facilitating reactive oxygen species–mediated degradation pathways. In comparison with bulk materials, nanostructured and thin-film SnS systems offer shorter charge diffusion lengths and more accessible active sites, which are particularly beneficial under visible-light and solar irradiation conditions. However, these advantages can only be fully realized when operational parameters such as light intensity, solution pH, catalyst loading, and pollutant concentration are carefully optimized.

This integrated approach establishes a clear process–property–performance relationship, in which fabrication parameters define material structure and electronic behavior, while operational conditions regulate reaction kinetics and photocatalytic efficiency. Recent studies emphasize that neglecting either aspect can lead to suboptimal or misleading performance evaluations, whereas coordinated optimization enables reproducible and scalable photocatalytic activity. Such a framework not only enhances fundamental understanding of SnS-based photocatalysis but also provides practical guidance for translating laboratory-scale results into real-world applications. Overall, this conceptual framework supports the rational design of SnS-based photocatalysts for environmental remediation and sustainable energy-related applications. By integrating material engineering with system-level operational optimization, SnS thin films emerge as promising candidates for efficient, solar-driven degradation of organic pollutants and for the development of next-generation, environmentally benign photocatalytic technologies.

METHODOLOGY

Methodology of the Review

This review was conducted using a structured and systematic approach to identify, analyze, and synthesize recent peer-reviewed studies focusing on strategies to enhance the photocatalytic performance of SnS thin films. The adopted methodology was designed to ensure the inclusion of comprehensive, relevant, and scientifically rigorous data that enable a coherent evaluation of reported

experimental outcomes. A detailed literature survey was performed using major scientific databases such as Web of Science, Scopus, and ScienceDirect, employing keywords related to SnS thin films, photocatalysis, deposition techniques, and operational parameters. Only studies published in reputable journals and providing clear experimental methodologies were considered. Particular emphasis was placed on research investigating the effects of deposition methods, post-deposition treatments, and resulting structural, morphological, and optoelectronic properties on photocatalytic activity.

The selected studies were comparatively analyzed to assess the influence of key factors including film thickness, crystallinity, surface morphology, band gap characteristics, and charge carrier dynamics. In addition, operational parameters such as light source characteristics, solution pH, catalyst loading, and initial pollutant concentration were evaluated in relation to photocatalytic efficiency and stability. This systematic evaluation provides insight into the interplay between material properties and operating conditions, offering guidance for the optimization and future development of SnS-based thin-film photocatalytic systems.

Literature Search Strategy

A systematic literature search was conducted using major scientific databases, including Web of Science, Scopus, and ScienceDirect, to identify peer-reviewed studies on the photocatalytic properties of SnS thin films. Relevant articles were selected based on predefined keywords related to SnS thin films, photocatalysis, and deposition methods. Only studies providing clear experimental details and photocatalytic performance data were included to ensure relevance and scientific rigor.

Inclusion and Exclusion Criteria

Studies were included if they focused on SnS thin films and reported experimental photocatalytic performance supported by clear synthesis or deposition methods and material characterization. Only peer-reviewed articles published in English were considered. Studies were excluded if they lacked sufficient experimental detail, did not evaluate photocatalytic activity, or focused solely on bulk or non-thin-film SnS materials.

Data Extraction and Organization

Relevant data were systematically extracted from the selected studies, including deposition methods, structural and optical properties, operational parameters, and photocatalytic performance metrics. The extracted information was organized in a comparative manner to facilitate the identification of trends and relationships between material properties and photocatalytic efficiency.

Critical Analysis and Synthesis

The extracted data were critically analyzed to identify common trends, performance-limiting factors, and optimization strategies affecting the photocatalytic activity of SnS thin films. Findings from different studies were synthesized to establish relationships between material properties, operational parameters, and photocatalytic performance, providing a coherent overview of current research outcomes.

CONCLUSION AND DISCUSSION

The comprehensive analysis presented in this mini-review highlights the significant potential of SnS-based photocatalysts, particularly SnS thin films and nanostructured SnS systems, for the degradation of organic pollutants under visible-light and solar irradiation. Owing to its narrow band gap (≈1.3–1.6 eV), strong absorption in the visible region, earth-abundant constituents, and low toxicity, SnS has emerged as a promising alternative to conventional wide-bandgap photocatalysts such as TiO_2 that rely primarily on ultraviolet excitation (Vidal et al., 2012; Kumar et al., 2018). The reviewed studies consistently demonstrate that the photocatalytic activity of SnS is governed by the coupled effects of light absorption, charge carrier generation and transport, and surface-mediated redox reactions. Upon visible-light irradiation, photogenerated electrons in the conduction band and holes in the valence band participate in the formation of reactive oxygen species (ROS), including superoxide ($O_2^{\bullet-}$) and hydroxyl (•OH) radicals, which play a dominant role in the oxidative degradation of organic contaminants. However, as with most narrow-bandgap semiconductors, rapid electron–hole recombination remains a primary factor limiting the intrinsic photocatalytic efficiency of pristine SnS.

Material engineering strategies reported over the last decade provide clear evidence that structural, morphological, and compositional optimization can significantly enhance SnS photocatalytic performance. Improved crystallinity and phase purity, achieved through controlled deposition techniques and post-deposition annealing, reduce defect-induced recombination centers and facilitate more efficient charge transport in SnS thin films (Aparna et al., 2023; Göktaş et al., 2022). In particular, thin films with near-stoichiometric Sn/S ratios and well-developed grain structures exhibit higher photocatalytic degradation rates compared to poorly crystallized or sulfur-deficient counterparts. Morphological control further plays a decisive role in determining photocatalytic efficiency. Nanostructured and powder SnS systems, such as nanoparticles and nanorods, benefit from increased surface area and shortened diffusion paths, which enhance surface reaction kinetics and ROS generation (Das & Dutta, 2015; Gadore et al., 2023). In contrast, SnS thin films offer superior mechanical stability, ease of recovery, and reproducibility during repeated photocatalytic cycles, making them particularly attractive for practical wastewater treatment applications despite their comparatively lower surface area.

Operational parameters strongly modulate the intrinsic photocatalytic properties of SnS-based materials. Light source characteristics, especially wavelength and intensity, directly influence charge carrier excitation efficiency. Numerous studies confirm that SnS exhibits robust photocatalytic activity under visible light and natural sunlight, highlighting its suitability for solar-driven environmental remediation (Venkatesh et al., 2024). While increased light intensity generally enhances degradation rates by promoting higher charge carrier generation, excessively high intensities may accelerate recombination processes and reduce quantum efficiency.

Solution pH is another critical parameter that governs surface charge characteristics, pollutant adsorption behavior, and ROS formation. Optimal pH conditions depend on the nature of the target pollutant but typically arise from a balance between favorable electrostatic interactions and efficient radical generation (Hoffmann et al., 1995; Göktaş et al., 2023). Similarly, catalyst loading, represented by film thickness in thin-film systems or catalyst dosage in powder systems must be carefully optimized to balance light absorption and charge transport. Excessive loading can limit light penetration and increase recombination losses, while insufficient loading reduces active site availability.

The influence of initial pollutant concentration further underscores the importance of operational optimization. At low concentrations, organic molecules are efficiently adsorbed and degraded on SnS surfaces, whereas higher concentrations can shield the photocatalyst from incident light and saturate reactive sites, leading to diminished degradation efficiency. These trends are consistently reported across both thin-film and nanostructured SnS photocatalysts, confirming their general applicability. Despite the encouraging results, several challenges remain. Long-term stability under varying pH conditions, the presence of competing ions, and real wastewater matrices requires further investigation. Additionally, while nanostructured SnS systems often exhibit higher degradation rates, issues related to catalyst recovery and aggregation may hinder large-scale application. Thin-film SnS photocatalysts partially address these limitations but require further optimization to maximize active surface utilization.

Conclusions

This mini-review demonstrates that SnS-based photocatalysts, particularly SnS thin films, represent a versatile and promising platform for visible-light-driven degradation of organic pollutants. The key conclusions can be summarized as follows: Photocatalytic Mechanism: The narrow band gap of SnS enables efficient visible-light excitation and ROS generation, which drive the oxidative degradation of organic contaminants through radical-mediated pathways.

Material Optimization: Improved crystallinity, controlled morphology, and near-stoichiometric composition significantly enhance charge transport and suppress recombination in SnS thin films and nanostructures. Operational Parameters: Light source characteristics, solution pH, catalyst loading, and initial pollutant concentration critically influence photocatalytic performance and must be jointly optimized to reveal the intrinsic activity of SnS. Performance and Stability: Optimized SnS-based systems commonly achieve high degradation efficiencies under visible light and exhibit good stability over multiple photocatalytic cycles, particularly in thin-film configurations. Sustainability Perspective: The earth-abundant nature, low toxicity, and solar-light responsiveness of SnS make it an

environmentally benign alternative to conventional photocatalysts, with strong potential for scalable wastewater treatment applications.

In summary, effective photocatalytic performance in SnS-based systems arises from the balanced optimization of fabrication parameters, material properties, and operational conditions rather than from a single dominant factor. Continued efforts focusing on controlled synthesis, mechanistic understanding, and real-water validation will be essential to translate laboratory-scale success into practical, sustainable photocatalytic technologies for environmental remediation.

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ALİ ŞERİATİ'NİN SANAT HAKKINDAKİ DÜŞÜNCELERİ
ALİ ŞERİATİ'S VIEWS ON ART

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ÖZET

Bu bildiride 20. yüzyılın en önemli İslam düşünürlerinden biri olan İranlı Ali Şeriati'nin sanat hakkındaki düşüncelerine değinilecektir. Ali Şeriati'nin aynı zamanda bir teolog olmasına karşın sanatın doğası, kaynağı, işlevi ve rolüne ilişkin ortaya koyduğu yaklaşımlar ve kendine özgü bakış açısı, sadece sanat eleştirisi açısından değil aynı zamanda İslam'i anlayışın sanata olan yaklaşımı açısından da son derece önemlidir. Çünkü Şeriati'nin hem Tanrı'nın bir emaneti olarak hem de insani kurtuluşun bir yolu ve aşkın/kutsal bir hakikat arayışının sonucu olarak görüp değerlendirdiği sanat, ortodoks İslam'i yorumdan son derece farklıdır. Dolayısıyla bildiride Şeriati'nin hem yaratılış gayesinin hem de insanın anlam arayışının bir neticesi olarak ortaya çıktığını düşündüğü sanatın teolojik ve estetik bir okuması yapılacaktır. Bu okuma çerçevesinde şu iki temel soruya da -birincisi, insanı sanata yönelten varoluşsal gerçekliğin metafiziksel kaynağının ne olduğuna; diğeri de insani fıtratın ve yaratıcılığın bir tezahürü olarak meydana gelen sanatın ferdin manevi tekâmülü açısından ne ifade ettiğine- değinilecektir.

Anahtar Kavramlar: Ali Şeriati, Sanat, Yaratıcılık, Metafizik, Din.

ABSTRACT

This paper will discuss the thoughts of Ali Shariati, one of the most important Islamic thinkers of the 20th century, on art. Despite being a theologian, Shariati's perspectives on the nature, source, function, and role of art, along with his unique approach, are significant not only in terms of art criticism but also in understanding the Islamic perspective on art. Shariati views art as both a divine trust and a means of human salvation, as well as a result of the search for a transcendent/sacred truth—an understanding that differs significantly from orthodox Islamic interpretations. Therefore, this paper will offer a theological and aesthetic reading of art, which Shariati considers to be both a manifestation of the purpose of creation and a product of humanity's quest for meaning. Within this framework, the paper will address two fundamental questions: first, what is the metaphysical source of the existential reality that drives humans toward art? And second, what is the significance of art, as an expression of human nature and creativity, in an individual's spiritual development?

Keywords: Ali Shariati, Art, Creativity, Metaphysics, Religion.

Giriş

İnsanlığın tarihiyle eşdeğer olan sanat, bir yaratım ve yaratıcılık faaliyeti olarak her zaman kültürün en önemli yanını oluşturmuştur. Nitekim yapılan arkeolojik araştırmalarda, ilkel dönemden başlamak üzere tarihin her döneminde insanların bir şekilde sanatla uğraştıkları ve sanatsal etkinliklerde bulundukları görülmüştür. Sanatın kadim kültürün en önemli parçası olmasının temel nedeni, onun gizli ve üstün bir güce sahip olması, hayatı anlamlandırması, metafizik bir yan içermesi ama daha da önemlisi insanın kendisini en net biçimde ifade etmesini sağlamasıyla doğrudan ilişkilidir. Çünkü beceri ve düş gücü kullanılarak meydan gelmiş/ getirilmiş olan faaliyetler, insanın yaratıcı yanını ortaya koyan sanatın varlığıyla mümkün olabilmiştir.

Onun için sanat, insanların sadece ilgisini çekmekle kalmamış aynı zamanda insanın yaratıcı yanını da geliştiren özelliğiyle her zaman ön plana da çıkmıştır. Sanatın tanımında güçlük çekilmesinin nedeni de sanırım sanatın insan için çok şey ifade etmesinden kaynaklanmıştır. Önreğin Platon ve Aristoteles,

sanatı doğanın/tabiatın bir taklidi olarak görürken; Sorokin, zihnin veya onun biyolojik özellikleri üzerine konulan anlam ve değerlerin estetik cisimleşmesi; Parsons ise anlamlı ve ifade edici semboller sistemi olarak tanımlamıştır (Ulusoy, 2005: 9-10). Her ne kadar kimileri sanatı güzellik ülküsü olarak görse de aslında bu konuda herkesin üzerinde ittifak ettiği ortak bir tanım söz konusu değildir. Sanatı bu açıdan bir takım özellikleriyle betimlemek ve dolayısıyla tanımlamak mümkündür.

İster heykel, resim, seramik ve mimari gibi görsel sanatlar olsun isterse metin, yazı ve senaryo gibi dilsel performansa dayalı sanatlar olsun, sonuçta insanın yaptığı ve yarattığı her şeyin sanatsal bir yanı olduğu söylenebilir. Bu açıdan bakıldığında sanatın, Tezcan'ın da (2018: 5) belirttiği gibi düşle gerçek arasında bir köprü işlevi görmüştür denilebilir. Dolayısıyla sanat, insanın kendisini tanıması, anlaması ve anlamlandırmaya çalışarak duygu ve düşüncecilerini aktarması veya bütün bunları dışa vurmasıdır. Bunun yanı sıra sanat, bireyden bireye değiştiği gibi toplumdan topluma hatta dönemden döneme de değişiklik göstermiştir. Onun için sanat, çoğu zaman yaşam tarzının bir ifadesi olarak görülmüştür (Soykan, 2021: 15). Ancak şurası da bir gerçektir ki, sanat, özellikle gelişmiş toplumlarda gelişmiştir. Bilim, felsefe ve teknolojinin geliştiği ve ilerlediği toplumlarda sanat da kaçınılmaz olarak kendisine öncelikli bir yer bulmuş ve sanatla uğraşan ciddi bir kesimin varlığı söz konusu olmuştur.

Ali Şeriati'nin Düşüncesinde Sanatın Kaynağı, Önemi ve Rolü

Ali Şeriati'nin sanata dair fikirleri genelde şu iki kitapta -Sanat, Medeniyet ve Modernizm- toplanmıştır. Sanata, bir uzman gözüyle bakamayacağını, zira her şeyden önce bir sanatçı olmadığını vurgulayan yazar, her ne kadar sanat hakkında bir şeyler öğrenmeye ve yazmaya çalışsa da nihayetinde sanatın öncelikli bir meslek ve teknik bir uzmanlık alanı olduğunu ve bunun yanında profesyonellik hatta belli ölçüde de teknik bir formasyona sahip olmayı gerektirdiğini vurgulamıştır. Ona göre sanat hakkında düşünmek, öncelikle sanatın neliğini, işleyişini ve hem bireysel hem de toplumsal düzeyde önemini bilmeyi gerektirir ki, bu da ancak üst düzeyde soyut bir düşünme pratiğiyle mümkün olabilir. Şeriati, günümüz dünyasında sanatın da hem şekil hem de içerik olarak ciddi bir değişim geçirdiğini düşünmüştür.

Ona göre sanatta yaşanan değişim, daha çok sanatta var olan sınıfsal tekelin kırılmasıyla ön plana çıkmıştır. Diğer bir ifadeyle sanat, artık belli bir sınıfın, zümrenin veya kitlenin sahip olduğu ve toplumun geride kalan kesimlerinin ulaşamayacağı bir şey olmaktan çıkmış durumadır. Zira bilim ve teknikte olduğu gibi sanat da eskiden genellikle eğitimli kesimlerin bir uğraşı olarak görülürdü. Sanat, özellikle de Ortaçğda Burjuva sınıfının adeta tekelinde bulunmuş ve sıradan halkın asla ulaşamayacağı bir yaratım faaliyeti olma hüviyetini sürdürmüştür. Çünkü sanat, uzun yıllar boyunca maddiyatın, lüksün, sosyal sınıfın ve toplumsal saygınlığın bir göstergesi olarak görülmüştür.

Örneğin geleneksel toplumlarda sanat, genelde aristokratların ve kent soylu ailelerin estetik ve görsel bir uğraşı olarak var olmuş; skolastik düşüncenin hâkim olduğu Avrupa'da ise sanatçıların çoğu ya Kilise ya da bazı zengin aileler tarafından desteklenmiştir. Nitekim 14. ve 17. yüzyıllar arasında İtalya'da yaşamış olan Medici ailesi, tiyatroculara verdikleri destekle ünlenmiştir. Kilisenin, dönemin sanatçılarını maddi açıdan desteklemesinin temel nedeni, yeni yapılan kiliselerin tavanları başta olmak üzere bu yapıların Hz. İsa ve havarilerinin figürleriyle donatmaya çalışmalarından ve resmedilmesini istemesinden kaynaklanmıştır. Dolayısıyla sanat, Şeriati'nin de belirttiği gibi yüzyıllar boyunca belli kesimlerin uhdesinde bir faaliyet olarak var olmuştur. Ancak düşünüre göre sanat artık sınıfsal kimliğinden sıyrılmaya, kitleler arasından yayılmaya ve dolayısıyla da demokratikleşmeye başlamıştır.

Şeriatı, günümüzde sanatın toplumda eğitimli kesimlerin yanı sıra aydınların, entelektüellerin, sempatik, bilinçli ve duyarlı insanların da uğraştığı olmaya başladığını ve bu yanıyla sanatın herkese hitap edecek düzeyde gündelik yaşamımızı anlamlı kılacak bir yaratım etkinliği haline geldiğini iddia etmiştir. Zira Şeriati' ye göre (1998: 107) "sanat, bundan böyle rahat ve asude yaşamımızı sağlayan hoş ve eğlendirici bir ilaç değildir. Günümüz düşüncesine yol göstermekte ve çağdaş fikirlerimizin önünde koşmaktadır." Bize düşen görev, sanatı sadece görsel ve estetik yanıyla değil, aynı zamanda onu fikirlerin kaynağı ve düşüncenin yolu olarak da görmek olmalıdır. Çünkü sanat, özü itibariyle insanın kendisi, çevresi, doğası ve daha da önemlisi yaratıcı üzerinde bir tefekkür denemesidir.

Düşünürün sanatın ontolojik ve teolojik yanıyla ilgili düşüncelerine geçmeden önce, onun sanatın işlevine ve doğasına dair fikirlerine değinmekte yarar var. Aslında Şeriati (2020: 19; 1998: 109) gerek Paris'te bulunduğu yıllarda yaptığı muhtelif konuşmalarda gerekse İran'da yaşadığı dönemlerde verdiği

tebliğlerde "-sanatın hep dini bir kategori; insanlığa kurtuluş bahşeden aşkın ve kutsal bir hakikat; madde üstü, yüce ve yüzde yüz insani bir misyon olduğu" gerçeğini ön plana çıkarmaya çalışmıştır. Onun nazarında sanat, insanın kendi yaratılışının ve hayattaki anlam arayışının bir tezahürü olarak ortaya çıkmıştır ve çıkmaya devam etmektedir. Sanatın dini duygudan ayrılamayacağını zira nasıl ki din duygusu, insanı kendi üzerine düşünmesini sağlıyorsa sanatın da bu anlamda insanı düşündürten çok önemli bir işlevi olduğunu vurgulayan Şeriati, hem dini hem de sanatı, insani özgürleşimin bir bileşeni olarak görmüştür.

Nitekim eserlerinde çoğunlukla dini düşünce yanında bilim, teknik ve sanat arasındaki ilişkiyi de ele alan yazar, bilimin her şeyden önce insanın var olanlar hakkındaki düşüncesi olduğunu; tekniğin, var olanlardan mümkün olduğunca nasıl yararlanılacağı fikrini içerdiğini, ancak sanatın ise bilim ve teknikten farklı olarak olması gerekenin, fakat olmayandan yararlanmak için gösterdiği çabanın bir sonucu olduğunu iddia etmiştir (Şeriati, 2020: 29). Bu nedenle insanın kendisine ya yabancı bulduğu için anlamadığı ya da hakkında bir fikir sahibi olmadığı için anlamaya çalıştığı her şeyi resmetmeye çalıştığını; örneğin bu çabasını ya resim tuvaliyle ya heykelle ya bedeniyle ya sesiyle ya dansla ya yazıyla ya da sözle gerçekleştirdiğini vurgulamıştır.

Buradan hareketle yaratılışın bir tezahürü olarak gerçekleşen sanatsal yaratımların, Ali Şeriati açısından, bir estetik sorunu olmaktan ziyade ontolojik bir sorun olarak öne çıktığı ama daha önemlisi modern insanın da en önemli ve zaruri bir meselesi olarak görüldüğü söylenebilir (Sakar, 2011: 72). Çünkü yazara göre insanın en önemli yanı, içinde yaşadığı dünyaya karşı sorgulayıcı bir tavrı olması, kendi gerçekliğini, benliğini ve kişiliğini silikleştirdiğini düşündüğü kültüre, inanca ve ideolojiye karşı başkaldırması ama hepsinden de önemlisi varoluşsal anlamda isyanla mündemiç bir varlık olmasıdır (Aslan-Bakış, 2020: 837). İnsanın isyankâr olması, kendisine verilenlerle yetinmeyip aynı zamanda hem o verilenleri sorgulaması hem de bunları reddetme cüretinde, kudretinde ve idrakinde bulunmasıdır.

Çoğu zaman düşünüldüğü üzere insanı bir zindana mahkûm eden doğaya/tabiata, tarihe, topluma ve benliğe itaat etmek yerine bütün bunlara başkaldıran bir insan profilinin tarihin her döneminde görüldüğünü vurgulayan yazar (2014), yine düşünen ve akleden insanın hakikat arayışı önünde bir engel olan bu durumların aşılmasında sanatın çoğunlukla bir imkân olarak kullanıldığını ve sanatın da bu anlamda çok önemli bir potansiyeli olduğunu düşünmüştür. Bunun yanı sıra Şeriati' ye göre sanatın bir diğer işlevi, olanı değil, olması gerekeni, somut olanı değil soyut olanı, fiziği değil, metafiziği ve dolayısıyla da insanın özünde hissettiği ama etrafında bulamadığı bir takım tinsel ihtiyacını gidermesidir. Yazar, sanatı, doğanın bir taklidi olarak gören Platon'un bu sözünü anlamlı ama eksik bulur. Çünkü ona göre eğer sanat, tabiatın bir taklidinden ibaret ise o zaman sanat bir oyun ve eğlence konusu olur.

Oysa ona göre sanat özde bir oyun ve eğlence konusu olamayacak kadar kıymeti bir uğraştır. Sanat, olsa olsa duyu ötesi, tabiat ötesi gerçeğin dışsal bir yansımasının aracı olabilir. Onun deyişiyle "sanat; tabiat ve varlığı, işlediği halde bulunmayan şekle sokmak veya isteyip de bulamadığı şeyleri meydana getirmek için, Tanrı'nın yaratmasının tecellisi olan bu varlığın sürdürülmesine insan yaratıcılığının tezahürüdür. Sanat, Hegel'in dediği gibi, tarihi boyunca, somutluk ve maddilikten zihinselliğe, makullüğe ve akliliğe doğru evrim geçirmiştir" (Şeriati, 2020: 30). Dolayısıyla sanat, var olandan ziyade var olmayanın ve görülenden ziyade görülmeyenin peşindedir. Şeriati, sanatın neliğini açıklamaya çalışırken yaratılış öykünü temel alarak bir çözümleme yapmaya çalışır.

Çünkü düşünüre göre sanat, nihayetinde Tanrı'nın insana verdiği bir nimet ve aynı zamanda da bir emanettir (2020: 30-31). Neden emanettir? Sorusuna düşünürün verdiği cevap tümüyle teolojiktir. Zira yazar, Tanrı'nın emanetini yere, göğe, dağa ve denizlere sunduğunu, ancak bunlardan hiçbirinin bu emaneti taşıyacak güçlerinin olmadığını itiraf etmeleri üzerine insanın bu emaneti yüklediğini vurgulamıştır. Çünkü Şeriati' ye göre ne yer ne gök ne dağ ne de denizler hissedebilir, yaratıcı olabilir, duyarlılık gösterebilir. Ama insan, hem hisseden hem yaratıcı olan hem dertlenen hem de yüceliği tasdik eden bir varlıktır. İnsan aynı zamanda hakikatin perdesini aralamaya, hayatını anlamlı kılmaya, sadece geçmişi veya bugünü değil, aynı zaman bakiyi de düşünen bir varlıktır.

İnsan, bütün bu özellikleriyle vardır ve var olmaya devam etmektedir. Sanat, insanın varlığının ve yaratıcılığının bir yansımasıdır. Dolayısıyla Şeriati' ye göre sanat, insanın anlam arayışının bir neticesi olarak ortaya çıkmaktadır. Dinle beraber sanat, adeta karanlık bir dehlize düşmüş olan ve karanlık

olduğu için de nereye düştüğünü ve oradan nasıl çıkacağını bilmeyen insanın eline tutuşturulan bir fener işlevi görmektedir. Nasıl ki, fener önümüzü aydınlatıp bizi karanlığın yalnızlığından ve soğuğundan kurtarıp aydınlığa çıkarıyorsa aslında din ve sanat da bunun gibi insanın ruhsal açlığını ve bedensel yalnızlığını gideren çok önemli bir işlev görmektedir.

Düşünüre göre insanın tarih boyunca her zaman sanat ve sanatsal etkinliklerde bulunmasının en öneli nedeni, insanın öncelikle kendinde eksik olduğunu düşündüğü bir yanını bu etkinlikle tamamlamaya; ikincisi de söz konusu ontolojik eksikliğin insanda meydana getirdiği yabancılaşma duygusunu aşmaya çalışmasıdır (Karakuş, 2020: 264). Bu açıdan bakıldığında sanatın insan için şu iki sorunu gidermenin bir yolu ve yöntemi olarak ortaya çıktığı söylenebilir. Bunlardan ilki, insanın ontolojik varoluşunu eksik olduğunu bilme sorunu, ikincisi de bu ontolojik varoluş nedeniyle kendisine, çevresine, doğaya ve diğer varlıklara karşı yabancılaşması sorunudur. Sanat, olsa olsa insanın maneviyatındaki bu iki eksikliği gidermenin bir aracıdır.

Şeriati'nin sanatı, insanın varoluşuyla ilişkilendirmesinin temel nedeni ise, Fransa'da doktora yaptığı dönemde en çok varoluşçu felsefeden etkilenmesi ve bu nedenle de gerek teolojik gerekse ideolojilere dair çalışmalarında hep bu felsefenin izlerini takip etmesidir. Örneğin düşünürde varoluşçuluğun izleri, sanata ve dine dair yaklaşımında da görmek mümkündür. Çünkü Şeriati' ye göre insanın kendi varlığının farkında olduğu ve kendisini keşfetmeye başladığı andan itibaren sürekli kendi varoluşunun neliğini sorgulama, onu anlama ve adlandırma arayışına ve çabasına girmiştir. Bu nedenle sürekli kendisine ben kimim, neden yaratıldım, kim yarattı beni, yaratıcı beni yaratmakla neyi murad etti, bu dünya hayatının esrarı ve hikmeti nedir?

Aynı şekilde ölüm bir son mudur yoksa yeni bir başlangıç mıdır ama daha da önemlisi hayatımı hangi referanslara (dini, seküler) göre düzenlemeli ve yaşamalıyım şeklinde sürekli bir soru yağmuruna tutmuştur. Hiç şüphesiz insanın bu soruları görmezden gelmesi mümkün değildir. Ancak insan, kimi zaman kendisini rahatsız etse de bu tür soruların anlamsızlığına inanarak kendisini farklı meşgalelerle de oyalayabilir. Hatta Epiküros'un, "ölüm varsa ben yokum; ben varsam ölüm yoktur; o zaman kaygılanacak ne var" şeklindeki felsefesine inanarak hayatını da yaşayabilir. Ancak Şeriati' ye göre insan ne kadar çok kendinden ve dünyadan kaçmaya çalışırsa çalışsın hiçbir zaman bu soruların muhatabı olmaktan kurtulamayacak; kendisini teselli edecek arayışlara girse de bu arayışlar onu bu sorulara cevap verme arayışından uzaklaştıramayacaktır.

Bu psikolojik hâl, kimi zaman insanın farkında olmaksızın yaşadığı bir haldır, ancak nihayetinden akleden, düşünen ve dolayısıyla da kendi varlığının ve benliğinin farkında olan her insanı ruhsal açıdan derin bir boşluğa sürükleyen ve onu dünyevi bir takım arayışlara sürükleyen en önemli nedendir ki, bu arayışın en somut hali de dini inançta ve sanatta ortaya çıkmaktadır. Dolayısıyla Şeriati' ye göre sanat ve din, insanı, anlamsızlık buhranından kurtaran ve hayatı anlamlı hale getiren en önemli kültürel değerlerdir (Aslan-Bakış, 2020: 836). Sanatın insanın yaratıcı özelliğini adeta deşifre etmesi, aslında insanın hem yaratılmış bir varlık olduğu hem de yaratıcının yaratıcı özelliğini taşıdığını gösterir.

Sonuç

İranlı yazar ve düşünür Ali Şeriati'nin sanat hakkındaki fikirlerinin ele alındığı bu bildiride, genelde sanatın bireysel ve toplumsal yanı özelde de söz konusu düşünürün bu konudaki düşünceleri ele alınmaya çalışıldı. Burada vurgulamamız gereken husus, Şeriati'nin yazdığı ve ele aldığı konuları sosyolojik bir çerçeveden ziyade daha çok teoloji yanı ağır basan bir yaklaşımla ele aldığıdır. Nitekim düşünür, sanat konusunu da dini duygu ve Tanrı inancıyla ilişkilendirerek ele almış; sanatın her ne kadar insan yaratımının bir ürünü olsa da özü itibariyle Tanrı'nın insana bahşettiği bir nimet olduğunu ve bu nimet sayesinde insanın hem kendi yaratılışını bulduğunu hem de hayatını anlamlandırdığını vurgulamıştır.

Bu anlamda Şeriati'nin sanat anlayışının realist olmaktan çok idealist olduğu söylenebilir. Çünkü sanatı, var olanlar üzerinde bir düşünme ve telakki çabası olmaktan çok, ki- bu işlevi daha çok bilim ve tekniğin yaptığını düşünmüştür- var olmayanın üzerinde bir düşünme ve yaratım çabası olarak görmüştür. Ona göre sanat, Platon ve Aristoteles'in söylediği gibi sadece doğanın taklit edilmesinden mütevellit bir kopya girişimi/çabası değildir. Sanat, her şeyden önce bir kopya değildir. Sanat, doğa ötesinin tam taklidi olabilir. Doğada olmayanı, var kılma çabasıdır. Yine ona göre sanat, Tanrı tarafından insana

verilen bir emanettir. Taşıması, yere düşürmemesi, ihanet etmemesi, yaşatması ve muhafaza etmesi gereken bir emanettir. Sanat, içinde insanın varoluşunun hikmetini barındıran sembolik bir gerçekliktir.

Bunun yanı sıra sanat, insanın ruhsal boşluğunu dolduran bir etkinliktir. İnsandaki ruhsal boşluğun nedeni, insanın her şeyden önce bu dünyaya Heidegger ve Sartre'ın deyişiyle fırlatılmış olmasından kaynaklanmaktadır. İnsan, doğası gereği bu dünyada gariptir ve garip olduğu için de içsel bir ıstırap çeken, yalnız ve yabancılaşmış bir varlıktır. Düşünüre göre insan, bu dünyaya istemediği halde gönderilmiştir. Bu istenmezlik hali, insanı kendi başına ve yabancısı olduğu bir yerde (dünya) hayatını sürmesine neden olmuştur. İnsanın asli yurdu olmayan bu dünya, aynı zamanda onun zindanıdır. Bu zindandaki insan, sıkılmaktadır. Yalnızlık korkusu yaşamakta ve yabancılık duygusu çekmektedir. İşte sanat hem insanın yaşadığı ama çoğu zaman anlamlandıramadığı bu sıkıntısını gidermekte hem de yaratıcısını düşünmesine vesile olmaktadır.

İnsan, sanat sayesinde gizli yanlarını ve potansiyelini keşfettikçe hayatını da anlamlı hale getirmektedir. Çünkü düşünüre göre insan ne kadar çok dünyada yaşasa da onun varlığı realizmde değil, idealizmdedir. İnsan, idealleri için yaşar ve idealleri uğruna ölür. Sanat, bu ideali somutlaştıran en önemli araçtır. Aynı zamanda insanın ruhunu besleyen bu idealizm, sanat sayesinde ete kemiğe bürünmektedir. Bunun yanı sıra sanat, bizdeki gariplik duygusunu da ortadan kaldıran, fizik ötesi aleme pencere açan, varoluşsal eksikliği gideren, ruhsal ıstırapları dindiren, iyiliği, güzelliği ve estetiği yücelten; insana yaşam sevincini bahşeden, duyguları nakşeden, sözlere ve renklere can veren ama daha da önemlisi hüznü ve aşkı yaşatan en önemli yaratımdır.

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BİR DÜŞÜNÜŞ VE PARADİGMA OLARAK MODERNLİĞİN DÜNYA TASAVVURU
THE WORLDVIEW OF MODERNITY AS A WAY OF THINKING AND A PARADIGM

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ÖZET

Bu bildiride, şu iki temel soruya- bir düşünüş biçimi ve inşa süreci olarak modernliğin, insana nasıl bir dünya vadettiğine ve bu vaadi(ni) gerçekleştirmek için de nasıl bir yol ve yöntem izlediğine- cevap aranmaktadır. Bu cevap arayışında temel referansımız, çağdaş sosyologlardan Giddens'ın "elimizden kaçıp giden dünya"; Taylor'ın "çağdaş toplumun çöküşü" ve Rose'un "dünyanın kontrol edilemezliği" tezleri olacaktır. Bu tezleri öne çıkartmamızın başlıca nedeni ise özellikle son yıllarda sosyal bilimcilerin sıklıkla gündeme getirdikleri hususun, yani modernlikle beraber insan, doğa ve dünya ilişkilerinde yaşanan keskin kırılmaların, değişim ve dönüşümlerin yaşanmasıdır. Ayrıca bildiride modernliğin sadece geleneksel tarım toplumlarının akabinde ortaya çıkmış bir zaman dilimi olarak görülemeyeceği, insan eliyle dünyayı yeniden biçimlendirmeye ve inşa etmeye çalışan bir paradigmanın da ürünü olduğu ama daha da önemlisi modernliğin, bir yanda dünyayı kontrol etmeye çalışırken diğer yanda beraberinde ontolojik bir kontrolsüzlüğü de getirmek suretiyle dünyayı başlı başına bir felaket ve risk alanı haline getirdiği yönündeki tespitlerin adeta ayyuka çıkmış olmasıdır.

Anahtar Kavramlar: Modernlik, İnsan, Doğa, Dünya, Bilim.

ABSTRACT

This paper seeks to answer two fundamental questions: What kind of world does modernity, as a mode of thinking and a process of construction, promise to humanity? And what path and method does it follow to fulfill this promise? In this search for answers, our primary references will be the contemporary sociologists Giddens' thesis on "the world slipping through our fingers," Taylor's argument on "the collapse of contemporary society," and Rose's perspective on "the uncontrollability of the world." The main reason for highlighting these theses is the increasing emphasis in recent years by social scientists on the sharp ruptures, changes, and transformations in human-nature-world relations brought about by modernity. Moreover, this paper argues that modernity cannot merely be seen as a historical period emerging after traditional agrarian societies; rather, it is also the product of a paradigm that seeks to reshape and reconstruct the world through human intervention. More importantly, modernity, while striving to control the world on the one hand, paradoxically generates an ontological uncontrollability on the other, ultimately turning the world into a domain of catastrophe and risk—a notion that has become increasingly evident.

Keywords: Modernity, Human, Nature, World, Science.

Giriş

16. yüzyılın en önemli düşünürlerinden biri olan ve aynı zamanda ampirizmin kurucu babası olarak da bilinen Francis Bacon'a isnat edilen, **"**Scientia est potentia", yani "bilgi güçtür" sözü, üzerinde yaklaşık dört yüz geçmesine rağmen halen önemini, değerini ve güncelliğini korumaya devam etmektedir. Aslında düşünürün, bilgiyi güç olarak görüp değerlendirmesinin hikmetini, modernlik paradigmasında aramak/görmek gerekir. Zira sonradan modernliğin adeta mottosu haline dönüşecek olan bu sözle, sadece bilginin insana inanılmaz bir kabiliyet, erk ve yaptırımda bulunma imkânı yaratacağı değil, aynı zamanda edinilecek bilgi sayesinde insanın eşyayla, doğayla ve dünyayla olan ilişkisinin de tümden

değişeceği vurgulanmaktadır. Yazarın niyeti bilinmez ancak, bu sözün bizi getirdiği nokta, bilginin salt bilgiden oluşmadığı gerçeğidir.

Odağına bilimsel bilgiyi alan modernlik paradigması ise, yukarıda genel çerçevesi çizdiğimiz rasyonel bir dünya tasavvurunu hayata geçirmeye, dünyayı şekillendirmeye, düzenlemeye, yaratmaya, tasarımlamaya ama daha önemlisi dünya üzerinde mutlak bir güç olmaya çalıştığı söylenebilir. Modern paradigmanın bu çaba ve niyeti, aşağıda daha ayrıntılı bir biçimde üzerinde duracağımız gibi, dünyada çok önemli yapısal, kurumsal ve zihinsel dönüşümleri de yaratmıştır. Bu dönüşümlerin ayrıntısına girmeden önce modernliğin/ modernitenin *ne*liğine ve nasıl bir paradigmaya sahip olduğuna ilişkin bazı açıklamalar yapmakta yarar var. Bilindiği gibi modernliğin kökeni olan modern kavramı, ilk kez İsa'dan sonra 5. yüzyılın sonunda "antiquus"un karşıt anlamlısı olarak, yani Hıristiyanları pagan geçmişlerinden ayırmak için kullanılmış olup (Habermas, 1994: 31) kabaca insanların içinde bulundukları dönemi, zamanı ve mekânı betimlemektedir.

Modernlik, on yedinci yüzyılda Batı Avrupa ve Amerika'da yaşayan tarıma dayalı geleneksel toplumların bilimsel, kültürel, ekonomik ve politik açıdan yaşadıkları yapısal ve kurumsal değişim ve dönüşüme işaret etmektedir (Eisenstadt, 1996; Giddens, 1998: 11; Taylor, 2011: 10-21). Burada, bizi ilgilendiren husus, söz konusu toplumlarda yaşanan bu sosyolojik değişim ve dönüşümden ziyade bu değişim ve dönüşümün zihinsel arka planında ne olduğu, modernliğin başlı başına nasıl bir düşünsel dünyadan hareket ettiği gerçeğidir ki, ancak bu gerçeklik bilindiğinde modernlik paradigması anlaşılabilir. Aslında modernliğin epistemik dayanağını, 18. yüzyılda Batı Avrupa'da ortaya çıkmış olan Aydınlanma felsefesi oluşturmuştur. Çünkü modernlik, nihayetinde bir aydınlanma projesidir; Wallerstein'in (1998: 77) ifadesiyle bir *Weltanschauung,* yani içinde aydınlanmayı, araçsal aklı, rasyonalizmi ve hümanizmini barındıran bir dünya görüşü, bir paradigmadır.

Böylece bir aydınlanma projesi olarak hayata geçen modernlik aynı zamanda "bir zihniyet, dünyaya bir bakış ve bu bakışın yöntemleri, yaklaşımı ve bilgi-kuramsal araçları bakımından belli bir tarzda belirlenişidir" denilebilir (Bumin, 2005: 7). Bu açıdan bakıldığında aydınlanmanın kurucu aklını ilke edinen modernlik paradigması, hem Kant'ın, bireyin kendi eylemleri üzerine düşünebilen özgür insan tipolojisine ve bu özgür insan tipolojisinin dayandığı rasyonalizme, hem de aklı ve deneyi temel alan pozitivizme ama daha da önemlisi dünyayı, insanın bireysel/toplumsal çıkarına/yararına göre yeniden tasarlayan pragmatizm felsefesine dayandığı söylenebilir. Bu üç kavram, -rasyonalizm, pozitivizm ve pragmatizm- modernliğin aydınlanma felsefesinden aldığı ve bunlarla dünyayı yeniden şekillendirmeye/inşa etmeye çalıştığı temel paradigmalardır. Modernitenin temelini oluşturan ve bir büyük anlatı olarak ortaya çıkan aydınlanma felsefesinin en önemli özelliği ise hem aklı araçsallaştırması hem de araçsallaştırılan akılla doğanın ve dünyanın insanın egemenliğine girmesini sağlamaya çalışmasıdır.

Dolayısıyla dünyanın kavrayışında aklın yegâne ölçü(t) olarak el alınması, insana yaratıcı olduğu kadar yıkıcı bir imkân da sağladığı söylenebilir. İşin yaratıcı yanı, insanın aklı, kurucu bir unsur haline getirmesiyle en başta politik ve kültürel bağımlılıklarından kendisini kurtarmış olmasıdır. Toplumsal ve siyasal açıdan bağımsızlaşan insan, aynı zamanda kendi kaderini de belirlemiş ve özgürlüğünü elde etmiştir. İşin yıkıcı yanı, bu süreçte rasyonalitenin temel alınmasıyla dünyanın büyüsünün bozulmasına ve dolayısıyla da insana, dünyanın istendiği şekilde yeniden yaratılmasına, inşa edilmesine, tasarlanmasına, kontrol edilmesine, üzerinde denetim ve egemenlik kurulmasına, yerine göre yıkıp yakmak/yok etmek yerine göre altında ve üstünde ne varsa hepsini sömürmek gibi bir olanak/imkan hatta meşruiyet de sağlamıştır ki, bugünkü içinde bulunduğumuz/yaşadığımız geç modern zamanda, dünyanın nasıl tehdit edici bir yer haline geldiğini/getirildiğini de görebiliyoruz.

Giddens, Taylor ve Rosa'ın Sosyal Analizlerinde Dünyanın Hal-i *Pür Melali*

Günümüzün en önemli sosyologları arasında gösterilen Anthony Giddens, çağda toplumların geçirmekte oldukları değişim ve dönüşüme odaklanan ve bu konuda toplum teorilerini geliştiren biri olarak bilinmektedir. Çalışmalarında daha çok modernliğin ontolojik ve epistemolojik dayanakları üzerinde duran Giddens, modernliğin her şeyden önce dünyamızı yeniden üreten, onun deyimiyle "yerinden çıkaran" yanını sorgulamış ve bu konuda bazı teorik çıkarımlarda bulunmuştur. Ona göre modernlik paradigmasının en önemli özelliği, geleneksel toplum yapısını ve bu yapıyı üreten düşünsel, dinsel ve

kurumsal ilişkileri hedef alması, bireyselleşmeyi öne çıkartmak suretiyle mekanik dayanışmanın ve dinsel değerlerin egemen olduğu toplumsal ve siyasal düzenleri çökertmesidir.

Dolayısıyla modernitenin ve onun paradigması olan rasyonalite, tarıma dayalı uygarlıklardaki kültürü, zamanı, uzamı ama daha da önemlisi modern öncesi dünyada var olan ontolojik güvenliği sağlayan aile, akrabalık ve din ilişkileri ile geleneği yerinden çıkartmış; bunların yerine bireyselleşmeyi, özel ve seküler alanı ve rasyonaliteyi ikame etmeye çalışmıştır. Böylece dünyamız, modernlikle beraber ontolojik bir güvensizlik yaşamaya başlamış; bu güvensizlik hali, dünyayı daha tehlikeli, öngörülmez ve kestirilmez tehditlerin ve risklerin söz konusu olabildiği bir yer haline getirmiştir. Giddens'a (1998) göre modernite, dünyayı, büyü ve mitlerden arındırmak suretiyle daha emniyetli ve daha rasyonel bir yer haline getirmek vaadiyle yola çıkmış; ancak gelinen noktada dünyamız güvenli, emniyetli olmak bir yana daha çok güvensiz ve emniyetsiz bir hale gelmiştir.

Bu vaatte başarısız olunmasının en önemli nedeni, modernliğin o güne kadar insanları belli bir inanca, kuruma ve değerlere bağlayan ilişki ağlarını yapı bozumuna uğratması ve bunların yerine koyduğu değerlerin ise bireyleri gittikçe daha çok yalnızlığa sürüklemesi, yabancılaştırması; yaşamın bizzat risklerin adeta cirit attığı bir alana dönüştürmesidir. Çünkü Risk, Giddens'a göre (2000: 37), "modern sanayi uygarlığının gerçekten temel karakteristik özelliği olarak geçmişinden kopmak için fiili uğraş veren bir toplumu varsaymıştır." Bugün tanıklık ettiğimiz şey, modernliğin her şeyden önce dünyayı bir risk alanına çevirmiş olmasıdır. Zira karşımızda sadece doğal değil aynı zamanda imal edilmiş riskler de durmakta ve bu imal edilmiş risklerin ne zaman ve nasıl hayatlarımıza dokunacağı, bizi öngörülmez tehlikelere sokacağı ve dolayısıyla da hayatlarımızı tehdit edeceği belli olmamaktadır.

Geldiğimiz noktada modernliğin dünyayı daha güvenli bir yer kılmadığını, içinde yaşamakta olduğumuz ve çoğunlukla da maruz kaldığımız imal edilmiş riskler tarafından çok net bir şekilde ortaya konulmuştur. Zira bugün hiçbir modern bireyin güvenliği, tam olarak sağlanmış değildir. Hiç kimse hayatından emin bir biçimde yaşamamaktadır. Çünkü, modern yaşam o kadar çok risklerle dolmuştur ki, insanın kendisini bu risksel ortamlardan kurtarması pek mümkün görünmemektedir. Örneğin günümüzde yediğimiz gıdalar bile genetiği değiştirilmiş besinler oldukları için bizde bin bir değişik hastalıklara yol açabilmektedir. Aynı şekilde bugün hiç kimse enerji güvenliğinden de söz edememekte, çünkü etrafımız, nükleer silahlarla dolmuş durumdadır.

Nitekim 1996'da Ukrayna'daki Çernobil Nükleer İstasyonunda meydana gelen kaza, yaklaşık iki yüz bin insanın hayatını kaybetmesine yol açmış; bu durum, insanın kendi eliyle yarattığı/imal ettiği risklerin ne derece tehlikeli ve geriye dönüşü/telafisi mümkün olmayan sonuçlara yol açabileceğini göstermiştir. Modernliğin dünyayı daha ulaşılabilir ve erişilebilir hale getirmesinin yarattığı konformizmin bedeli çok ağır olmuştur. Yaşam standardının yükseltmesi, sosyal güveliği artırması, refahı ve rahatlığı getirmesi beklenen bilim ve teknoloji, kimi zaman insanın hayatıyla ödemesine yol açan neticeler doğurabilmiştir. Aslında sorun, çağımızın eski kuşaklara göre çok daha riskli bir hayat yaşaması değildir. Sorun, kendisini modern paradigma ekseninde konumlandıran insanın dünyayla ve doğayla kurduğu ilişkinin adilane olmamasıdır.

Nitekim böyle olduğundan dolayı modern dünya, insan için kimi zaman bir cehenneme veya kıyamete dönüşebilmektedir. Kısacası Giddens, iki yüzyıldır dünyamıza hâkim olan akıl temelindeki modernlik paradigmasının, bireylerde ve toplumlarda ontolojik bir güvensizlik yarattığını vurgulamış ve yeni yaşam politikalarının geliştirilmesini ve doğayla da yeni bir sözleşme imzalanmasını savunmuştur. Giddens' la beraber modernliği sanık sandalyesine oturtan diğer bir düşünür de Charles Taylor'dır. O da tıpkı Giddens gibi hem modernliğin nimetini hem de külfetini sorgulamaya çalışmış; modern paradigmanın dünya tasavvurunda üç temel sorunun göze çarptığını vurgulamıştır. Taylor, "modernliğin sıkıntıları" (2011: 9-19) adını verdiği bu sorunları şu üç başlık altında toplamıştır.

Buna göre modernliğin en önemli sorunu, bireyi, içinde yaşadığı topluma ve doğaya yabancılaştırması, dünyanın geleneksel kavrayışını ters yüz etmesi ve dolayısıyla dünyayı büyü bozumuna uğratması ve komünteryalizmin kaybına yol açan bireyselliği kutsallaştırmasıdır. İkincisi, modernliğin araçsal aklın egemenliğini sağlaması, doğanın ve dünyanın anlam yitimine neden olması, katı olan her şeyin buharlaşarak aklın her şeyin ölçütü/ölçüsü haline gelmesidir. Üçüncüsü ise siyasal alanda bürokratik devlet geleneğinin kurulması, insanın adeta bir demir kafese kapatılması ve bireysel özgürlüğün ve özyönetimin kayba uğraması/ uğratılmasıdır. Dolayısıyla modernite, dünyayı ve doğayı mekanik bir

hale getirmek, insanı da bu mekanik yapı içinde hareket eden ama kendi başına bağımsız ve özgür olmayan bir bireye dönüştürmek suretiyle mutlak bir despotluk düzeni kurmuştur.

Özetle Taylor's göre modernite, geleneksel toplumdan tevarüs eden değerleri irrasyonel oldukları gerekçesiyle bir kenara atmış ve yerine koyduğu değerler ise yeni bir anlam yaratmak yerine daha fazla anlamsızlık üretmiştir. Modernlik bu bağlamda, insanın özgürlüğünü artırmak bir yana insanın daha çok benmerkezci yaşamasını salık veren bir ekonomi-politik de üretmiştir. Dünya, bu ekonomi-politik yapıda sömürülecek bir yer haline gelmiş/getirilmiştir. Bugün dünyanın her köşesinde görüp karşılaştığımız ama kendi adımıza en ufak bir hesap bile çıkartmaya yanaşmadığımız ekolojik felaket tabloları, aslında modernliğin bize sunduğu veya ödettiği hayatın adeta bir özetidir.

Modernliğin dünya tasavvuruna dair görüşlerine başvuracağımız diğer bir kişi de günümüzde eleştirel teorinin en önemli düşünürleri arasında gösterilen ve zamanın sosyolojisi alanındaki çalışmalarıyla bilinen Hartmut Rosa olacaktır. Rosa, 2018 yılında Almanya'da yayınladığı ve Türkçeye "Dünyanın Kontrol Edilemezliği" başlığıyla çevrilen kitabı, modern paradigma ve yaşam biçiminin temelinde dünyanın denetlenmesi fikrinin yattığı, ancak iki yüz yıla yakındır dünyaya egemen olan bu fikrin hiçbir zaman dünyayı kontrol edemediğini savunmaktadır. Rosa'a göre (2024: 8-9) modernite, dünyayı tüm yönleriyle ölçülebilir, görülebilir, erişilebilir, ulaşılabilir ve dolayısıyla da elde edilebilir, kontrol edilebilir ve üzerinde egemenlik kurulabilir bir hale getirme konusunda bitmeyen bir arzuya sahip olduğunu; ancak bu arzunun hiçbir şekilde gerçeklemediğini, gerçekleşemeyeceğini zira kontrol etme çabasının en önemli sonucunun beraberinde kontrol edilemezliği getirmesi olduğunu vurgulamıştır. Onun ifadeyle (2024: 14);

> Biz geç modern özneler olarak söz edilen tüm düzeylerde -bireysel, kültürel, kurumsal ve yapısal- dünyayı kontrol etmeyi amaçladığımız için, dünyayla her zaman bir "saldırganlık merkezi" ya da bir dizi saldırganlık merkezleri olarak karşılaşmaktayız. Bu saldırganlık merkezleri bir başka deyişle, bilinmesi, ulaşılması fethedilmesi, hâkim olunması veya kullanılması gereken nesneler olarak ifade edilebilir. Bu tutumumuzdan ötürü "hayat" bize, canlı hissetme ve dünyayla gerçekten karşılaşma deneyiminden- rezonansı mümkün kılan şey- mahrum bırakır ve elimizden kaçıyor gibi görünür. Bu durum, kaygıya, hayal kırıklığına, öfkeye ve hatta umutsuzluğa yok açmakta ve daha sonra diğer şeylerin yanı sıra güçsüz siyasi saldırganlık biçimiyle kendini göstermektedir.

Rosa, içinde yaşamakta olduğumuz geç modern toplumlarda başta bilimsel ve teknolojik gelişmeler olmak üzere finansal kapitalizmi ve serbest rekabeti öne çıkaran neoliberal politikaların dünyamızı daha öncesinden görülmemiş boyutlarda elde edilebilir hale getirdiğini, ancak bu elde edilebilir halin sanıldığı gibi dünyayı istediğimiz şekilde kontrol edebileceğimiz anlamına gelmediğini, zira her kontrol çabasının beraberinde kontrolsüzlüğü da getirdiğini vurgulamıştır. Her şeyi kontrol etme düşüncesinin temelinde modernlik paradigmasının pragmatizm fikri yattığını iddia eden Rosa, bu fikrin bizi daha güvenli ve huzurlu bir dünyaya değil, tam aksine daha güvensiz ve huzursuz bir dünyaya sevk ettiğini düşünmüştür. Ona göre modern paradigmanın dünyayı kontrol edilebilir hale getirmesinin farklı boyutları bulunmaktadır. Bir yanda bilim, dünyanın bilinebilir kılmasını sağlarken diğer yanda teknoloji, dünyada var olan kaynaklardan maksimum düzeyde yararlanmayı sağlamıştır.

Dolayısıyla bilim ve teknoloji, insanın dünyayı fethetmesi aruzunu hayata geçiren en önemli unsurlardır. İnsan, bilim sayesinde dünyanın gizemini çözmüş; yeni yerler keşfetmiş ve keşifler sayesinde kendisine daha konforlu denebilecek bir yaşam alanı yaratmıştır. Aynı şekilde teknoloji, dünyanın yer altı ve yer üstü kaynaklarından daha fazla yararlanmayı sağlamıştır. Rosa'a göre (2024:27) "dünyayı kontrol edilebilir kılma konusundaki bu kültürel vaat, sadece "işe yaramamakla" kalmamış, aslında tam zıddına dönüşmüştür. Bilimsel ve teknik, ekonomik ve politik olarak kontrole açık haldeki dünya, gizemli bir şekilde bizden kaçar ve bizi engelliyor gibi görünür, geri çekilir, okunamaz ve sessiz hale gelir. Daha da ötesi hem tehdit altında olduğunu hem de tehdit oluşturduğunu ve böylece yapısal olarak kontrol edilmez olduğunu kanıtlar."

Kısacası Rosa, geç modern toplumlarla beraber dünyayı kontrol etme yönündeki arzumuzun aslında beyhude bir arzu/çaba olduğunu, zira hem dünyayı kontrol ettiğimizi düşündükçe aslında dünyanın bizden kaçmaya başlamakla kalmayıp aynı zamanda bize karşı bir düşmana dönüştüğünü iddia etmiştir. Çünkü insan, dünyaya ve doğaya yönelik hasmane bir tutum içinde kaldığı sürece dünya ve doğa, kendi

intikamını almaya ve kendisine yapılanları misliyle geri vermeye çalışacaktır. Nitekim günümüzde doğal ve imal edilmiş afetlerin ve risklerin her geçen gün daha fazla yaşamımızı alt üst etmesinin nedeni, söz konusu doğaya olan tavrımızdan ve onu durmadan sömürmemizden kaynaklanmaktadır.

Sonuç

Bu bildiride genelde, pozitivizme, rasyonalizme ve pragmatizme dayanan modernlik paradigmasının nasıl bir dünya tasavvur ettiğini, özelde de çağdaş sosyologlardan Giddens, Taylor ve Rosa'nın modenlik paradigmasına yönelik yapmış oldukları tartışmalar ve tespitler üzerinde duruldu. Giddens, Habermas' tan hareketle aydınlanmanın tamamlanmamış bir proje olduğunu, modernliğin hem yaratıcı, devrimci, yıkıcı ve yıpratıcı olduğunu hem de her şeyden önce bireylerde ontolojik bir güvensizlik yarattığını ama daha da önemlisi dünyada bir cennet kurma vaadini yerine getirmek bir yana dünyayı imal edilmiş risklerle yapısal düzeyde derin bir krize sevk ettiğini vurgulamıştır. Yazara göre bu krizden çıkmanın yolu, modernliğin doğa ve dünya paradigmasını değiştirmesinden geçmektedir.

Kanadalı sosyolog Taylor ise modernliğin üç temel sorununu gündemine almaktadır. Bunlardan ilki, bireyin toplumdan soyutlanmasına ve izole edilmesine neden olan modern yaşam, diğeri, modern çağın aklı araçsallaştırması, dolayısıyla da araçsal aklın egemen olması ve bir diğeri de modern yaşamda insanın anlam kaybı yaşamasıdır. Düşünüre göre bütün bu sıkıntı ve sorunlar, modernliğin pragmatizme ve rasyonalizme dayalı paradigmasından kaynaklanmaktadır. İnsanı özne olmaktan çıkartan bu çıkar eksenli paradigma, özü itibariyle bireyi her tür kolektif bağdan ve ilişki ağından kopartmış; kendi başına kendisi için yaşayan bir birey profili yaratmıştır. Aynı şekilde bu paradigma, doğanın da kullanılması, sömürülmesi ve tüketilmesi gereken bir kaynak olarak görmüştür. İnsanı nesne, doğayı kaynak olarak gördüğü için modern paradigma, yaşamı da yaşanılır kılmaktan çıkartmıştır.

Görüşlerine başvurduğumuz bir diğer düşünür Rosa ise, tıpkı Giddens ve Taylor gibi o da modernliğin dünya tasavvurunu sorunlu bulmuştur. Ona göre geç modern bireyler olarak yürüyen merdivenlerde bile hareket halindeyiz. Hareket, dinamizm, değişim, dönüşüm ama daha da önemlisi her şeyi bilme ve kontrol etme sevdası, biz geç modern toplumların en önemli özelliği olmuştur ki, bu özellik, bizi dağları, ovaları, okyanusları, ormanları kirletmemize ve tüketmemize; dünyayı sessiz ve renksiz bir hale getirmemize neden olmuştur. Biz, dünyaya saldırdıkça dünya da bize saldırmaya ve intikamını almaya çalışmıştır. Biz, dünyayı kontrol etmeye çalıştıkça aslında dünya kontrolden çıkıp hayatlarımızı adeta cehenneme çevirmiştir. Yapılması gereken şey, hesapçı ve pragmatik yanımızı terk etmek suretiyle dünyayla ve doğayla yeniden barışmaktır. Onun için de öncelikle dünyayı kontrol etme arzumuzdan vazgeçmemiz gerekir.

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PAZARLAMADA TÜKETİCİ GÜVENİNİN ROLÜ: BİLİMSEL YAYINLARIN HARİTALANDIRILMASI

THE ROLE OF CONSUMER TRUST IN MARKETING: MAPPING SCIENTIFIC PUBLICATIONS

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ÖZET

Bu çalışmanın amacı 1995-2024 yılları arasında yapılan ve Web of Science veri tabanında taranan pazarlama alanındaki tüketici güveni kavramına ilişkin çalışmaları bibliyometrik özellikler açısından incelemek ve değerlendirmektir. Çalışma bu süre aralığında yayınlanan 446 adet çalışmayı kapsamaktadır. Araştırmanın analizi sırasında R yazılım programında yer alan bibliometrix ve biblioshiny paketlerinden yararlanılmıştır. Çalışma kapsamında tüketici güvenine ilişkin tanımlayıcı temel bilgiler, yıllara göre en çok yayın yapan ve atıf alan yazarlar, iş birlikleri en etkili yayınlar ve yazarlar, iş birlikleri, ülkeler ve kurumlar, anahtar kelimeler, anahtar kelimelerin kavramsal yapısı ve tüketici güveni konu başlığının tüm detaylı incelenmiştir. Araştırma bulguları sonucunda pazarlama ve tüketici güveni konusunda en çok çalışma yapan araştırmacının Kenny Basso ve en çok yayın yapan derginin de International Journal of Bank Marketing, en sık tekrar edilen kelimelerin "trust" ve "consumer trust" olduğu bilgilerine ulaşılmıştır. Bu çalışma, pazarlamada tüketici güvenine ilişkin yapılmış olan yayınların kapsamlı bir analizini sunarak bu alanda yapılacak olan bilimsel çalışmaların kapsamının genişletilmesine yönelik katkı sağlamayı amaçlamaktadır.

Anahtar Kelimeler: Pazarlama, Tüketici Güveni, Bibliyometrik Analiz, Güven, Sadakat

ABSTRACT

The purpose of this study is to examine and evaluate studies on the topic of consumer trust in marketing, which were conducted between 1995 and 2024 and scanned in the Web of Science database, in terms of bibliometiric features. The study covers 446 studies conducted. The bibliometrix and biblioshiny packages in the R software programme were used during the analysis of te study. Within the scope of the study, descriptive basic informartion consumer trust, the most published and cited authors by year, collaborations, the most effective publications and authors, counbrtires and institutions, keywords and conceptual structure of keywords and the consumer trust topic were examined in detail. As a result of the research findings, it was found that the researcher who conducted the most studies on marketing and consumer trust is Kenny Basso; the journal with the most publications is International Journal of Bank Marketing; and the most frequently repeated words are "trust" and "consumer trust". This study aims to contribute to expad the scope of scientific studies in this field by presenting a comprehensive analysis of publications on consumer trust in marketing.

Keywords: Marketing, Consumer Trust, Bibliometric Analysis, Trust, Loyalty

Giriş

Güven, çeşitli alanlarda hem bireyler hem de kurumlar için kritik öneme ve belirleyicilere sahip geniş ve karmaşık bir kavramdır. İlk anlamı ile güven, korku, çekinme ve kuşku duymadan inanma ve

bağlanma duygusu; emniyet, itimat şeklinde açıklanmaktadır (Türk Dil Kurumu-TDK, 2025). Bir başka tanıma göre güven, bir başkasının niyetine ilişkin olumlu beklentilerden kaynaklanan kırılganlığı kabul etme niyetinin bir sonucu olan psikolojik bir durum olarak açıklanmaktadır (Rousseau vd., 1998). Farklı bir ifade ile güven, bireylerin, organizasyonların, örgütlerin veya sistemlerin güvenilirliğine ve bütünlüğüne karşı hissedilen itimat ve inanç ile ilişkilendirilen duygusal ve psikolojik bir durum olarak da ifade edilebilir.

Pazarlama açısından değerlendirildiğinde ise değişime taraf olanlar için güven, bir tarafın diğer ortağın güvenilirliğine ve dürüstlüğüne güvenmesi durumunda ortaya çıkan sonuç olarak ifade edilebilir (Morgan ve Hunt, 1994). Tüketicilerin satın alma davranışları içsel ve dışsal birçok faktörden etkilenmektedir. Bir tüketicinin satın alma davranışı ilk olarak bir ihtiyaç ya da istek duyması ile başlamakta ve memnuniyet veya memnuniyetsizlik ile devam etmektedir (Blackwell, vd.,2006). Tüketicilerin memnuniyeti sonrasında ise güven beklenen sonuçlardan bir tanesidir. Tüketicinin duyduğu güven ve alışveriş sonrasında yaşadığı memnuniyet ise tüketici bağlılığı şeklinde ilerlemekte ve tekrar satın alma, olumlu ağızdan ağıza reklam gibi istenilen sonuçlar doğurmaktadır. Dolayısıyla güven, pazarlama süreci içerisinde çok önemli bir yere sahiptir. Tüketicinin satın alma niyetini etkileyen faktörlerin arasında güven de önemli bir kavramdır (Çolakoğlu Gürer & Demir, 2021:15). Güven kavramı, geleneksel pazarlamada olduğu kadar dijital pazarlamada da son derece önem arz etmektedir. Teknolojinin gelişmesiyle birlikte hayatımıza pek çok dijital pazarlama yöntemi girmiş bulunmaktadır. Dijital pazarlama yöntemi fark etmeksizin tüketici güveni işletmeler ve markalar açısından vazgeçilmez değerlerden bir tanesini oluşturmaktadır.

1. Pazarlamada Tüketici Güveni

Güven kişiler arası ilişkilerin temelini oluşturmakta ve yine kişiler arası iş birliği için de öncelikli ihtiyaç olarak kabul görmektedir. Türk Dil Kurumu ise güveni korku, çekinme ve kuşku duymadan inanma ve bağlanma duygusu; emniyet, itimat olarak açıklamaktadır (TDK, 2025). Güven, tutarlı, olumlu deneyimler yoluyla ortaya çıkmaktadır ve bu şekilde derinleşmekte; şeffaf etkileşimler, tüketicilerin algılarını, kararlarını ve davranışlarını önemli ölçüde şekillendirmektedir (Schilke, vd., 2021).

İçinde bulunulan çağda işletmelerin ya da markaların tüketicileri ile sadece iletişimde bulunmaları yeterli kabul edilmemektedir. Artık aranan şey iletişimden ziyade etkileşim içerisinde olabilmektir (Uzkurt, 2008: 33). İşletme ve tüketici arasında yaratılan etkileşim başarılı olduğu sürece işletmeler rakipleri arasından sıyrılarak daha başarılı olabilmektedirler. İki tarafın da birbiri ile güvene dayalı bir etkileşimlerinin olması istenilen bir durumdur. Tüketicilerin bir ilişkiyi sürdürmeye devam edebilmeleri için güven başlıca gereklilik olarak kabul edilmektedir (Gwinner vd., 1998). Bu noktada da işletmeler güvene dayalı bu etkileşimin sürdürülebilir olması yönünde stratejiler geliştirmeli ve çaba sarf etmelidirler. Tüketiciye verilen güven ve bunun bir sonucu olarak oluşan bağlılık, uzun vadede işletmeler ve markalar için önemli bir kazanımdır (Gecikli vd., 2021:318). Olumlu bir işletme – tüketici ilişkisinin temelinde güven bulunmaktadır. Tüketici güveni, ilişkide tarafların birbirlerine verdikleri sözlerin tutulacağına yönelik hissedilen inancın derecesi ile ilişkilidir. Underwood vd. (2001)'e göre tüketicinin her alışverişinde herhangi bir değişiklik olmadan aynı ürünle buluşmaya devam ettiği sürece bir başka ifade ile ürünün sürekliliği sağlandığı süre boyunca markalar ve tüketiciler arasında güven sürdürülebilir olacaktır.

Teknolojinin geldiği yer düşünüldüğü zaman günlük aktivitelerin pek çoğunu teknolojiden faydalanarak ve hatta internet üzerinden gerçekleştirildiğini ifade etmek yanlış olmayacaktır. İnternet üzerinden gerçekleştirilen eylemlerin önemli bir kısmını da internetten yapılan alışverişler oluşturmaktadır (Karabulut, 2013: 5533). Tüketicilerin internet alışverişlerini yapma eğilimleri ve isteklilikleri güven, kolaylık ve daha pek çok unsurdan etkilenmektedir (Yaşlı & Parıltı, 2022: 250). Tıpkı geleneksel pazarlamada olduğu gibi dijital pazarlamada da güven inşa etmek oldukça zor olarak kabul edilmektedir. Dolayısıyla geleneksel veya dijital fark etmeksizin tüketici güveni pazarlamada çok önemli bir rol oynamaktadır (Gürkaynak Gürbüzer & Hasıloğlu, 2024: 2). Günümüz pazarlamasında amaç en basit ifade ile tüketici ihtiyaçlarına en hızlı ve etkili biçimde cevap verebilmek ve tüketiciyi memnun edebilmekle açıklanmaktadır. Memnuniyet ise genellikle tüketicinin bir markaya duyduğu güven ve inanç ile ilişkilendirilmektedir. Bunun yanı sıra önemli kabul edilen bir diğer kavram olan marka

sadakatinin de öncelikle tüketici güvenine dayandığı kabul edilmektedir (Yaşlı & Parıltı, 2022: 252). Tüketici güveni, tüketici kararlarında ve tüketici sadakatinde hayati bir rol oynamaktadır.

Zaman içerisinde tüketim, çevrimiçi ve çevrimdışı olacak biçimde evrimleşmiştir. Gerek çevrimiçi gerek çevrimdışı tüketicileri etkileme konusunda güvenin önemi ve değeri asla hafife alınmamalıdır. Çevrimiçi ya da çevrimdışı fark etmeksizin güven, tüketici açısından satın alma kararını etkileyen kavramlar arasında en önemlilerindendir. Grabner-Krauter ve Faullant (2008) yaptıkları internet bankacılığı ve çevrimiçi finansal hizmet kullanımına ilişkin çalışmalarında tüketici açısından internet güveninin önemini incelemişlerdir. Çalışmalarının sonucu ise internet güveninin, dijital bankacılık ile ilgili risk algısı ve tüketici duygusu üzerinde oldukça önemli bir etkisi olduğunu göstermektedir. Ayrıca aynı araştırmanın sonuçlarından güvenin, kişiler arası ilişkilerde ve teknolojik etkileşimde temel faktör olduğu sonucuna da ulaşılmıştır.

Son yıllarda e-ticaretin ve online alışverişlerin büyüme hızı değerlendirildiğinde çevrimiçi tüketici güveninin mevcut tüketici alışkanlıklarını anlama ve tüketicilerin gelecekteki online alışveriş eğilimlerine ilişkin tahminde bulunma noktalarında önemli bir araç olduğu aşikardır. Bauman ve Bachman (2017) online tüketiciler ile ilgili olan çalışmalarında teknoloji ve sosyal faktörlerin online tüketici güveni ile yakından ilişkili oldukları sonucuna ulaşmışlardır. Bu çalışma ile teknoloji, sosyal faktörler ve tüketici güveni arasında güçlü bir ilişki olduğu sonucuna ulaşılmıştır. Dolayısıyla tüketici güveninin önemi geleneksel pazarlamada olduğu kadar dijital pazarlamada da geçerlidir. Shiver (2021) dijital pazarlama ve tüketici davranışıyla ilişkili çalışmasında da benzer sonuçlara ulaşarak dijital platformlarda satın alma kararı verirken güvenin önemli bir belirleyici olduğu sonucuna ulaşmış ve tüketicilerin güveni değerlendirirken çevrimiçi yorumların önemli bir referans olduğunu ifade ettiğini belirtmiştir. Çalışma sonucunda çevrimiçi tüketici yorumları ile kazanılan güven ve inancın birçok tüketici için karar alma sürecinde kritik bir unsur olduğu sonucuna ulaşılmıştır (Yaşlı & Parıltı, 2022: 251). Benzer şekilde Google, Facebook ve diğer tüketici merkezli platformlardan erişilen tüketici yorumları, güven kazanmada en değerli unsurlar olarak değerlendirilmektedir. İçeriklerin etkili ve güvenilir olabilmesi için tüketiciye konuyla ilişkili ve yüksek seviyede uzmanlık (expertise), yetki (authority) ve güven (trust) sunması bir başka ifade ile EAT özelliklerine sahip olması gerekmektedir. Google, EAT formülünü çevrimiçi içerik arama sıralamaları için önemli bir belirleyici olarak tanımlamaktadır. Dolayısıyla da bu süreç, işletmeler ve markalar için uzun vadeli iş geliştirme stratejisi olarak düşünülmelidir.

Markaya duyulan güven, ortalama bir tüketicinin tercih ettiği bir markanın belirli düzeyde bir işlevi tutarlı bir şekilde yerine getireceğine olan güvenme isteğini ifade etmektedir (Jun ve Yi, 2020). Bu duyulan güven, belirsizlik olan durumlarda rasyonel kararlar almaya çalışan tüketicilerin belirsizliğini azaltmaktadır. Markaya duyulan güven, bugün her alan ve boyuttaki işletme için önemli bir faktör haline gelmiştir. Kantar Millward Brown (2016) tarafından gerçekleştirilen bir araştırmanın sonucuna göre marka güveni konusunda yüksek puan alan işletmeden işletmeye (B2B) markaların son on yılda marka değerinde %80 büyüme gözlemlenirken, daha az güven duyulan markaların ise sadece %25 büyüme gösterdiği tespit edilmiştir. Bütün bunlar göz önüne alınarak değerlendirildiğinde ise tüketici güveninin markalar ve işletmeler, için ne kadar vazgeçilmez ve önemli olduğu tartışılamaz bir gerçek haline gelmektedir. Bireylerin online aktivitelerinin artmasının doğal bir sonucu olarak artan dijital pazarlama kavramı da yine benzer şekilde tüketici güveni ile doğrudan ilişkilidir (Çolakoğlu Gürer & Demir, 2021:16). Geleneksel pazarlamada güven kavramı ne kadar önemliyse ve tüketici davranışını etkilemekteyse dijital pazarlamada da o derece önemli ve tüketici satın alma kararı üzerinde etkili bir kavram olarak kabul görmektedir. Hem geleneksel hem de dijital pazarlamada vazgeçilmez bir role sahip olan tüketici güveni, bu çalışmada da bütünüyle ele alınmaya çalışılarak uluslararası alanda yer alan çalışmalar bibliyometrik analiz yöntemiyle incelenmiştir.

2. Yöntem

Bibliyometrik analiz, akademik çalışmalar üzerinde uygulanan matematiksel ve istatiksel bir uygulamadır (Nebioğlu, 2019:2). Bibliyometrik analizi araştırmacıyı bir alandaki ilgili çalışmalara yönlendirerek ve bu çalışmaları haritalandırarak alandaki bilgiyi genişletmeyi amaçlayan bir analiz türüdür. Bu analiz yöntemi ile alandaki araştırma eğilimleri haritalama ile tanımlanabilir. Bir başka ifade ile bibliyometrik analiz, belirli bir alan ya da konu başlığına ilişkin bilimsel literatürü sistematik bir

biçimde inceleyen, ilgili araştırmacıları ilgili çalışmalara yönlendiren ve bu çalışmaların yapısal ilişkilerini haritalandırmakta kullanılan bir analiz yöntemidir. Bu analiz yöntemi ile çalışılmak istenen araştırma alanları dikkatli ve detaylı bir şekilde analiz edilerek alana ilişkin güncel durum, söz konusu alandaki iş birlikleri, alana ilişkin yayın trendlerinin ne olduğu ve yıllar içerisindeki değişimi gibi veriler ortaya koyulmaya çalışmaktadır (Güçlü, 2024: 69).

Çalışmanın başlangıç aşamasında anahtar kelimeler belirlenmiş ve Web of Science veri tabanında tüketici güveni ve pazarlama ilişkisine yönelik araştırmalar taranmıştır. Saha araştırması "consumer trust" ve "marketing" konu başlıkları ile yapılmıştır. Bu çalışmada 1995 -2024 yılları arasında yapılmış ve Web of Science veri tabanında taranmış olan 446 adet çalışma incelenmiştir. Bunun yanı sıra Web of Science veri tabanı araştırmacılara kullanım kolaylığı sunarak birçok kontrol fırsatı tanıyan mekanizmaya ve ileri arama göstergelerine sahiptir. Dolayısıyla Web of Science, detaylı verilere ulaşmada kolaylık sağlaması sebebiyle araştırmacılar tarafından sık sık tercih edilen, güncel ve güvenli verilen sunan bir veri tabanı olduğu için tercih edilmiştir. Araştırmaya makaleler, kitap bölümleri, kongre bildirileri, kongre bildiri makaleleri ve incelemeler gibi farklı çalışma türlerinin sadece İngilizce dilinde yapılmış olanları dahil edilmiştir.

Bu çalışmada bibliyometrik analiz için R yazılım programı tercih edilmiştir. Analizler, R yazılım programında bibliometrix ve biblioshiny paketleri kullanılarak gerçekleştirilmiştir (Aria ve Cuccurullo, 2017). Bu paket ile tüketici güveni ve pazarlama ilişkisine dair akademik literatür detaylı bir şekilde analiz edilmiştir.

Bu çalışma kapsamında belirlenen amaçlar doğrultusunda araştırma soruları oluşturulmuştur:

Araştırma sorusu 1: Yıllar içerisinde tüketici güveni ve pazarlama araştırma konusunun büyüme oranı nedir?

Araştırma sorusu 2: Tüketici güveni ve pazarlama alanında en çok çalışma yayınlayan dergiler hangileridir?

Araştırma sorusu 3: Tüketici güveni ve pazarlama alanında en çok çalışma yapan araştırmacılar kimdir?

Araştırma sorusu 4: Tüketici güveni ve pazarlama alanında en çok atıf alan çalışmalar hangileridir?

Araştırma sorusu 5: Tüketici güveni ve pazarlama alanında en çok çalışma yapılan ülkeler hangileridir?

Araştırma sorusu 6: Tüketici güveni ve pazarlama alanında en çok kullanılan anahtar kelimeler hangileridir?

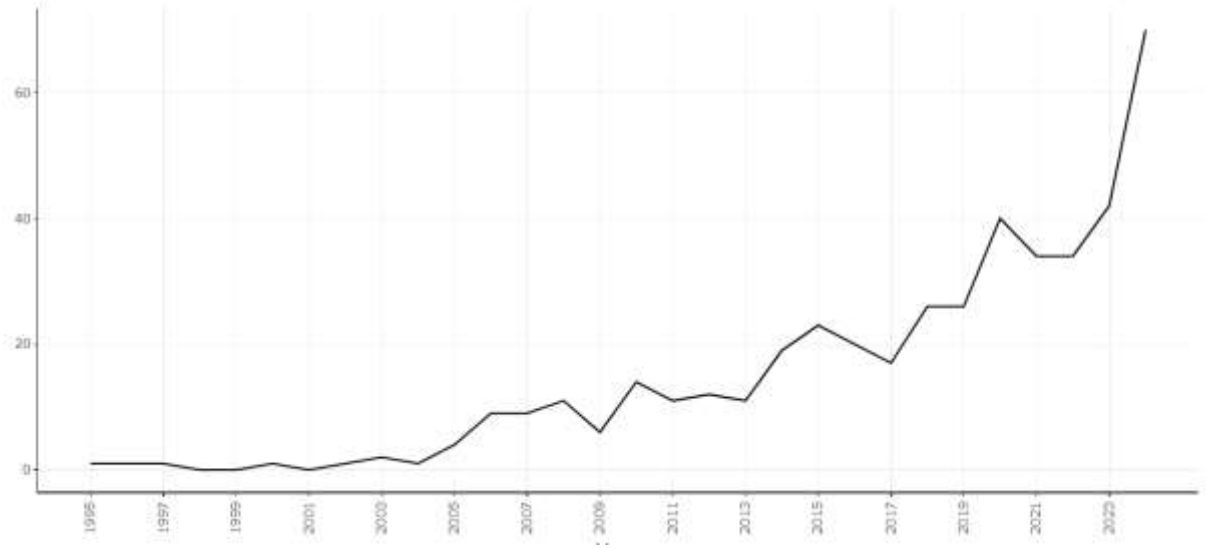
3. Bulgular

Araştırma kapsamına dahil edilen akademik çalışmalar, çalışma türleri, çalışmaların yıllara göre dağılımı, en çok atıf alan çalışmalar, en çok atıf alan yazarlar, en çok makale yayımlanan dergiler, en fazla çalışma yapılan ülkeler, en çok tekrar edilen kelimeler başlıklarında incelenmiştir. Tablo 1'de elde edilen temel bilgiler yer almaktadır.

Tablo 1: Elde Edilen Temel Bilgiler

Tanım	Sonuçlar	Tanım	Sonuçlar
Veriler Hakkında Ana Bilgiler		**Yazar İş Birliği**	
Zaman Aralığı	1995-2024	Tek Yazarlı Çalışmalar	42
Kaynaklar (Dergiler, Kitaplar, vb.)	182	Yayın Başına Ortak Yazarlar	404
Yayınlar	446	Uluslararası Ortak Yazarlıklar	31,17
Yıllık Büyüme Oranı %	15,78		
Yayın ortalama Yaşı	6,25	Çalışma Türleri	
Yayın Başına Ortalama Atıf	42,33	Makale	368
Atıflar	23,574	Kitap Bölümü	8
Yayın İçerikleri		Erken Erişim Makale	17
Anahtar Kelimeler Plus (ID)	921	Geri Çekilmiş Yayın	1
Yazar Anahtar Kelimeleri (DE)	1450	Kongre Bildiri Makalesi	2
Yazarlar		Kongre Bildirisi	39
Yazar Sayısı	1163	İnceleme	11
Tek Yazarlı Çalışmaların Yazarları	42		

Tablo 1, 1995'ten 2024'e kadar olan dönemde İngilizce olarak yazılan "Consumer Trust" ve "Marketing" kavramlarının birlikte incelendiği yayınların geniş ve detaylı bir analizini ortaya koymaktadır. Bu dönem boyunca araştırmacılar tarafından 182 kaynakta yayımlanan 1163 farklı yazar tarafından 446 adet çalışma gerçekleştirilmiştir. Bu çalışmaların 42'si tek yazarlıyken, 404'ü birden fazla yazar tarafından kaleme alınmıştır. Verilere göre uluslararası yazar iş birliklerinin %31,17 olduğu görülmektedir. Analiz sonuçlarına göre her bir yayın ortalama 42,33 alması ve yıllık %15,78'lik bir büyüme oranına sahip olması bu konu başlıklarına olan ilginin de arttığını göstermektedir.



Şekil 1: Tüketici Güveni ve Pazarlama Çalışmalarının Yıllara Göre Dağılımı

Şekil 1 ise tüketici güveni ve pazarlama ilişkisini inceleyen çalışmaların yıllar içerisinde istikrarlı bir büyüme gösterdiğini ortaya koymaktadır. 2006'ya kadar yılda sadece 1 ya da 2 hatta bazı senelerde hiç çalışma yapılmayan bir konuyken 2006 ve sonrasında sıklıkla çalışılan bir konu haline gelen tüketici güvene ve pazarlama ilişkisi artan akademik ilgiyi göstermektedir. Şekilde 1'de görüldüğü üzere özellikle 2014 ve sonrasında hızlı bir artış dikkat çekmektedir.

Tablo 2: Tüketici Güveni ve Pazarlama Çalışmalarının Türleri

Yayın Türü	Yayın Sayısı	Yüzde %
Makale	368	82,51
Kitap Bölümü	8	1,79
Erken Erişim Makale	17	3,81
Geri Çekilmiş Yayın	1	0,22
Kongre Bildiri Makalesi	2	0,45
Kongre Bildirisi	39	8,74
İnceleme	11	2,47

Analiz edilen veriler değerlendirildiği zaman çalışmaların makale, konferans bildirisi, inceleme ve kitap bölümü gibi farklı çeşitlerde yapılmış akademik çalışmalardan oluştuğu Tablo 2'de görülmektedir. 446 adet akademik çalışmanın çoğunluğunu 368 adet çalışma ile makaleler oluşturmaktadır. Sonrasında ise sırasıyla 41 çalışma ile kongre bildirileri, 17 çalışma ile erken erişim makaleler ve çalışma ile kitap bölümü takip etmektedir. Farklı çeşitlerde yapılan bu çalışmaların tüketici güveni ve pazarlama ilişkisinin incelendiği literatürü zenginleştirdiği görülmektedir.

Tablo 3: Tüketici Güveni ve Pazarlama Konularına İlişkin En Çok Yayın Yapan Dergiler

Kaynak	Çalışma Sayısı
International Journal of Bank Marketing	40
Asia Pacific Journal of Marketing and Logistics	16
Journal of Islamic Marketing	15
Marketing Intelligence \& Planning	15
Psychology \& Marketing	12
Journal of Services Marketing	11
European Journal of Marketing	10
Frontiers in Psychology	10
Journal of Research In Interactive Marketing	9
Journal of Financial Services Marketing	8

Tablo 3'te tüketici güveni ve pazarlama konularında en çok yayın yapmış dergiler listelenmekte ve dergilerin yayın sayıları gösterilmektedir. International Journal of Bank Marketing dergisinin 40 çalışma ile bu alanda en çok dikkat çeken kaynak olduğu görülmektedir. Ardından ise Asia Pacific Journal of Marketing and Logistics 16, Journal Of Islamic Marketing ile Marketing Intelligence /& Planning 15'er çalışma ile sıralanmaktadır.

Akademik çalışmaların analizi sırasında tercih edilen bir yöntem de Bradford Yasası'dır. Bradford Yasası belirli bir araştırma alana ait temel akademik dergileri belirlemek amacıyla kullanılan bibliyometrik bir ilkedir (Batra vd., 2023) ve Samuel Clement Bradford tarafından 1934 senesinde geliştirilmiştir. Bradford Yasası'na göre yayınlar konsantre bir şekilde dağılım göstermektedir. Bu yasa, az sayıdaki derginin ilgili konuya ilişkin olan çalışmaların büyük bir kısmını içerdiği öngörüsüne dayanmakta ve temel olarak bir konuda yayımlanmış olan çalışmaların ilgili dergiler arasında nasıl ve ne yoğunlukta dağıldığını açıklamayı amaçlamaktadır (Bradford, 1934). Buna göre ilgili alanda yayımlanan makaleleri temel alarak, dergiler üç farklı bölgeye ayırılarak sınıflandırılmaktadır. Bradford Yasası'na göre belirli bir alana ilişkin en çok yayın yapan birkaç temel dergi bulunmaktadır ve sonrasında daha az sayıda yayın yapan dergiler gelmektedir. Sonuç olarak Bradford Yasası yayın yapan dergileri yayın sayılarına göre gruplara ayırmaktadır (Egghe, 1986).

Birinci bölgede belirli bir konuya yoğun şekilde odaklanan ve bu konuda makalelerin çoğunluğunu içeren temel dergiler bulunmaktadır. Bu dergiler, alanla ilgilenen araştırmacılara en güvenilir ve en çok referansa sahip olan kaynakları sunan dergiler olup konuya ait en kapsamlı ve güncel yayınları içermektedir. Bu sebeple araştırmacılar alana ait araştırma yaparlarken ilk önce alanda temel ve merkezi bir konumda yer alan bu dergilerden faydalanmaktadırlar ve böylelikle birinci bölgedeki bu dergiler ilgili bilimsel alana ait akademik literatürü şekillendirmektedir (Batra vd., 2023). Sonuç olarak

araştırmacılar en üst düzeyde verim alabilmek amacıyla ilk önce temel dergilerin yer aldığı birinci bölgedeki dergileri sonrasında ise sırasıyla ikinci ve üçüncü bölgedeki dergileri incelemelidirler. Özet olarak Bradford Yasası, araştırmacıların alana ait literatürü tararken çalışmalarını daha verimli yapmalarına imkân tanıyan bibliyometrik bir araçtır.

Tablo 4: Bradford Yasası'na Göre Konuya En Uygun Kaynaklar

Kaynak	Yayın Sayısı	Alan	Atıf
International Journal of Bank Marketing	40	Alan 1	1426
Asia Pacıfic Journal of Marketing and Logistics	16	Alan 1	302
Journal of Islamic Marketing	15	Alan 1	269
Marketing Intelligence \& Planning	15	Alan 1	301
Psychology \& Marketing	12	Alan 1	1253
Journal of Services Marketing	11	Alan 1	450
European Journal Of Marketing	10	Alan 1	834
Frontiers in Psychology	10	Alan 1	77
Journal of Research In Interactive Marketing	9	Alan 1	288
Journal of Financial Services Marketing	8	Alan 1	89
Journal of Retailing and Consumer Services	8	Alan 1	684
Innovative Marketing	7	Alan 2	8

Tablo 4'te verilerin Bradford yasası ile analizi ile ulaşılan dergilerin sıralaması görülmektedir. Tabloda alandaki önemine istinaden ilk on iki dergi listelenmektedir. Bu on iki dergi arasından ilk on bir derginin birinci bölgeye girebildiği görülmektedir. Bradford Yasası'nın özelliği olduğu üzere bu ilk on bir dergi alandaki temel ve güçlü kaynaklar olarak kabul edilmektedir. Bradford Yasası, alana ilişkin temel dergi listeleri oluşturduğu ve belirli bir konudaki en çok atıf almış çalışmaları ve yayın yapılmış dergileri belirlediği için bilimsel üretkenliği de teşvik etmekte ve güçlendirmektedir. Bu sebeplerden ötürü Bradford Yasası, araştırmacıların kaynak koleksiyonlarını planlarken faydalandıkları önemli araçlardan bir tanesi olarak kabul görmektedir (Bradford, 1934).

Tablo 5: En Üretken Yazarlar

Yazarlar	Toplam Çalışma	Toplam Atıf	Yayın Yılı Başlangıcı
Basso K.	5	142	2012
Ben Mrad S.	3	95	2017
Connolly R.	3	3	2006
Devlın Jf.	3	46	2015
Flavian C.	3	428	2006
Johnson D.S.	3	233	2007
Kaabachı S.	3	95	2017

Tablo 5 incelendiği zaman tüketici güveni ve pazarlama ilişkisini inceleyen ve bu alanda en çok yayın yapmış olan yazarları, bu yazarların toplam çalışma sayısını, atıf sayısını ve yayın yılı başlangıçlarını göstermektedir. Basso K. 5 çalışması ile dikkat çekmektedir. Onun ardından gelen diğer yazarların ise 3'er adet çalışmaları olduğu görülmektedir. Flavian C. 428 atıf ve Johnson D.S. ise 233 atıf sayısı ile tüketici güveni ve pazarlama ile ilişkili çalışmalarda önemli araştırmacılardır.

Tablo 6: En Etkili Çalışmalar

Yazar(lar)	Makale Adı	Kaynak Adı	Atıf Sayısı	Yıllık Ortalama Atıf Sayısı
Sirdeshmukh D., Singh, J., Sabol, B. (2002)	Consumer Trust, Value, and Loyalty in Relational Exchanges	Journal of Marketing	2128	92,52
Chen Y.S. (2010)	The Drivers of green brand equity: Green brand image, green satisfaction and green trust	Journal of Business Ethics	763	50,87
Vlachos P.A., Vrechopoulous, A.P., Avramidis, P.K. (2009)	Corporate social responsibility: Attributions, loyalty and the mediating role of trust	Journal of Academy of Marketing Science	545	34,06
Kim M.J., Chung, N., Lee, C.K. (2011)	The effect of perceived trust on electronic commerce: Shopping online for tourism products and services in South Korea	Tourism Management	437	31,21
Aguirre, E., Mahr, D., Grewal, D., Ruyter K., Wetzels, M. (2015)	Unraveling the personalization paradox: The effect of information collection and trust-building strategies on online advertisement effectiveness	Journal of Retailing	375	37,50
Jalilvand M.R., Samiei, N. (2012)	The impact of electronic Word of mouth on a tourism destination choice: Testing the theory of planned behaviour	Internet Research	337	25,92
Mukherjee A., Nath, P. (2007)	Role of electronic trust in online retailing: A re-examination of the commitment-trust theory	European Journal of Marketing	331	18,39
Escobar-Rodriguez T., Carvajal-Trujilo, E. (2014)	Online purchasing tickets for low cost carriers: An application of the unified theory of acceptance and use of technology (UTAUT) model	Tourism Management	327	29,73
Hansen S.D., Dunford, B.B., Boss, A.D. (2011)	Corporate social responsibility and the benefits of employee trust: A cross-disciplinary perspective	Journal of Business Ethics	319	22,79
Steenkamp J.B.Em., Geyskens, I. (2006)	How country characteristics affect the perceived value of web sites	Journal of Marketing	313	16,47
Stanaland A.J.S., Lwin, M., Murphy, P.E. (2011)	Consumer perceptions of the antecedents and consequences of corporate social responsibility	Journal of Business Ethics	305	21,79

Bilgihan A. (2016)	Gen Y customer loyalty in online shopping: An integrated model of trust, user experience and branding	Computers in Human Behaviour	283	31,44
Kim Y., Peterson, R.A. (2017)	A meta-analysis of online trust relationships in E-commerce	Journal of Interactive Marketing	282	35,25
Xie Y., Peng, S. (2009)	How to repair customer trust after negative publicity: The role of competence, integrity, benevolence and forgiveness	Psychology & Marketing	281	17,56
Yousafzai S.Y., Pallister, J., Foxall, G. (2003)	A proposed model of e-trust for electronic banking	Technovation	245	11,14
Pappas N. (2016)	Marketing strategies, perceived risks, and consumer trust in online buying behaviour	Journal of Rteailing and Consumer Services	234	26,00
Osterhus T.L. (1997)	Pro-social consumer influence strategies: When and how do they work?	Journal of Marketing	231	8,25
Casalo L.V., Flavian, C., Guinnaliu, M. (2008)	The role of satisfaction and website usability in developing customer loyalty and positive Word-of-mouth in the e-banking services	International Journal of Bank Marketing	231	13,59
Harris L.C., Goode M.M.H (2010)	Online servicescapes trust, and purchase intentions	Journal of Services Marketing	229	15,27
Sichtmann C. (2007)	An analysis of antecedents and consequences of trust in a corporate brand	European Journal of Marketing	200	11,11
Yahia I.B., Al-Neama, N., Kerbache, L. (2018)	Investigating the drivers for social commerce in social media platforms: Importance of trust, social support and the platform of perceived usage	Journal of Retailing and Consumer Services	196	28,00
Al-Ansi A., Han, H. (2019)	Role of halal-friendly destination performances, value, satisfaction and trust in generating destination image and loyalty	Journal of Destination Marketing & Management	194	32,33
Tussyadıah I.P., Park, S. (2018)	When guests trust hosts for their words: Host description and trust in sharing economy	Tourism Management	180	25,71
Shin D.H., Shin, Y.J. (2011)	Why do people play social network games?	Computers in Human Behaviour	178	12,71

Tablo 6'da Tüketici güveni ve pazarlama konularında yapılmış ve en yüksek atıf sayılarına sahip olan çalışmalar listelenmektedir. Sirdeshmukh vd. (2002) ve Chen (2010) gibi araştırmacılar tüketici güveni ve pazarlama ilişkisi üzerine detaylı çalışmalar ve analizler sunarak alana önemli katkılarda bulunmuşlardır.

Tablo 7: Konu ile Alakalı En Fazla Çalışma Yapan Kurumlar

Kurum	Makale Sayısı	Kurum	Makale Sayısı
University of Nottingham	16	Rmıt University	7
Coventry University	10	School of Management	7
Islamic Azad University	10	University of Center Florida	7
Nova Southeastern University	8	University of Malaya	7
Sun Yat Sen Unıversity	8	Florida State University	6
University of North Carolina	8	Kaunas University of Technology	6
University of Zaragoza	8	Maastricht University	6
Business School	7	Shenzhen University	6
Griffith University	7	Universidade Federal do Rio Grande Do Sul	6
Indıan Institute Management	7	University of Florida	6

Tablo 7, tüketici güveni ve pazarlama ilişkine dair en fazla çalışma yayımlayan kurumları göstermektedir. 16 çalışma ile University of Notthingham listenin başında gelmektedir. Ardından ise 10 adet çalışma ile Coventry University ve Islamic Azad University gelmektedir.

Tablo 8: Çalışmalarda Sık Kullanılan Kelimeler

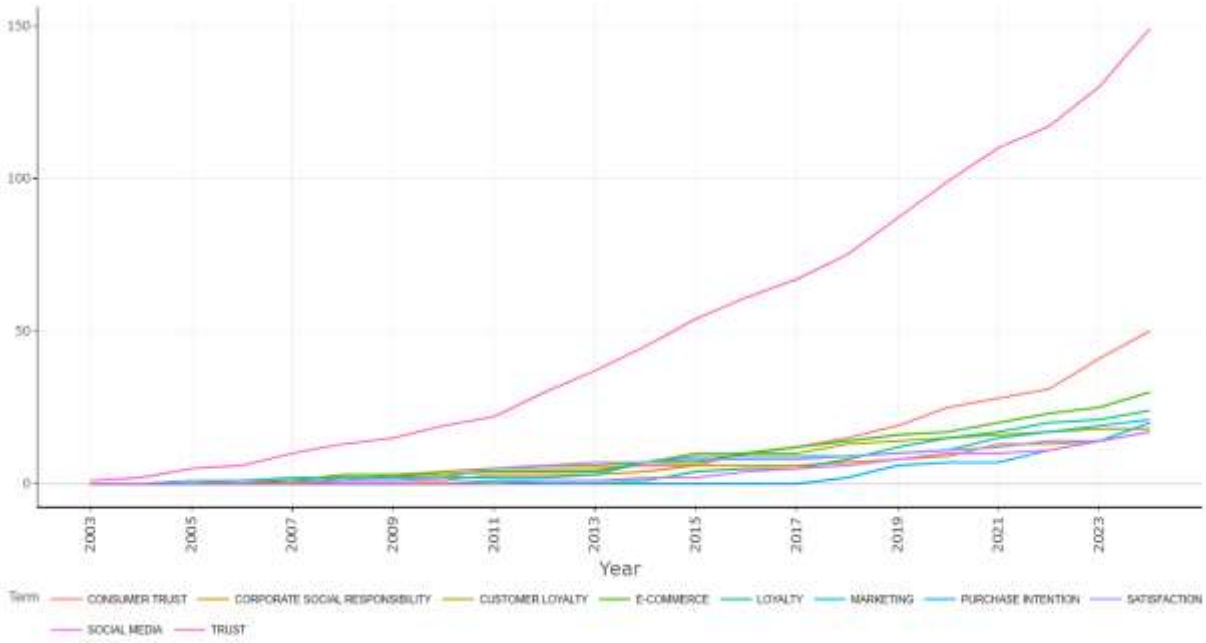
Yazar Anahtar Kelimeleri		Referanslardaki Kelimeler		Özette En Çok Kullanılan Kelimeler	
Kelime	**Sıklık**	**Kelime**	**Sıklık**	**Kelime**	**Sıklık**
trust	149	consumer trust	106	Trust	149
consumer trust	50	Satisfaction	92	Study	50
e-commerce	30	İmpact	91	consumer	30
loyalty	24	Loyalty	81	consumers	24
marketing	21	consumer-trust	79	Online	21
purchase intention	20	Model	72	research	20
customer loyalty	18	e-commerce	64	Brand	18
corporate social responsibility	17	trust	57	Marketing	17
satisfaction	17	commitment	51	Customer	17
social media	17	antecedents	48	Findings	17

Tablo 8 incelendiği zaman tüketici güveni ve pazarlama ilişkisine dair yapılan çalışmalarda sıklıkla kullanılan anahtar kelimeler görülmektedir. "Trust", "Consumer Trust" gibi terimlerin sıklıkla kullanılması bu kavramların bu alanda yapılan araştırmalarda etkili olduğunu göstermektedir. Tablo 8'de de görüldüğü üzere tekrar edilen kelimeler "Yazar Anahtar Kelimeleri", "Referanslardaki

Kelimeler" ve "Özette En Çok Kullanılan Kelimeler" olmak üzere 3 farklı kategoriye ayrılmıştır. Bu 3 kategoride de "trust" ve "consumer trust" kelimelerinin bulunduğu dikkat çekmektedir.

Şekil 2: Çalışma Özetlerinde En Sık Kullanılan Kelimeler

Şekil 2'de araştırma kapsamında incelenen çalışmaların özet kısımlarında en sık tekrar edilen 30 kelime gösterilmektedir. Şekil 2'de de görüldüğü üzere "trust", ve "consumer" kelimelerinden sonra en sık tekrar edilen kelimeler "study", "online", "research" ve "marketing" kelimeleridir. Bu şekilde bir bulut oluşturarak en sık kullanılan kelimelerin kullanıldığı kelime bulutu oluşturmak için R programında "bibliometrix" paketi içerisinde sunulan okuyucu için görsel kolaylık sağlayan özelliklerden bir tanesidir. Kelime büyüklükleri o kelimelerin kullanım sıklıkları ile doğru orantılıdır ve dolayısıyla daha büyük olan kelimelerin daha sık olarak çalışmalarda kullanıldığını ifade etmektedir.

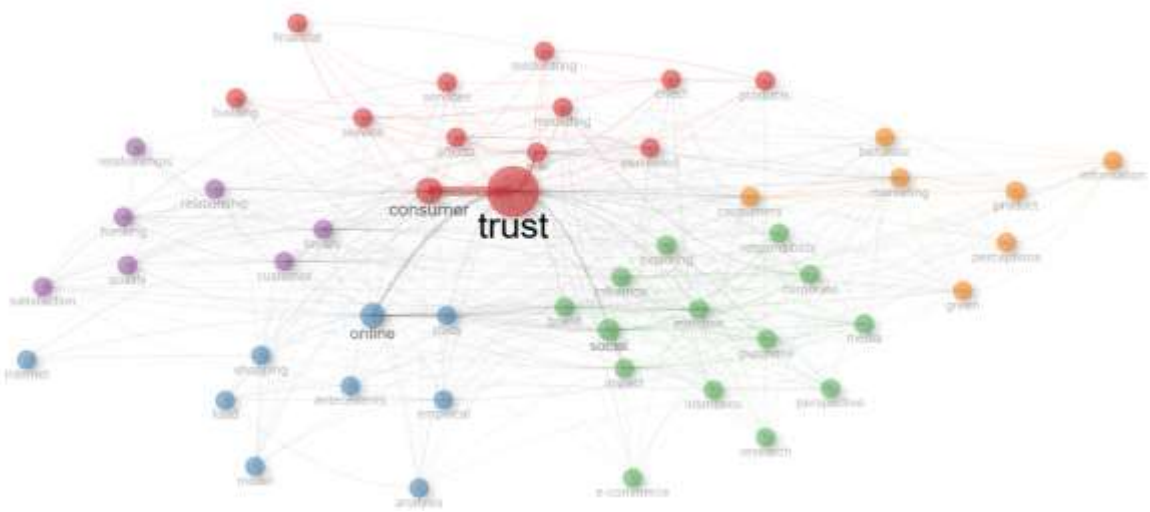


Şekil 3: Yazar Anahtar Kelimelerinde Kullanılan Kelimelerin Yıllara Göre Değişimi

Şekil 3'te ise bu araştırmada incelenmiş olan çalışmalarda yazarlar tarafından en çok kullanılan anahtar kelimelerin son 10 yıl içerisindeki gelişim trendi görülmektedir. Görüldüğü üzere "trust" kelimesinin

2017'den, "consumer trust" kelimesinin 2021'den ve "e-commerce" kelimesinin de 2023'ten itibaren ivme kazandığı anlaşılmaktadır.

Bibliyometrik çalışmalarda incelenen çalışmalar ortak özelliklerine göre kümelendirilmektedir. Bunun sebebi okuyucuların ya da diğer araştırmacıların incelenen konuya ilişkin büyük resmi daha kolay görmelerine yardımcı olmaktır. Literatürde "science mapping" bir başka ifade ile "bilim haritalandırma" olarak adlandırılan bu sürecin amacı çalışılan disipline ait çalışmaların analizini ve görselleştirilmesini sağlamaktır (Kurutkan ve Orhan, 2018). Bilim haritalandırma sürecinde amaç çalışılan konuları kavramsal (conceptual), entelektüel (intellectual) ve sosyal (social) yapılar bağlamında inceleyerek birbirleri arasındaki bağlantıları bulmak ve ortaya koymaktır (Börner vd., 2003; Ergün, 2016).



Şekil 4: Başlıklardaki Kelimelere Göre Çalışma Konularının Kavramsal Yapıları

Şekil 4'te başlıklardaki kelimelere göre çalışma konularının kavramsal yapıları görülmektedir. Bu araştırma kapsamında incelenen 446 çalışmanın da kavramsal yapılarını incelemek ve değerlendirmek amacıyla makale isimlerinde kullanılan kelimelerin birbirleri ile olan bağlantıları incelenmiştir (co-occurence analysis) (Aria ve Cuccurullo, 2017). Şekil 4'te yer alan analiz sonuçları incelendiğinde çalışma başlıklarının 4 temel başlıkta kümelendiği söylenebilir: trust (güven), consumer (tüketici), online, social(sosyal). Ayrıca şekilde "güven" ve "tüketici" arasındaki bağ ile "güven" ve "online" ve son olarak "güven" ve "sosyal" arasındaki bağın çok kuvvetli olduğu görülmektedir. Kelimeler arasındaki bağların kalınlık ve koyuluk dereceleri kavramlar arasındaki ilişkilerin kuvvetini vurgulamaktadır.

Tablo 9: Alanda En fazla Çalışma Yapmış Ülkeler

Ülke	Yayın Sayısı	Atıf Sayısı
CHINA	243	5934
USA	226	2182
UK	126	1917
INDIA	101	101
SPAIN	73	1351
AUSTRALIA	55	227
MALAYSIA	47	289
SOUTH KOREA	46	46
BRAZIL	39	250
INDONESIA	38	103
CANADA	34	363
PAKISTAN	31	31
FRANCE	28	127
GERMANY	28	338

Tablo 9, tüketici güveni ve pazarlama ile ilişkili yayın yapan ülkelerin analizini göstermektedir. Tabloda görüldüğü üzere en çok yayın yapmış olan ülkeler, yayın ve yayınlarının aldığı atıf sayıları sıralanmaktadır. Tablo incelendiği zaman Çin'in en fazla yayın ve atıf sayısı ile listenin başında bulunduğu görülmektedir. Çin 243 yayını ile 5934 atıf alarak literatüre önemli katkılarda bulunmuştur. Ardından ise 226 yayın ve bu yayınların aldığı 2182 atıf sayısı ile Amerika sonrasında 226 yayın ve 1917 atıf ile İngiltere gelmektedir. Listenin alt sıralarına bakıldığında ise İspanya, Avusturalya, Malezya, Brezilya, Kanada gibi ülkelerin de aldıkları atıf sayıları ile bu alanda literatüre önemli katkıları olduğu görülmektedir. Listede yer almayan Türkiye ise 11 çalışma ve 88 atıf sayısı ile literatüre katkı sağlayan ülkelerden bir tanesidir. Ülkelerin çalışma ve atıf sayıları değerlendirildiği zaman listenin ilk sıralarında yer alan ülkelerin tüketici güveni ve pazarlama ilişkisine yönelik çalışmalarda önemli etkilerinin olduğu görülmektedir.

Sonuç

Bu bibliyometrik analiz çalışmasında, 1995-2024 yılları arasında Web of Science veri tabanında yayımlanmış olan 446 adet çalışma analiz edilerek pazarlama literatüründe tüketici güvenini dikkate alan çalışmalara ilişkin detaylı bir değerlendirme sunulmuştur. Bulgular, tüketici güvenine ilişkin akademik ilginin ve uluslararası iş birliklerinin yıllar içerisinde kayda değer bir artış gösterdiğini ortaya koymaktadır. Çalışma verilerine göre 1995-2006 yılları arasında çok ilgi görmeyen bir konu iken 2014 ve sonrasında alana olan ilginin hızlı bir şekilde arttığı görülmektedir. Tüketici güveni kavramının artan önemi işletmelere ve markalara gelecek için önemli stratejiler sunmaktadır. Yine benzer bir şekilde 368 tanesini makalelerin ve hemen sonrasında 41 tanesini kongre bildirilerinin oluşturduğu 446 adet çalışmanın konuya ilişkin literatürü zenginleştirdiği de dikkat çekmektedir.

Çalışma bulguları içerisinde de görüleceği üzere konuya ilişkin en çok çalışma yayımlayan dergilerin sırasıyla International Journal of Bank Marketing, Asia Pacific Journal of Marketing and Logistics, Journal of Islamic Marketing ve Marketing Intelligence and Planning dergileri olduğu dikkat çekmektedir.

Literatürde yapılan çalışmalar incelendiği zaman en çok tekrar ve tercih edilen anahtar kelimelerin "trust", "consumer trust" sonrasında ise tüketici güveni ile ilişkilendirilen "satisfaction" ve "impact" kelimeleri olduğu görülmektedir. Pazarlamada literatüründe her geçen yıl daha da dikkat çeken bir konu olan tüketici güveninin önemi benzer bir biçimde Çetinkaya Bozkurt ve Gürbüz tarafından 2016 yılında yapılmış olan çalışma sonuçlarında da ulaşılmıştır. Çalışma sonuçlarına göre 2008-2016 yılları arasında Pazarlama ve Pazarlama Araştırmaları Dergisinde yayımlanmış olan 75 makalede en çok kullanılan anahtar kelimenin "tüketici güveni" olduğu dikkat çekmektedir (Çetinkaya Bozkurt & Gürbüz, 2016: 18).

Tüketici güveni, marka bağlılığı ve müşteri sadakati kavramlarıyla ilişkilendirilmekte olduğu için işletmeler ve markalar için oldukça önemlidir. Akademik çalışmalar, tüketici güveninin tüketicilerin marka sadakati ve bağlılığı ve satın alma niyetleri üzerinde etkileri olduğunu ortaya koymaktadır. Bu sebeple tüketici güveninin önemsenmesi ve buna yönelik stratejilerin oluşturulması, benimsenmesi ve tercih edilmesi uzun vadede iş başarısını da önemli bir biçimde etkileyecektir. Geleneksel veya dijital fark etmeksizin pazarlama tarafların karşılıklı güvenine dayanan bir ilişki biçimidir. Dolayısıyla güven pazarlama olmazsa olmaz kabul eden önemli bir değer ve kavramdır. Tüketicilerin olumlu deneyimler yaşaması ile oluşan güven ilerleyen aşamalarda marka sadakatine dönüşmektedir. Marka sadakati ise bugünün pazarlama dünyasında işletmelerin ulaşmak istedikleri nihai hedeflerden bir tanesidir.

Teknoloji ile gelinen noktada potansiyel tüketiciler dijital dünyaya son derece uyumlu bir hayat sürmektedirler. Dolayısıyla da yaşam alışkanlıkları buna uygun bir şekilde evrimleşmekte ve uyum göstermektedir. Bugünün ve geleceğin potansiyel tüketicileri, geleneksel pazarlama araçlarını tercih ettikleri kadar dijital pazarlama araçlarından da faydalanmaktadırlar. Dijital pazarlama araçları sosyal medya platformları, arama motorları web siteleri, mobil uygulamalar ve diğer pek çok teknoloji araçlarından oluşmaktadır ve internete erişimi olan pek çok birey tarafından tercih edilmektedir. Öyle ki artık geleneksel pazarlamanın yerine geçtiği söylenen dijital pazarlama her an her saniye hayatın içerisinde görülebilmektedir. Ancak Kotler, Kartajaya ve Setiawan (2017)'in de ifade ettiği gibi dijital dünyanın ve dijital pazarlamanın avantajlarından her şekilde faydalanılsa bile geleneksel pazarlamadan vazgeçilmesi mümkün değildir. Geleneksel pazarlamadan vazgeçmek yerine dijital pazarlama ile

geleneksel pazarlamayı bir arada kullanarak çok kanallı alışveriş deneyimleri yaratmak yeni hedefler arasında yer almaktadır. Dolayısıyla bu kadar iç içe geçmiş iki kavramın birbirine benzer olması da kaçınılmazdır. Bugüne kadar var olan geleneksel pazarlamada tüketici güveni ne anlama gelmekteyse dijital pazarlamada da aynı anlama gelmektedir. Bu sebeple yaşam her ne kadar dijitalleşirse dijitalleşsin tüketicilerin işletmelere ya da markalara duyduğu güven her zaman önemli olmaya ve tüketici satın alma kararlarını etkilemeye devam edecektir.

Sonuç olarak bu çalışma, pazarlamada tüketici güvenini inceleyen akademik çalışmaların kapsamlı bir değerlendirmesini sunarak tüketici güvenine ilişkin çalışmaların geliştirilmesine katkıda bulunmayı amaçlamaktadır. Bu çalışma ayrıca farklı bakış açılarını da geliştirmek ve desteklemek amacıyla pazarlamada tüketici güvenini inceleyen araştırmacılara farkındalık yaratabilir. Bu bağlamda araştırma bulgularının gelecekte yapılacak olan çalışmalara bir yol haritası sunması, akademik literatüre katkı sağlaması hedeflenmektedir. Tüketici güveni, geleneksel ya da dijital her daim tüketici satın alma kararını etkileyen unsurlardan biri olacaktır. Bu bağlamda karar vericiler, pazarlama alanında yetkili kişiler bu çalışmadan faydalanabilir ve tüketici güveni merkezli yeni stratejiler oluşturabilirler. Bu çalışma pazarlamada tüketici güveni alanında çalışma yapan araştırmacılara önemli bir kaynak olmasının yanı sıra birtakım kısıtlara sahiptir. Çalışmada incelenmiş olan kaynaklar Web of Science veri tabanı ile sınırlandırılmıştır. Her ne kadar Web of Science veri tabanı ile ulusal ve uluslararası pek çok kaynağa ulaşmak mümkün olsa da araştırma sadece İngilizce dilinde gerçekleştirilmiştir. Dolayısıyla diğer dillerde yapılmış olan çalışmalar bu çalışma içerisinde değerlendirilememiştir. Gelecekteki araştırmacılar benzer bir çalışmayı farklı dillerde gerçekleştirebilirler.

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WOOD LOW-DENSITY WOOD MATERIAL AND VARIATION IN COMPRESSIVE STRENGTH

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ABSTRACT

Wood has been used for heating, shelter, and hunting since the dawn of humanity. Throughout history, the uses of wood have diversified with technological advancements. Today, wood, both as solid wood and wood products, plays a significant role in many areas of human life. However, it has also been observed that wood possesses negative characteristics that limit its use or create problems during application. The structural properties of wood, such as its ability to absorb and release moisture, loss of dimensional stability, susceptibility to biological decomposition, and damage from various pests, contribute to problems in its use.

Thermal modification, also known as densification, is one of the most suitable methods for using low-specific-gravity wood. It is applied to improve the quality of wood, protect it from external factors, and expand its areas of use. The fact that no chemicals are used in thermal densification and that it is an environmentally friendly application is one of its most important advantages. Densification is generally applied to low-density wood types to improve dimensional stability, hygroscopicity, durability, and mechanical properties. In this study, Larex (*Larix decidua*) samples prepared according to the ISO 3129 standard were dried in an automatically controlled drying oven until an average moisture content of 12% was reached. To achieve a temperature of 120°C and compression ratios of 25% and 50%, the test samples to be compressed were brought to two different thicknesses (13.33 mm and 20 mm). The compressive strength value in the control sample was 56.97 N/mm², while the highest value was determined to be 105.38 N/mm² at a compression ratio of 50%.

Key Words: Wood properties; Termo-mechanic densification; Heat treatment; Pressure strength; Forests.

INTRODUCTION

The Finnish Technical Research Center (VTT) has carried out significant work on industrial heat treatment applications. Wood can be heat-treated in various ways (Finland-ThermoWood, Netherlands-Plato method, Germany-Oil heat treatment, France-Retification and Le Bois Perdure). Among these methods, the one developed by VTT and commercially most reputable in Europe is known as "ThermoWood" (Aydemir and Gündüz, 2009; Korkut, 2009; Güller, 2012).

Another thermal modification method, known as densification, is applied to improve the quality of wood, protect it against external factors, and expand its areas of use. The fact that no chemical substances are used in thermal densification and that it is an environmentally friendly application is one of its most important advantages. Density enhancement, often applied to low-density tree species, improves dimensional stability, hygroscopicity, durability, and mechanical properties (Wang et al., 2000; Welzbacher et al., 2008; Tosun and Sofuoğlu, 2021).

Wood has been used for heating, shelter, and hunting since the dawn of humanity. Throughout history, the uses of wood have diversified with technological advancements (Bozkurt and Erdin, 1997). Today, wood, both as solid wood and wood products, plays a significant role in many areas of human life. However, it has also been observed that wood possesses negative characteristics that limit its uses or create problems during its application. These include its ability to absorb and release moisture due to its structural properties, loss of dimensional stability, susceptibility to biological decomposition, and

damage from various pests, all of which can create problems in its areas of use (Mayes and Oksanen, 2002; Karakaş, 2008).

Ağaç The density of wood is an important factor that gives an idea about its other properties and usability. For example, heavy wood has greater strength, flexibility and hardness than light wood (Örs et al.,2008). Low-density and commercially unattractive wood species can be modified by densification processes to become high-performance and valuable products. Even in woods with relatively high density, hardness and strength properties can be further improved by densification processes (Nairn, 2006).

Wood can be densified by compressing it under pressure, impregnating the cell walls with certain chemicals, or by using compression and impregnation together (Rowel et al. 1987). In densification with chemical substances, liquid natural and artificial resins are impregnated into the voids of the wood material, and then solidified in place by chemical reaction or cooling to obtain wood material with increased density (Kamke,2006). In densification by compression, the void volume of the wood material is reduced and the cell wall is collapsed to achieve densification (Pelit, 2014).

A significant disadvantage of the compression densification method is that if the densified wood is exposed to high levels of moisture or water, it returns to its initial dimensions before compression. This is due to the expansion of the cell wall under the influence of water, the relief of internal stresses in the material structure caused by compression, and especially the tendency of the cell to return to its original shape (Seborg,1956). One of the wood material modification methods, which is increasingly used to improve some properties of wood material (dimensional stability, biological resistance, etc.) and expand its usage area, is heat treatment (Pelit,2014).

The main objective of this study was to increase the durability of low-density wood materials using this method. Avoiding chemical treatment is a significantly important approach from the perspective of human and environmental health.

METHODOLOGY

Wood Material

For this study, Larex (*Larix decidua*) wood, which is commonly used in the furniture industry, was chosen. The wood was sourced as slats from randomly selected timber from Trabzon timber yards, and was not subjected to technical drying. Care was taken to ensure the wood material was free of rot, knots, voids, and uneven fibers.

Densification

Wood test samples were densified in an open system using the Thermo-Mechanical (TM) method by compressing them at a press temperature of 120°C for 15 minutes. The densification process was carried out in a specially designed hydraulic press with table dimensions of 60x60 cm, capable of temperature and pressure control, located within the Faculty of Forestry at Artvin Çoruh University, at a loading speed of 60 mm/min in the radial direction. The densified materials were held under the press for 15 minutes, then removed from the press and allowed to cool to room temperature under a pressure of 5 kg/cm2 to minimize the springback effect.

Preparation of Test Samples

Layered test specimens were obtained from the sapwood portion of logs of the tree species, in accordance with the principles specified in the TS ISO 3129 standard. The prepared coarse-sized wood materials were left to dry in natural climatic conditions until they reached the required moisture content. The aim was to obtain a thickness of 20 mm by compression and densification. For this purpose, test specimens measuring 430 mm x 85 mm were prepared in two different thicknesses of 25 and 33.3 mm, to be densified with compression ratios of 20%, 40%, and 50%. Afterwards, the test specimens were kept in a climate chamber at 20 ± 2°C and 65 ± 5% relative humidity until they reached a constant weight and a moisture content of 12%, according to TS 2471.

Compressive Strength [N/mm²]

Compressive strength samples in the direction parallel to the fibers were prepared according to the principles specified in the TS 2595 standard. Sample dimensions and experimental setup are given in Figure 1. The universal test mechanism used in the compressive strength tests of the samples was designed to ensure that fracture occurs within 1.5-2 minutes from the moment of loading. Before the tests, the cross-sectional area where the force is applied was measured, and the maximum force at fracture (Fmax) was determined. The compressive strengths (σb) were calculated using the following formula: σb = Fmax / a x b

a,b: Sample cross-sectional dimensions (mm)- Fmax: Force at fracture (N)

CONCLUSION AND DISCUSSION

The compressive strength values obtained according to wood type and fabric type are given in Table 1.

Table 1. Compressive Strength Values (N/mm^2)

Compressive Strength Values	$\bar{X}$	HG
Control	69.64	C
%25	72.05	B
%50	81.56	A
LSD: 8.419 HG: *Homogeneity Group*		

The highest compressive strength value in terms of compression ratio was determined at 50% (81.56 N/mm2), and the lowest was in the control sample (69.64 N/mm2). This indicates that the resistance may vary depending on the amount of pressure, wood anatomy, and wood type. Compared to the control sample, both the 20% and 50% compressive strength values showed a significant increase. Many literature studies have also detected significant increases in specific gravity, surface hardness, surface gloss, various mechanical properties, etc.)

As a result of heat treatment and increased processing temperature, air-dry density values decreased. These decreases can be explained by the mass losses and the decrease in equilibrium moisture content in the samples due to heat treatment. In the literature, it has been stated that mass loss plays an important role in density losses due to heat treatment (Yıldız,2002; Perçin,2012). In addition, it has been stated that the main reasons for the decrease in wood material density after heat treatment are; the conversion of wood components, mainly hemicellulose, into volatile products during heat treatment, the evaporation of extractive substances, and the lower equilibrium moisture content as a result of the wood being less hygroscopic due to heat treatment (Korkut,2019).

By using readily available and inexpensive wood materials in our country, laminated solid wood materials, which are generally produced at a high cost using only one type, can be manufactured more cheaply using fiberglass fabric. This also ensures dimensional stability, making them suitable for use in interior and exterior building spaces in areas with high earthquake risk. Thus, extending the lifespan of the material will provide significant economic advantages.

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WOOD MATERIAL ENGINEERING AND GLASS FIBER FABRIC USAGE SCALE

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ABSTRACT

As Glass fiber is used in many different fields and is a sought-after material, especially in the construction sector. In addition, glass fiber is frequently used in the aviation, automotive, and transportation sectors. Glass fiber is also used in fabric production. The use of glass fiber fabric dates back 300 years. One of the applications of glass fiber is in the defense industry, in the manufacture of ballistic shields (not as the main material, but as a reinforcing element, which is its best function). Glass fiber also finds its place in the textile sector. This material is one of the important materials used in mold and part manufacturing. In the shipbuilding sector, it can be used in ship hulls. It is also used in sports and hobbies in the manufacture of many materials such as fishing rods, bows, and arrows. This material can be used as a reinforcing element in the construction of tanks used for transporting and storing all kinds of other materials.

The rapid depletion of forest resources, drought, and climate change have significantly increased the importance of using wood as a material. Therefore, the effects of glass fiber fabric reinforcement on the compressive strength of Scots pine wood have been investigated. Experimentally, woven glass fiber fabrics with weights of 200, 300, and 400 g/m² and oriented in a 0°-90° direction were used and applied to the tangential surfaces with epoxy resin. Subsequently, the change in the compressive strength of the wood material was measured using a universal testing machine. The compressive strength value was determined as (47.25 N/mm²) in the control sample and (64.56 N/mm²) in the woven glass fiber fabric 400 g/m² (WGFF200).

Key Words: Resistance, Fiberglass fabric, Epoxy resin, Pressure resistance; Wood.

INTRODUCTION

Glass fiber yarn F9 air filter paper is primarily composed of glass fiber and is produced by a wet-laying process similar to methods used in paper production. It is a very strong and durable product. It has an extremely consistent structure and exhibits good mechanical performance. Glass fiber F9 filter paper is the main material of air filters. These filters can be used for air filters in air conditioning systems such as the medical, food, electronics, textile industries and high-quality office/entertainment industries. It offers an inexpensive method for ventilation processes. Fiberglass F9 air filters are more efficient the longer they are installed in the filter system. Glass fiber F9 filters can get rid of dust and debris that can be very small (URL-1).

Laminated wood material, which is becoming increasingly common in the woodworking industry, is defined according to TS EN 386 as a structural element obtained by gluing wood veneers parallel to each other. The moisture difference between the layers forming the laminated element should not exceed 4%. Otherwise, stresses resulting from different working conditions may exceed the tensile strength perpendicular to the fibers, causing cracks. In addition, the relative humidity of the environment where the lamination process is carried out should be between 40-70%, and the temperature should be at least 15°C (Keskin et al. 2003).

In recent years, engineers and technical personnel have been making intensive efforts to obtain more useful materials by combining materials such as concrete, steel, wood, stone, plastic, and glass in various shapes and proportions. In addition, new materials such as high-strength glass, carbon, boron, and aramid fiber are being developed. While these developed materials were initially used in high-risk

applications, they later began to be used in structural applications. Today, using wood as a single piece in large-sized structural elements in wooden structure design is not feasible from both a technical and economic point of view. In addition, the possibilities of using wood as a single piece in the production of load-bearing elements are limited. Because it is not possible to completely eliminate the defects such as spiral grain, knots, cracks, etc. found in wood material. This situation significantly affects the safety of the wooden structure (Ekinci 2004).

In recent years, studies have shown that wood is laminated with some materials other than wood, and different composite products are obtained in this way. Below are some scientific studies found in the literature research on the lamination process. Determination of some physical and mechanical properties of wood laminated elements prepared from Scots pine (*Pinus sylvestris L.*) wood, with support elements (plaster mesh, fiber wire mesh, aluminum wire mesh) placed between the lamellas in 9 layers and glued with PVAc-D3 glue [8], determination of some technological properties of laminated Scots pine material reinforced with glass and carbon fiber [9], determination of some physical properties of wood structural elements reinforced with glass fiber fabric (Togay et al 2014; Bal et al. 2015).

Bal et al. (2015) in the results of the bending strength test of plywood reinforced with glass fiber woven fabric. Some of the important differences between this study and previous studies are; the weaving properties of the reinforcement material, the gram weight of the reinforcement material, the location where the reinforcement material is applied in the laminated wood material, the type of glue used, the pressing pressure, and the pressing temperature. They interpreted the differences in the results obtained as an expected outcome, given the differences in this regard compared to previous studies.

This was investigated by Laufenberg et al. (1984). Their study reported that the least costly reinforcement could be achieved using E-glass fiberglass and phenol formaldehyde. A study by Basterra et al. (2012) examined some mechanical properties of poplar beams produced with the I-214 poplar clone. Fiberglass woven, carbon fiber woven, and flax fiber woven reinforcements were used. The tests showed that only the differences in reinforcement using carbon fiber were statistically significant. Ribeiro et al. (2009) conducted a study on the reinforcement of glued laminated timber beams made from Maritime pine with fiberglass and pultrusion boards. The data from this study showed that reinforcement with fiberglass did not have a statistically significant effect on the modulus of elasticity of the test samples. Rowland et al. (1986) conducted experiments on laminated timber material made from maple using 10 different types of glue and many different forms of fiberglass, graphite fiber, and Kevlar. According to the data obtained, they stated that the most successful type of adhesive is epoxy and the most suitable fiber for reinforcement is glass fiber.

Wood is an organic-based structural material obtained from trees, which have a living structure, and has a heterogeneous, fibrous structure in terms of texture. At the same time, its ease of processing and its molecular and chemical structure, which allows it to be used for a wide variety of purposes, have made it the most preferred material as a technical material by humankind for centuries. In addition, its fibrous structure has caused it to show high strength and flexibility in engineering applications (Öztürk, 2006). Although there are alternative materials such as steel and plastic as substitutes for solid wood in some applications, the superiority of wood over these materials, both as a natural engineering material and as a sustainable and renewable product, remains valid today (Çolakoğlu, 2004).

Advantages such as its sustainability and ease of supply, which complement its mechanical and physical properties, also increase the demand for wood. Thanks to these properties, wood, which was preferred as a building and furniture material in the past, is now used in many areas as a packaging material with the developing industry. In particular, the demand of the packaging and pallet industry made from timber shows a derivative demand characteristic when timber production is considered. That is, the growth of the country's industry, the increase in exports also increases the demand for pallets and packaging (Special Commision, 2014).

This study aimed to increase the scale and scope of wood usage, and to optimize its technological properties by using fiberglass and carbon fiber fabrics in applications such as earthquakes, fires, various natural disasters, indoor/outdoor furniture, wooden bridges, restoration of historical artifacts, and in swamp/water-contact areas. This research will also make significant contributions to science and technology in the coming century.

METHODOLOGY

Wood Material

Sandwich panel boards were produced by covering the top and bottom surfaces (tangential surfaces) of the wood material with strength-enhancing fabrics. To produce sandwich panel boards, one coniferous and one broadleaf tree species were chosen as the core material to represent different specific gravities. Turkish red pine (*Pinus brutia Ten*), frequently preferred in horizontal/vertical load-bearing and decorative applications in the Turkish construction industry, was selected as the experimental material. The wood material was obtained from the Adana/Karaisalı forest enterprises using a completely random method, and care was taken to ensure the timber was flawless, its fibers were straight, free of splinters, without reaction wood, and free from sapwood and fungal/insect damage.

Covering Material

Layered composite structures generally contain a core material. This core material should generally be lightweight, hard, and durable. For the core material, solid wood was selected, and as a strength-enhancing reinforcement element, 0-90° bidirectional woven glass fiber fabric in 200, 300, and 400 g/m² variations, 0-90° bidirectional woven carbon fiber fabric at 200 g/m², and ready-to-use shredded glass fiber in rolls at 450 g/m² with a yarn length of 5 cm were used.

Adhesive Material

The third step is to control the potential ethical issue and align them with the goals of the ethical system. The ethical risks must be fully identified, and the security requirements necessary to overcome perilous situations must be formed at this stage. Another main point is that artificial intelligence systems are designed, programmed, or developed according to their purpose. In determining the ethical possibilities, the design and architecture of the artificial intelligence system should be analysed according to the possibilities of inducing any ethical violations. The system's potential to meet security requirements should be evaluated, and if necessary, it must be reconfigured and validated.

Preparation of Test Samples

Test samples were first cut into 2x5×75 cm blanks according to TS ISO 3129 standards. To determine their moisture content, they were kept in a climate chamber at 20±2°C and 65±5% relative humidity according to TS ISO 13061-1 standards until they reached 12% moisture. The test samples were prepared as follows: 1 control and 5 replicates, and 6 fabric and fiber types. The final dimensions of the double-sided coated test samples for compressive strength are 30x20x20 mm.

Coating of Experimental Samples

Since there were only a few samples for coating the wood material, the "hand lay-up method," which is commonly used at low production levels, was preferred. In this process, liquid resin, prepared by mixing it with a hardener as an adhesive, was applied to both the reinforcement material (fabric and shredded fiber) and the surface of the wood material used as the core with a roller. After the reinforcement material is coated on the wood material, it is subjected to a rolling process until the resin hardens. Air bubbles trapped between the resulting sandwich panels are removed by rolling. This rolling process is repeated intermittently after each layer of reinforcement material application. Then, the sandwich panels, which are left to cure at room temperature for 24 hours, harden the material through chemical reactions occurring in the resin, allowing for the production of high-strength and lightweight products.

Compressive Strength [N/mm²]

Compressive strength samples in the direction parallel to the fibers were prepared according to the principles specified in the TS 2595 standard. Sample dimensions and experimental setup are given in Figure 1. The universal test mechanism used in the compressive strength tests of the samples was designed to ensure that fracture occurs within 1.5-2 minutes from the moment of loading. Before the tests, the cross-sectional area where the force is applied was measured, and the maximum force at fracture (Fmax) was determined. The compressive strengths (σb) were calculated using the following formula: $\sigma b = Fmax / a \times b$

a,b: Sample cross-sectional dimensions (mm)- Fmax: Force at fracture (N)

CONCLUSION AND DISCUSSION

The compressive strength values obtained according to wood type and fabric type are given in Table 1.

Table 1. Compressive Strength Values According to Fabric Type (N/mm^2)

Fabric Type (B)	$\bar{X}$	HG
Control (CONTROL)	47.25	D
Woven Glass Fiber Fabric 200 gr/m2 (WGFF200)	55.68	C
Woven Glass Fiber Fabric 300 gr/m2 (WGFF200)	59.27	B
Woven Glass Fiber Fabric 400 gr/m2 (WGFF200)	64.56	A
LSD: 8.419 HG: *Homogeneity Group*		

When the table is examined, the highest compressive strength value was determined for woven fiberglass fabric 400 gr/m2 (WGFF200) at 64.56 N/mm2, while the lowest compressive strength value was determined in the control sample at 47.25 N/mm^2. A significant increase in compressive strength was observed compared to the control sample. This can be attributed to the adhesive and fabric density structure.

Karaman et al. (2018) prepared laminated materials from chestnut (Castenea sativa) wood using polyvinyl acetate (PVAc-D4) and polyurethane (PU-D4) adhesives to determine the four-point bending strength of glass fiber reinforced wood laminated materials used in strengthening wood laminated materials obtained from wood. To increase the strength of the laminated elements, they preferred 100 gr/m2 plain loosely woven (Type 1) and 200 gr/m2 plain tightly woven (Type 2) glass fiber fabrics. According to the experimental results, the highest static bending strength parallel to the glue line (85.20 N/mm2) was observed in the laminated samples using Type 2 glass fiber fabric (200 gr/m2 loosely woven) and polyurethane (PU-D4) adhesive, while the lowest value (75.10 N/mm2) was observed in the laminated samples without glass fiber fabric between the layers. They reported that it was detected in control group laminated samples using polyvinyl acetate (PVAc-D4) glue.

Güler et al. (2012) In a study, some mechanical properties of laminated material reinforced with glass fiber and carbon fiber in different ratios on solid Scots pine were investigated. As a result of the research, it was stated that the mechanical properties of laminated material reinforced with glass fiber and carbon fiber were better.

By using readily available and inexpensive wood materials in our country, laminated solid wood materials, which are generally produced at a high cost using only one type, can be manufactured more cheaply using fiberglass fabric. This also ensures dimensional stability, making them suitable for use in interior and exterior building spaces in areas with high earthquake risk. Thus, extending the lifespan of the material will provide significant economic advantages.

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EPIDEMIOLOGICAL AND ECONOMIC EVALUATION OF BRUCELLOSIS, TUBERCULOSIS, AND PARATUBERCULOSIS IN CATTLE SENT TO SLAUGHTER

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ABSTRACT

The aim of this study is to evaluate the epidemiological distribution and economic impacts of brucellosis, tuberculosis, and paratuberculosis in cattle sent for compulsory slaughter, based on official slaughter records from 2024 onward. The research was conducted using retrospective records obtained from a slaughterhouse operating under the supervision of the Provincial Directorate of Agriculture and Forestry in Adana and surrounding provinces. The number of animals sent for slaughter, total carcass weight, and compensation payments to producers were analyzed according to disease type. Payments are converted to US dollars using the effective selling exchange rates of the Central Bank of the Republic of Türkiye. According to the findings, a total of 257 cattle were compulsorily slaughtered during the study period, with a total carcass weight of 47,818 kg. Paratuberculosis ranked first in terms of both the number of animals slaughtered and total payments, followed by tuberculosis and brucellosis. It was determined that a total of US$205,751 in compensation payments were made to producers. Furthermore, it is estimated that implementing formal pre- and post-slaughter inspection procedures for animals at risk of zoonotic infections has prevented approximately 1.000.000 people from being exposed to foodborne infections. In conclusion, the findings of this study demonstrate that chronic and zoonotic infections not only cause significant economic losses in livestock production but also pose significant risks to public health. In this context, effective surveillance, early detection, and integrated control programs are essential components for ensuring sustainable livestock production and protecting public health.

Keywords: Brucellosis, Tuberculosis, Paratuberculosis, Foodborne Infections, Livestock.

INTRODUCTION

Animal production represents a cornerstone of global food security; however, zoonotic and chronic infectious diseases constitute some of the most significant threats to the sustainability of this sector. In cattle populations in particular, brucellosis, tuberculosis, and paratuberculosis are widely prevalent and are associated not only with substantial per-animal productivity losses but also with trade restrictions and direct risks to public health. The “One Health” framework, as endorsed by the World Health Organization (WHO) and the World Organisation for Animal Health (WOAH), emphasizes that the eradication of these infections is imperative not only for veterinary health management but also for the safeguarding of human health (Zinsstag et al., 2020).

Brucellosis continues to maintain its endemic status in the Mediterranean basin, including Türkiye, and leads to substantial economic losses for breeders not only through marked reductions in milk and meat yield but also through abortion cases. Recent studies identify uncontrolled animal movements and inadequate biosecurity practices as the principal factors underlying the failure to achieve effective disease control (Ghssein et al., 2025; Moriyón et al., 2023). Similarly, Mycobacterium bovis, the causative agent of bovine tuberculosis, imposes a significant burden on the livestock economy,

particularly in developing countries. It continues to represent a serious zoonotic threat through transmission to humans via the consumption of unpasteurized milk and dairy products, as well as contaminated meat and meat products. The literature further discusses the cost-effectiveness of bovine tuberculosis eradication programs and emphasizes that post-mortem inspections conducted in slaughterhouses constitute one of the most critical components of surveillance systems (Blanco et al., 2022).

Paratuberculosis, a chronic infectious disease, is regarded as one of the most challenging conditions to diagnose due to its insidious and frequently subclinical progression. Beyond causing a 10–25% reduction in milk yield, the disease is associated with significant live weight loss due to cachexia and a consequent marked decline in carcass value. In the contemporary literature, paratuberculosis is described as a "silent thief" within the cattle industry, with particular emphasis on opportunity costs especially those related to herd replacement (replacement costs) as constituting a substantial proportion of the overall economic burden (Rathnaiah et al., 2017; Whittington et al., 2019). In a comprehensive analysis conducted by Rathnaiah et al. (2017), the economic impact of paratuberculosis was demonstrated with striking data, estimating that annual losses to the United States cattle industry range between USD 250 million and 1.5 billion. Moreover, studies employing advanced statistical methodologies, including Bayesian approaches, have indicated that the true prevalence of this pathogen in dairy operations may exceed 90%. These findings suggest that the burden of "hidden infection" may be considerably greater than previously anticipated.

Despite the implementation of eradication and test-and-slaughter compensation programs in Türkiye, data derived from animals sent to slaughter due to these three diseases constitute one of the most tangible indicators for assessing the infection burden in the field. However, analyses of the associated economic losses particularly those calculated on the basis of carcass weight and current exchange rates (USD-based) remain limited in the literature.

The aim of this study is to analyze the epidemiological distribution of cattle subjected to compulsory slaughter due to brucellosis, tuberculosis, and paratuberculosis by utilizing official slaughter data from 2024, and to provide an up-to-date perspective by evaluating the direct economic impacts of this process based on carcass value.

However, this analysis is not limited solely to the identification of financial losses; it also seeks to emphasize the critical importance of control mechanisms that prevent the entry of these zoonotic pathogens into the food chain in terms of food safety. In this regard, the study aims to demonstrate the indispensable role of sustainably disposing of infected materials in protecting public health, thereby offering a contemporary perspective that contributes to the "One Health" framework spanning animal production and public health.

METHODOLGY

Study Area and Data Sources

This study was conducted in a high-capacity slaughterhouse facility located in Adana Province, one of the regions of strategic importance for livestock production in Türkiye. The primary material of the study consisted of retrospective slaughter data covering the period from January to December 2024, obtained from official record systems maintained under the supervision of the Provincial Directorate of Agriculture and Forestry.

Data Collection and Classification

Within the scope of the study, data pertaining to cattle subjected to "compulsory slaughter" (compensated or conditional slaughter) due to diagnoses of brucellosis, tuberculosis, and paratuberculosis were obtained from digital record systems. The retrieved data were transferred to Microsoft Excel and systematically classified for analysis.

The following parameters were evaluated:

- Number of animals slaughtered according to disease type,

- Province-level disease prevalence,
- Carcass weights (kg) determined following post-mortem inspection,
- Carcass unit prices established by official appraisal commissions.

Epidemiological Evaluation

The epidemiological assessment of the cases was conducted based on the monthly distribution of disease prevalence and the proportional contribution of each infection type to the total number of slaughters.

Ante-mortem (pre-slaughter) and post-mortem (post-slaughter) inspections performed on animals referred for slaughter were carried out by official veterinarians in accordance with Law No. 5996 on *Veterinary Services, Plant Health, Food and Feed* and the relevant secondary legislation, forming the basis of the routine control procedures applied within the scope of this study.

Economic Analysis Method

The "Market Price Method" was employed to calculate direct economic valuation in this study. To ensure the comparability of the economic data with the global literature, payments made in Turkish Lira (TRY) were converted into United States Dollars (USD) based on the effective selling exchange rates of the Central Bank of the Republic of Türkiye (CBRT) on the respective slaughter dates. The total economic value represents the overall compensation or payment amount calculated by multiplying carcass weight, number of animals, and the relevant unit price parameters for the corresponding period.

Public Health Projection

The impact analysis aimed at preventing zoonotic infection risk was conducted based on the per capita annual red meat consumption data for 2024 provided by the Ministry of Agriculture and Forestry and the total carcass amount (47,818 kg) obtained in this study. In this calculation, the number of individuals potentially protected from the risk of foodborne infections through the safe inclusion of infected materials into the food chain via controlled slaughter practices was mathematically modeled.

RESULTS AND DISCUSSION

In this study, data pertaining to cattle referred for slaughter following the diagnosis of brucellosis, tuberculosis, and paratuberculosis in 2024 were evaluated, and the epidemiological distribution and economic impacts of these diseases were determined. The findings indicate that chronic zoonotic infections impose a considerable economic burden on the livestock sector and pose significant risks to public health. Data regarding the number of animals referred for slaughter according to disease type, total carcass weights, and corresponding economic values are presented in Table 1.

Paratuberculosis ranked first in terms of the number of animals referred for slaughter (Table 1, Figure 1). This finding may be attributed to the long incubation period and predominantly subclinical progression of the disease, which facilitates undetected transmission within herds. Indeed, Ott et al. (1999) and Barkema et al. (2018) reported that paratuberculosis leads to significant productivity losses and compulsory culling at the herd level. The higher total economic loss associated with paratuberculosis observed in the present study (Table 1, Figure 2) is consistent with these reports in the literature.

Tuberculosis cases ranked second in terms of both the number of animals referred for slaughter and total carcass weight (Table 1, Figure 1). Considering the zoonotic potential of *Mycobacterium bovis* infections, the referral of infected animals for slaughter represents not only an economic necessity but also a critical measure for the protection of public health (Thoen et al., 2006; Michel et al., 2010). As emphasized in OIE (2022) reports, the identification and controlled slaughter of infected animals constitute the cornerstone of official control programs. In this study, the substantial economic losses attributable to tuberculosis cases (Table 1, Figure 2) provide a concrete indication of the sectoral impact of existing control measures.

Brucellosis was represented by a comparatively lower number of animals referred for slaughter than the other two diseases (Table 1, Figure 1). Nevertheless, despite the relatively lower number of affected animals, the zoonotic nature of brucellosis maintains its public health significance. Godfroid et al. (2013)

emphasized that the eradication of brucellosis is of critical importance not only for animal health but also for human health. The relatively limited economic losses associated with brucellosis observed in this study (Table 1, Figure 2) may suggest the partial effectiveness of ongoing vaccination and control programs.

An examination of the provincial distribution of diagnosed cases revealed that infections were concentrated in specific regions (Figure 3). This pattern suggests that regional variations in animal movement, herd management practices, and biosecurity levels may influence disease transmission dynamics.

The findings of this study demonstrate that without early diagnosis, regular screening, and effective biological safety measures, persistent infections will ultimately lead to mandatory slaughter. This process is of critical importance for preserving valuable livestock resources, ensuring the sustainability of production, and preventing zoonotic infection risks from entering the food chain.

In conclusion, a total of 47,818 kg of carcass was safely introduced for consumption following official ante-mortem and post-mortem inspection procedures conducted in accordance with the applicable legislation (Table 1). During this process, a total payment of USD 205,751 was made to producers, thereby preventing substantial economic losses. Furthermore, preventing the entry of products carrying zoonotic infection risks into the food chain through official control procedures may have reduced the risk of foodborne infections for approximately 1,000,000 individuals, based on per capita average red meat consumption data. These findings clearly demonstrate that science-based control and decision-making mechanisms are indispensable for both economic sustainability and the protection of public health across the continuum from animal production to community health.

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Table 1. Quantity, carcass weight (kg), and price datas according to diseases.

DISEASES	QUANTITY	CARCAS KG	PRİCES (TL)	PRICES(USD)
TUBERCULOSIS	99	19470	2.528.232,80	79.007,28
BRUCELLOSIS	42	9304	1.208.889,30	37.777,79
PARATUBERCULOSIS	115	19044	2.846.919,80	88.966,24
TOTAL	**257**	**47818**	**6.584.041,90**	**205.751,31**

Figure 1. Distribution of Cattle Referred to Slaughter according to Disease Type

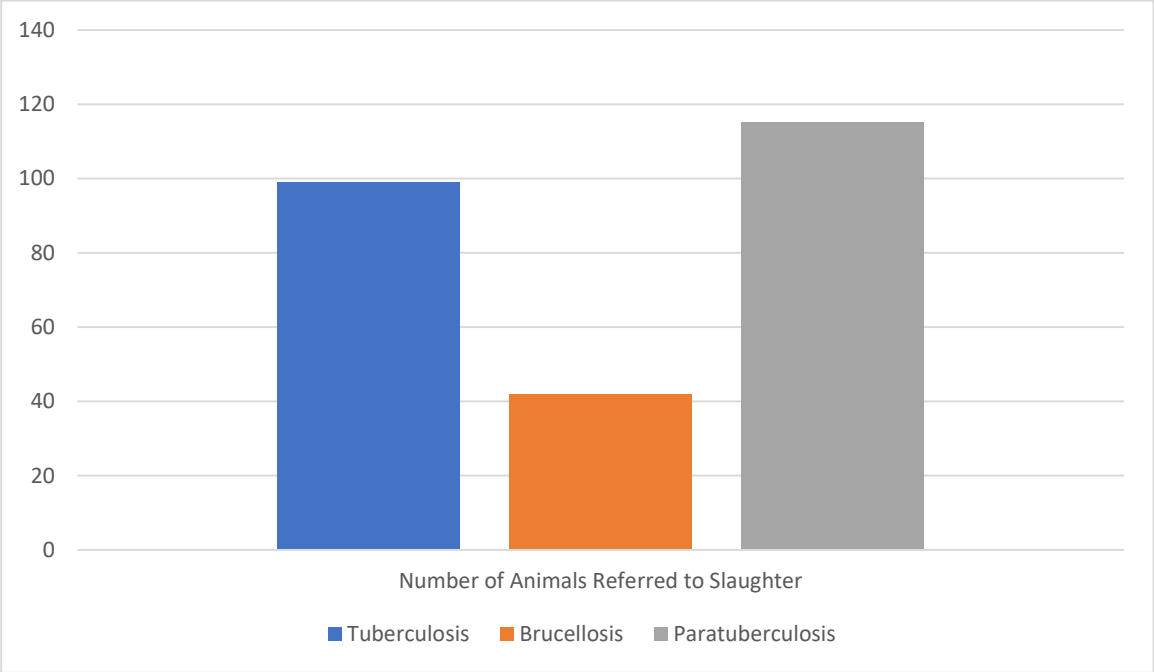


Figure 2. Carcasses Values according to Disease Type

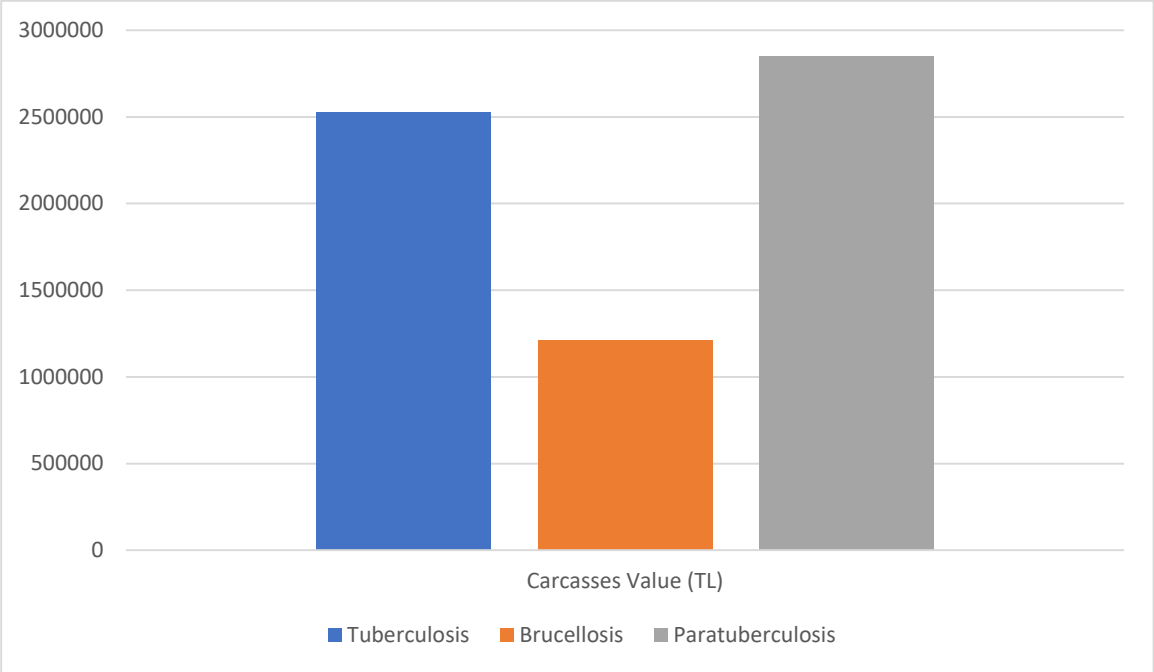
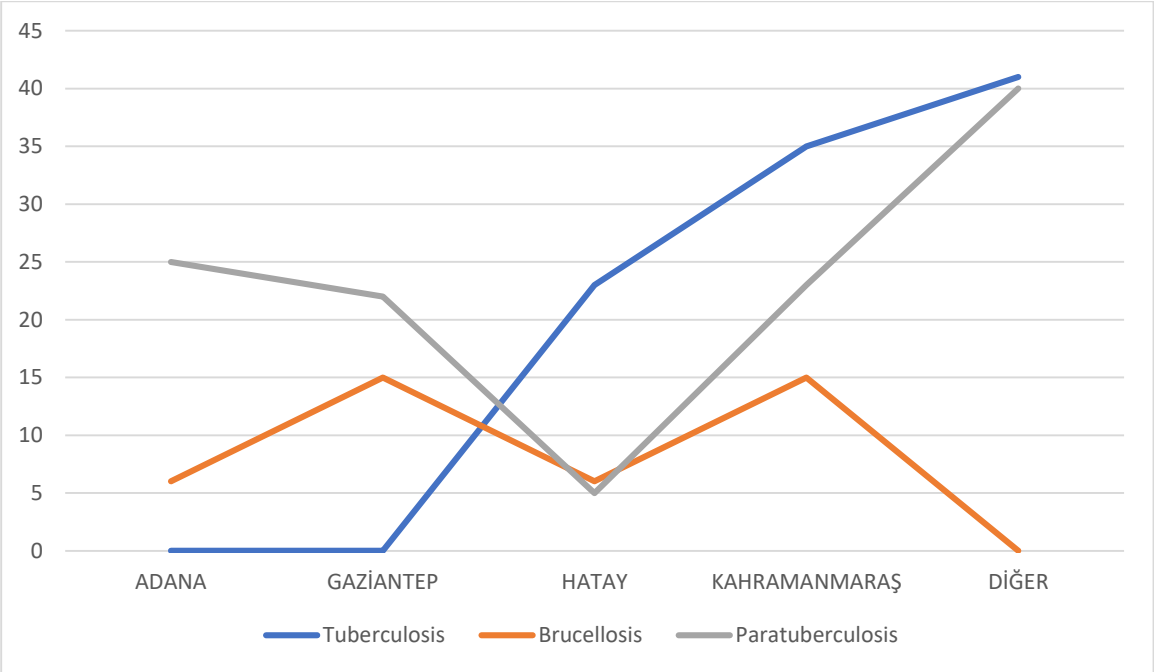


Figure 3. Provincial Distribution of Diagnosed Cases



HESPERIDIN MODULATES OLAPARIB-INDUCED APOPTOSIS IN U2OS CELLS

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ABSTRACT

Hesperidin is a flavonoid with a broad pharmacological profile, including anticancer, antioxidant, and anti-inflammatory properties, and is a key phytochemical found particularly in citrus fruits such as lemons, oranges, and mandarins. Numerous in vitro and in vivo studies have demonstrated the anticancer potential of hesperidin alone, but recently, its synergistic effect with chemotherapy agents has attracted attention. Osteosarcoma is a common type of cancer affecting young individuals, usually occurring between the ages of 15-19, and predominantly found in long bones such as the legs. Olaparib is a next-generation chemotherapy agent that exerts its activity by inhibiting DNA repair in cancerous cells by suppressing the Poly (ADP-ribose) polymerase (PARP) enzyme. In this study, the synergistic effects of the hesperidin + olaparib combination on human U2OS osteosarcoma cells were investigated. Cell viability was assessed using WST-1 analysis, and half maximal inhibitory concentrations (IC_{50}) were calculated for olaparib and hesperidin. Additionally, a wound healing scratch assay was performed to examine the synergistic effect on cell migration. Caspase-3 ELISA and Cell Death Detection ELISA (CDDE) analyses were performed to evaluate apoptosis. The findings of the study show that when hesperidin is administered in combination with olaparib, it significantly inhibits the viability and migration of U2OS cells, inducing their tendency towards apoptosis. The potential synergistic interaction of hesperidin with chemotherapeutics may offer new clinical approaches in cancer treatment.

Key Words: Olaparib; Hesperidin; Osteosarcoma; Apoptosis

SYNERGISTIC INTERACTION BETWEEN GENISTEIN AND IRINOTECAN IN CACO-2 COLON CARCINOMA CELLS

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ABSTRACT

Colon cancer is one of the cancer types with the highest incidence and mortality worldwide. Clinical approaches to colorectal cancer (CRC) treatment include surgery, radiotherapy, and chemotherapy; however, these approaches, whether used alone or in combination, have serious side effects. Irinotecan is a camptothecin derivative chemotherapeutic agent that targets the topoisomerase-I enzyme, causing double-strand breaks in DNA during replication and transcription, thereby suppressing the proliferation of cancerous cells. It is known that the use of irinotecan in colon cancer patients can cause several side effects, including loss of appetite, diarrhea, shortness of breath, increased risk of infection, and vomiting. Many phytochemicals are being investigated as promising agents to reduce the side effects of chemotherapy when used in combination. Genistein, found in significant amounts in many plants such as soy, is an isoflavone with pharmacological potential. This study comprehensively investigated the synergistic effect of genistein combined with irinotecan on human Caco-2 colon carcinoma cells. In this context, the effects of genistein alone and in combination with irinotecan on cell viability were evaluated using the MTT assay. Furthermore, the effects of the combined treatment on colony survival, cellular migration, reactive oxygen species (ROS), and vascular endothelial growth factor (VEGF) levels were also analyzed. The findings revealed that genistein exhibited a synergistic interaction with irinotecan, suppressing proliferation, colony formation, and migration in colon cancer cells. This study suggests that genistein's pharmacological effects may have significant potential when used in combination with chemotherapeutic agents.

Key Words: Genistein; Colon cancer; Irinotecan; VEGF

İSLAM ASTRONOMİSİNDE BİR TEORİSYEN: ŞEMSÜDDÎN el-HAFRİ VE GEZEGEN MODELLERİ

A THEORIST IN ISLAMIC ASTRONOMY: SHAMS AL-DIN al-HAFRI AND PLANETARY MODELS

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ÖZET

XVI. yüzyıl başlarında bir astronom olarak çalışan Şemsüddîn el-Hafri, Safevi Devleti (1501-1736) yıllarında yaşamış ve faaliyet göstermiştir. İslam biliminin gerileme döneminde olduğu sanılan bir dönemde devrim niteliğinde yaptığı teorik astronomi çalışmaları ile ün kazanmıştır. Safevi Devleti'nin Şiiliği resmi mezhep yapma sürecinde dini bir otorite olarak da rol oynamıştır. Eserleriyle bilim ile dinin o dönemde bir çatışma içinde olmadığını kanıtlayan önemli bir figürdür. Onun en önemli çalışması, Nasîrüddin et-Tûsî'nin *et-Tezkire*'sine yazdığı *el-Tekmile* adlı şerhtir. Bu eserde el-Hafri, Batlamyus astronomisindeki fiziksel tutarsızlıkları -özellikle düzensiz hızı temsil eden ekant problemini- gidermeyi amaçlamıştır. Ay, üst gezegenler ve Merkür için *Tûsî Çifti* ve *episikl* gibi matematiksel teknikleri kullanmış ve Batlamyus'un matematiksel doğruluğunu korumaya çalışmıştır. Ancak bunları yaparken bir taraftan da fiziksel olarak daha tutarlı modeller geliştirmiştir. El-Hafri'nin ay modeli, kendinden önceki Müeyyeddîn el-Urdî ve Kutbüddîn Şîrâzî'nin teorilerini birleştirse de Batlamyus'un gözlemsel verilerine aşırı bağlılığı nedeniyle Ay'ın görünür boyutuyla ilgili hataları tekrarlamıştır. Bu durum el-Hafri'nin bir gözlemciden ziyade matematiksel bir teorisyen olduğunun göstergesidir. Özellikle Merkür için sunduğu birbirine eşdeğer dört farklı model, bilim tarihinde "*modellerin statüsü*" üzerine önemli tartışmalar başlatmıştır. El-Hafri'ye göre bir model, fiziksel gerçeğin kendisinden ziyade, gezegen konumlarını hesaplamaya yarayan matematiksel bir araç olabilir. Bu yaklaşım, Greko-İslam astronomi geleneğinde radikal bir bakış açısıdır. El-Hafri sadece bir astronom değil, o aynı zamanda çözülememiş karmaşık problemleri ele alan bir matematikçi ve din âlimidir.

Anahtar Kelimeler: El-Hafri, Sasaniler, Astronomi, Müeyyeddîn el-Urdî, Kutbüddîn Şîrâzî

ABSTRACT

Shams al-Din al-Khafri, an astronomer who worked in the early 16th century, lived and was active during the Safavid Dynasty (1501-1736). He gained fame for his revolutionary theoretical astronomical studies during a period believed to be in decline for Islamic science. He also played a role as a religious authority in the Safavid Dynasty's process of making Shi'ism the official religion. He is an important figure who, through his works, proved that science and religion were not in conflict during that period. His most important work is his commentary, al-Takmila, on Nasir al-Din al-Tusi's al-Tadhkira. In this work, al-Khafri aimed to resolve the physical inconsistencies in Ptolemaic astronomy—especially the problem of the quanta representing irregular velocity. He used mathematical techniques such as the Tusi pair and the epicycle for the Moon, the outer planets, and Mercury, and tried to preserve Ptolemy's mathematical accuracy. However, while doing this, he also developed more physically consistent models. Although al-Khafri's lunar model combined the theories of his predecessors, Mu'ayy al-Din al-Urdi and Qutb al-Din al-Shirazi, its excessive reliance on Ptolemy's observational data resulted in errors regarding the apparent size of the Moon. This indicates that al-Khafri was more of a mathematical theorist than an observer. His four equivalent models, particularly for Mercury, sparked significant debates in the history of science regarding the "status of models." According to al-Khafri, a model could be a mathematical tool for calculating planetary positions, rather than the physical reality itself. This approach represents a radical perspective within the Greco-Islamic astronomical tradition. Al-Khafri

was not only an astronomer but also a mathematician and religious scholar who tackled complex, unsolved problems.

Keywords: Al-Khafri, Sasanids, Astronomy, Mu'ayy al-Din al-Urdi, Qutb al-Din al-Shirazi

ASTRONOMİ BİLMİNİN ORTA ÇAĞ'DAKİ SESİ: EBÜ'S-SAKR el-KABÎSÎ VE ESERLERİ

THE VOICE OF ASTRONOMY IN THE MIDDLE AGES: ABU'S-SAKR AL-QABISI AND HIS WORKS

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ÖZET

X. yüzyılın ikinci yarısında Irak'ta yaşayan Ebü's-Sakr el-Kabîsî, Orta Çağ'ın en etkili astronom ve astrologlarından biridir. Hamdânî Emiri Seyfüddevle'nin himayesinde çalışmış ve eğitimini dönemin ünlü matematikçisi Ali b. Ahmed el-İmrânî'den almıştır. Batlamyus'un *Almagest* adlı eseri üzerine yoğunlaşmıştır. Hayatı hakkında kısıtlı bilgi olsa da eserlerinin Orta Çağ bilim dünyasındaki etkisi oldukça geniştir. Kabîsî'nin en tanınmış eseri, *Kitâb el-mudhal ilâ sınâ'ati ahkâmi'n-nücûm (Astroloji Sanatına Giriş)* adlı beş bölümlük çalışmasıdır. Bu eser Latinceye çevrildikten sonra Orta Çağ Avrupa üniversitelerinde, özellikle tıp eğitiminin bir parçası olarak okutulan temel bir ders kitabı haline gelmiştir. XV. ve XVI. yüzyıllarda ise defalarca basılmıştır. Astronomik açıdan Kabîsî, gezegenlerin uzaklıkları ve hacimleri üzerine teknik risaleler yazmış ve bu veriler daha sonra Bîrûnî tarafından kaynak olarak kullanılmıştır. Ayrıca astronomik tabloların (zîc) mantığını açıklayan ve Batlamyus'un teorilerini eleştirel bir süzgeçten geçiren *Şükûk el-Mecistî* (*Almagest Üzerine Şüpheler*) gibi ileri düzey çalışmalar kaleme almıştır. Onun özgün yönlerinden biri de astrologları entelektüel derinliklerine göre dört kategoriye ayırdığı *Risâle fî imtihâni'l-müneccimîn* (Astrologların İmtihanı) adlı eseridir. Burada sadece aletlere güvenen veya bilgiyi körü körüne kabul edenleri eleştirerek, kanıta dayalı bilgiye sahip olan "*kâmil*" astronom tipini yüceltmiştir. Kabîsî, astrolojiye yönelik bilimsel eleştirilere karşı bu disiplini savunmuş, ancak onu matematik ve astronomi temelli bir yetkinlik alanı olarak tanımlamıştır.

Anahtar Kelimeler: Kabîsî, Astronomi, Batlamyus, Hamdânîler

ABSTRACT

Living in Iraq during the second half of the 10th century, Abu al-Sakr al-Qabîsî was one of the most influential astronomers and astrologers of the Middle Ages. He worked under the patronage of the Hamdanid Emir Sayf al-Dawla and received his education from the renowned mathematician Ali ibn Ahmad al-Imrani. He focused on Ptolemy's Almagest. Although limited information is available about his life, the influence of his works on the medieval scientific world is quite extensive. Qabîsî's most famous work is his five-part treatise, Kitab al-mudhal ila sina'ati ahkam al-nujum (Introduction to the Art of Astrology). After being translated into Latin, this work became a fundamental textbook in medieval European universities, especially as part of medical education. It was reprinted numerous times in the 15th and 16th centuries. From an astronomical perspective, al-Qabîsî wrote technical treatises on the distances and volumes of planets, and this data was later used as a source by al-Biruni. He also authored advanced works such as Shuquq al-Majisti (Doubts on the Almagest), which explained the logic of astronomical tables (zij) and critically examined Ptolemy's theories. One of his original works is Risala fi imtihani al-munajjimin (The Test of the Astrologers), in which he categorized astrologers into four categories based on their intellectual depth. Here, he criticized those who relied solely on instruments or blindly accepted information, while glorifying the "perfect" astronomer who possessed evidence-based knowledge. Al-Qabîsî defended astrology against scientific criticisms, but defined it as a field of expertise based on mathematics and astronomy.

Keywords: Al-Qabîsî, Astronomy, Ptolemy, Hamdanids

METHOED OF VARIATION OF PARAMETER AND ITS APPLICATION IN ENGINEERING

NITHISH V

ELECTRONICS AND COMMUNICATION ENGINEERING

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ABSTRACT

Introduction and Purpose:

The Method of Variation of Parameters is an important analytical technique used to obtain particular solutions of non-homogeneous linear differential equations. Unlike other methods, it does not impose restrictions on the form of the non-homogeneous term, making it highly versatile. This method is widely applied in engineering mathematics for modeling physical systems such as mechanical vibrations, electrical circuits, and control systems. The purpose of this study is to present a systematic explanation of the Method of Variation of Parameters and to emphasize its significance in engineering applications.

Materials and Methods:

This study is based on a theoretical and analytical approach. The method is derived from the general solution of homogeneous linear differential equations by allowing the constants to vary as functions of the independent variable. Standard mathematical formulations were used to obtain the particular solution. Representative engineering-based examples were analyzed to demonstrate the practical implementation of the method.

Results:

The analysis shows that the Method of Variation of Parameters provides an exact and reliable solution for a wide class of non-homogeneous differential equations. It is particularly effective when other methods such as the method of undetermined coefficients fail. The method ensures mathematical accuracy and flexibility in solving engineering problems involving external forces or inputs.

Discussion and Conclusion:

The study highlights that the Method of Variation of Parameters is a powerful tool in engineering mathematics, offering a deeper understanding of system behavior governed by differential equations. Its broad applicability makes it essential for engineering students and researchers. In conclusion, the method serves as a fundamental analytical technique for solving complex engineering problems involving non-homogeneous systems.

Key Words: Method of Variation of Parameters; Differential Equations; Engineering Mathematics; Non-homogeneous Equations; Mathematical Modeling

DETERMINATION OF MONOSODIUM GLUTAMATE (MSG) AND SODIUM ION CONCENTRATION IN SELECTED SEASONING SOLD IN SOKOTO METROPOLIS

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ABSTRACT

Monosodium glutamate (MSG) and sodium ions (Na^+) are widely used as flavour enhancers in commercial seasonings, contributing to the characteristic umami taste. However, excessive intake of MSG and sodium has been associated with adverse health effects, including hypertension, cardiovascular disorders, and renal dysfunction. This study aimed to determine the MSG and sodium contents of selected seasoning brands commonly consumed in the study area, evaluate their potential health implications, and relate the findings to WHO/JECFA and NAFDAC regulatory standards. MSG was extracted from the seasoning samples using formic acid, which effectively solubilizes MSG while minimizing interference from other components. The extracted MSG was quantified as a percentage of the sample using established analytical protocols. Sodium ion concentration was determined by Flame Atomic Emission Spectrophotometry (FAES) at 589.0 nm, following sample filtration and appropriate dilution to bring concentrations within the linear range of the instrument. The results revealed significant variations in MSG content among the analyzed samples. Ajinomoto and Vedan recorded the highest MSG levels (67.4%), while Maggi (62.2%), Onga (60.6%), Mr. Chef (60.4%), and Royce (60.3%) contained moderate amounts. Bean seasoning showed the lowest MSG content (37.4%). Sodium analysis mirrored these trends, confirming that these seasonings contribute substantially to daily sodium intake. Although MSG and sodium additives are permitted under WHO/JECFA guidelines and regulated by NAFDAC, the high concentrations observed suggest that frequent consumption of these seasonings could pose potential health risks, particularly among sensitive individuals or populations with pre-existing conditions. This study underscores the importance of moderation in seasoning use, accurate product labeling, and consumer awareness, as well as the need for continuous regulatory monitoring to ensure food safety and minimize the public health risks associated with excessive MSG and sodium consumption. The findings also highlight the effectiveness of formic acid extraction coupled with FAES as reliable methods for quantitative determination of MSG and sodium in seasoning products.

Key Words: Monosodium glutamate (MSG), Glutamate, Seasoning, Sodium

Introduction

Flavoring is a food additive that can add flavor and aroma to food. The demanding need for that food that tastes good and delicious causes the use of flavoring agents to increase over time such as monosodium glutamate (MSG). Monosodium glutamate use has become controversial since 1980 and many questions have been raised since then about its safety (Tuschar, & Parmeshwar, 2017). It has been identified as a determining factor of a syndrome known as “Chinese Restaurant Syndrome” (Muhammad, Kabir, & Adeleke, 2021). Industrial food manufacturers use MSG as a flavour enhancer because it balances, blends and rounds the total perception of other taste (Lonliger, 2022).

Monosodium glutamate (MSG) is a widely used food additive classified primarily as a flavor enhancer, valued for its ability to impart the savory taste known as ‘umami’ (Izah, & Aigberua, 2017). From a food chemistry perspective, MSG is the sodium salt of L-glutamic acid, a non-essential amino acid that occurs naturally in both plant and animal proteins. It is sold as a fine white crystals substance similar in appearance to salt or sugar; it ionizes in water into free sodium and glutamate ions. It has a carboxylic (-COOH) group and an amino ($-NH_2$) group attached to an alpha carbon (Mustapha, Yasir, & Samina 2015). The chemical structure of glutamic acid and monosodium glutamate are shown in Figure 1.0 and 1.1 respectively.

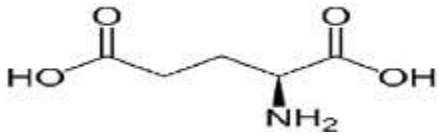

Figure 1.0 Chemical Structure of Glutamic Acid

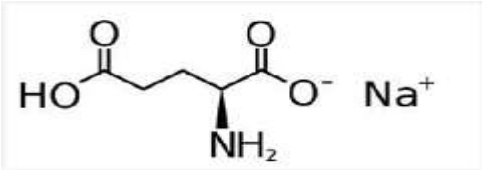

Figure 1.1 Chemical Structure of Monosodium Glutamate (MSG)

Free glutamate is responsible for umami perception, while protein-bound glutamate contributes to nutritional amino acid pools following digestion. The glutamate present in MSG is chemically identical to glutamate naturally occurring in foods such as tomatoes, mushrooms, cheese, meat, fish, and fermented products, making MSG a purified source of free glutamate rather than a synthetic foreign compound (Mustapha *et al.*, 2015).

In food systems, MSG functions by dissociating into sodium ions and glutamate upon dissolution. The glutamate component interacts with umami-specific taste receptors (mGluR4, T1R1/T1R3) on the tongue, enhancing palatability and depth of flavor. This interaction not only intensifies savory perception but also synergistically enhances other taste compounds, allowing for improved sensory quality at relatively low concentrations (Muhammad *et al.*, 2021). From a formulation standpoint, MSG is particularly valuable in processed and convenience foods, where it can compensate for flavor losses due to reduced fat or salt content. Notably, MSG contains approximately one-third the sodium of sodium chloride, making it useful in sodium-reduction strategies without compromising taste (Prasetyo, 2022).

Within the Nigerian context, the safety, regulation, and use of MSG fall under the oversight of the National Agency for Food and Drug Administration and Control (NAFDAC). NAFDAC regulates MSG as a permitted food additive and flavor enhancer, ensuring that products containing MSG comply with established safety, labeling, and quality standards (Walker, & Lupien, 2020). In line with international best practices, NAFDAC's regulatory framework aligns with guidelines from global authorities such as the Codex Alimentarius Commission, the World Health Organization (WHO), and the Food and Agriculture Organization (FAO), all of which recognize MSG as safe for consumption when used in accordance with good manufacturing practices (Prasetyo, 2022).

In Nigeria, MSG is commonly present in commercially packaged seasonings and flavoring agents, widely used in household cooking and food service establishments. As such, toxicological risk assessment emphasizes exposure level, frequency of consumption, and overall dietary pattern, rather than MSG as an isolated chemical entity (Sharma, 2023). Public health concerns surrounding MSG in Nigeria often stem from misinformation, confusion between MSG and excessive consumption of highly processed foods, and the broader nutritional challenges associated with high salt and fat intake (Muhammad *et al.*, 2021). Regulatory agencies therefore emphasize consumer education, proper labeling, and moderation rather than outright restriction.

Monosodium Glutamate in Seasoning Cubes

Food seasoning is a substance that adds flavor to food, they include salt, peppers and other spices. Spices are vegetables substances of indigenous origin which are aromatic and have hot piquant tastes, used to enhance the flavor of foods or to add to them the stimulant ingredient contained in them (Muhammad *et al.*, 2021). Seasoning can also be used to replace common salt in a great variety of other industrially prepared food items as well as in the preparation of foods items as well as in the preparation of food both in restaurants, catering, home kitchen etc. Such seasonings are particularly suitable for soups, beefs, and other foods in which salty or spiced seasonings are used (Zhou, & Da-Costa, 2018). The ingredients mixture and seasonings when added to various food items change the food composition (Prasetyo, 2022). There are various brands of food seasonings readily available in Sokoto Central Markets, in street shops and supermarkets. These include: Mr chef, Maggi star, Royco, Larsor (powdered), knorr, Doyin,

Jumbo (cubes), Onga, Mixpy, Benny (powdered), Aluba shrimps seasoning (powdered), A-one, Vedan, Aji-no-mo-to, Salsa, Doli etc. Reports have indicated that the major active ingredient in flavor enhancers are salts (NaCl) and monosodium glutamate (MSG) (Muhammad *et al*., 2021).

Toxicity and safety of Monosodium Glutamate

MSG has been used for more than 100 years to season food, with a number of studies conducted on its safety (Bera, Shankar, Parmeshwar, Sanji, & Bishal, 2017). Concern about the hazard of MSG for health has been debated all over the world for many decades. Since 1958, glutamate has been listed as a safe substance by the U.S Food and Drug Administration (FDA). Its safety is proven by numerous biochemical, toxicological and medical studies, hence, nowadays it is used as food ingredients. At that time, an acceptable daily intake of 0-120 mg/kg of body weight was set (Zanfirescu, Ungurianu, Tsatsakis, Nițulescu, Kouretas, Veskoukis, & Margină, 2019).

On the opposite side, MSG is described as having potential side effect related to few health problems. A study by He, Zhao, Daviglus, Dyer, Van, and Stamler (2018) from China concluded that glutamate intake may indirectly increase overweight in humans. The study by Geha, Ren, Beiser, and Yarnold (2020) also tried to find if there is any reaction of body to glutamate. Although there were claims that glutamate might cause headache or other symptoms (Bera *et al.*, 2017). The first published report of a reaction to monosodium glutamate appeared in 1968 when Robert Ho Man Kwok, who had emigrated from China, reported that although he never had the problem in China, about 20 minutes into a meal at certain Chinese restaurants, he suffered numbness, tingling, and tightness of the chest that lasted for approximately 2 hours. When certain people consume food that contains monosodium glutamate, symptoms may occur such as nausea, facial pressure, tightness, chest pain and warmth (Kazuhiro, Masaharu, Soichi, Yoichi, Mitsuru, & Takuya, 2018). MSG causes retinal degeneration, endocrine disorder, addiction, stroke, epilepsy, brain trauma, neuropathic pain, schizophrenia, anxiety, depression, Parkinson's disease, Alzheimer's disease, Huntington disease, and amyotrophic lateral sclerosis (Eweka & Ucheya, 2017).

Mounir and Zaid (2013) carried out direct assay of monosodium glutamate multi-sourced bouillon cubes by first derivative potentiometric titration. The percentage purity of 99.94% was obtained in their study for the standard MSG. The highest percentage MSG content in the work was 75.14% while the lowest percentage recorded was 55.96%.

Malina, Amran and Ulianas (2018) conducted a research on monosodium glutamate analysis in meatballs soup. The highest and lowest reproducibility and recovery of monosodium glutamate in their research was 93% and 82% respectively. The analysis of MSG content in the meatball soup was 0.00372M and 0.0370M in their two samples respectively.

Colorimetric determination of monosodium glutamate in food samples using L-glutamate oxidase was carried out by Inuwa (2011) which was based on the bioreaction for quantitation of MSG in food. The average L-glutamate in the common food samples of their research ranged from 0.93-4.9g/kg.

Statement of Research Problem

Monosodium glutamate (MSG) is a common flavor enhancer used in seasonings to improve the savory taste of foods. While generally considered safe, excessive consumption may contribute to health issues such as headaches, flushing, and increased sodium intake, which can affect blood pressure. In Sokoto metropolis, seasonings are widely consumed, but there is limited information on their actual MSG content, especially for products sold in informal markets with minimal regulatory oversight. This lack of data makes it difficult to assess potential health risks and guide safe consumption. Therefore, it is necessary to determine the MSG levels in selected seasonings consumed in Sokoto metropolis to provide baseline information for public health and regulatory purposes.

Justification of the Study

The widespread use of monosodium glutamate (MSG) in seasonings highlights the need for awareness of its concentration in foods commonly consumed in Sokoto metropolis. Excessive intake of MSG can contribute to health concerns such as headaches, flushing, and elevated sodium intake, which may increase the risk of hypertension and other cardiovascular conditions. Despite its popularity, there is

limited data on the actual MSG content of seasonings in local markets, particularly in informal or unregulated sources.

This study is justified as it will provide quantitative information on MSG levels in selected seasonings, enabling consumers, researchers, and regulatory bodies like NAFDAC to make informed decisions regarding food safety and dietary exposure. Furthermore, the findings can support public health awareness campaigns, encourage compliance with food additive regulations, and guide safe consumption practices, ultimately contributing to improved nutrition and food safety in the community.

Aim and Objectives

Aim

The aim of this study is to determine the level of monosodium glutamate (MSG) in Maggi, Royco, Onga, Mr chef, Lucust bean, Vedan and Ajinomoto seasonings sold within Sokoto metropolis.

Objectives

The objectives of the research include:

i. To extract glutamate from the seasoning samples using formic acid.

ii. To determine concentration of MSG in each of the sample using UV-Vis

iii. To determine other alkali metal (Na) in the glutamate containing seasoning samples using FAES (Flame Atomic Emission Spectroscopy).

Scope and Limitations of the Study

This study focuses on the quantitative determination of monosodium glutamate (MSG) levels in selected seasonings commonly consumed in Sokoto metropolis. It includes branded and locally produced seasonings obtained from retail outlets and formal markets within the metropolis. The study will employ appropriate analytical techniques to measure MSG content. The study is limited to MSG as a flavor enhancer and does not cover other food additives, preservatives, or chemical contaminants in seasonings. It is also restricted to Sokoto metropolis and may not represent MSG content in seasonings sold in other regions of Nigeria. The findings aim to provide baseline data for consumer awareness, regulatory monitoring, and public health guidance regarding safe MSG consumption.

Methodology

Samples collection

Samples were collected randomly at Sokoto central market. The samples include Ajinomoto, Vedan, Maggi, Royco, Onga, and Mr Chef. The local seasoning locust bean (Daddawa in Hausa) was obtained at Marina market, Sokoto North Local Government of Sokoto state.

Glutamate Extraction

The samples were grounded into powdered form using mortar and pestle. The powdered samples were transferred into a dry clean crucible and placed in an oven set at temperature of 110^0C for 2 hours to remove the moisture. This was repeated until constant weight of the sample was obtained. Thereafter, approximately 2g of the dried powdered sample was dissolved in $25cm^3$ 0.1M formic acid solution. The solution was filtered into a beaker and the filtrate was placed on a boiling water bath set at 100^0C. The solution was constantly stirred at 3 minutes intervals. The solution was evaporated to dryness and allowed to cool at room temperature. The procedure was repeated for six remaining samples (Andarwulan & Hanifah, 2024).

Determination of Sodium Ion by Flame Atomic Emission Spectrophotometry

Sodium ion in the seasoning samples was determined using Flame Atomic Emission Spectrophotometry (FAES). About 1.0 g of each sample was dissolved in distilled water, filtered, and diluted to 100 mL in a volumetric flask. Appropriate dilutions were made where necessary. Sodium standard solutions were prepared from a 1000 mg/L stock solution. Analysis was carried out using an air–acetylene flame at a wavelength of 589.0 nm. The instrument was calibrated with the standards, and sample emission

intensities were measured in triplicate. Sodium concentrations were obtained from the calibration curve and expressed as percentage sodium content as reported by Mustapha *et al.,* (2015).

Determination of Percentage Content of MSG in the Selected Samples Using UV-Vis

A concentration of 1 gdm^{-3} of one the seasoning sample was taken and run in a UV-Vis spectrophotometer at a wavelength of 600nm. The process was repeated trice to obtain the average concentration and standard deviation. The absorbance obtained was at pH 10. The entire process was repeated for the remaining samples and the concentration of the various seasoning samples was calculated using the equation below (Muhammad *et al.*, 2021):

$$Concentration\ \left(\frac{g}{dm3}\right) = Concentration\left(\frac{mol}{dm3}\right) \times Molar\ mas(\frac{g}{mol})$$

$$\%MSG = \frac{\text{Concentration of MSG in Sample}(\frac{g}{dm3})}{Concentration\ of\ Sample(\frac{g}{dm3})} \times 100$$

Results and Discussion

Results of the Extraction of Glutamate from the Seasoning Samples Using Formic Acid

The extraction of monosodium glutamate (MSG) from the selected seasoning samples using formic acid proved to be effective, as evidenced by the clear solubilization of MSG from the complex food matrix. Formic acid provided a mildly acidic environment that enhanced the release of free glutamate by protonating the glutamate moiety, thereby increasing its solubility in the aqueous phase. The clarity of the extract and absence of excessive turbidity suggest minimal interference from insoluble components such as fats, starches, and spices, indicating good selectivity of the extraction method. The effectiveness of formic acid in extracting MSG can be explained by its chemical action on glutamate. In acidic conditions, glutamate exists predominantly in a protonated form, which enhances its solubility and facilitates separation from other food constituents. Unlike strong mineral acids, formic acid minimizes excessive protein hydrolysis and matrix degradation, thereby reducing analytical interference. This agrees with literature reports indicating that weak organic acids are suitable solvents for MSG extraction due to their efficiency and minimal alteration of the analyte.

Concentration of Monosodium Glutamate (MSG) in the Samples Using UV-Vis

The concentration of MSG was determined using UV-Visible spectroscopy and the results obtained are presented in Table 1.0

Table 1.0 Percentage MSG in samples using UV-Vis spectrometry

Samples	Code	Percentage MSG(%)
Ajinomoto	A	77.7
Vedan	V	62.9
Maggi Star	MS	51.6
Onga	O	41.4
Mr chef	MC	26.5
Royco	R	47.1
Locust bean	LB	11.8

The percentage composition of monosodium glutamate (MSG) in the analyzed seasoning samples (Table 1.0) reveals substantial variation among brands, with values ranging from 11.8% to 77.7%. These findings are significant when considered alongside international and national regulatory guidelines established by the World Health Organization (WHO), the Joint FAO/WHO Expert Committee on Food Additives (JECFA), and Nigeria's National Agency for Food and Drug Administration and Control (NAFDAC). According to JECFA, MSG is classified as a food additive with an "Acceptable Daily

Intake (ADI) not specified", implying that MSG is considered safe when consumed at levels necessary to achieve its technological function in food. However, WHO and FAO emphasize that excessive intake may lead to transient adverse effects in sensitive individuals, particularly when consumed in large quantities or without food. NAFDAC similarly permits the use of MSG in seasonings and processed foods but mandates proper labeling and compliance with Good Manufacturing Practices (GMP) to prevent excessive exposure. In the present study, Ajinomoto recorded the highest MSG content (77.7%), followed by Vedan (62.9%). These high values indicate that these products are largely MSG-based and, when used excessively or frequently, could significantly contribute to daily glutamate intake. Although MSG itself is not inherently toxic, high consumption has been associated in some individuals with symptoms such as headache, flushing, sweating, chest discomfort, nausea, and weakness, collectively referred to as MSG symptom complex. Frequent use of high-MSG seasonings may therefore increase the likelihood of these symptoms, particularly among sensitive consumers. Seasonings such as Maggi Star (51.6%), Royco (47.1%), and Onga (41.4%) showed moderate MSG levels. These products are typically used in multiple meals daily in many Nigerian households, which may result in cumulative MSG intake that approaches or exceeds levels considered comfortable for sensitive individuals. When combined with MSG naturally present in foods such as tomatoes, meat, and fermented products, total glutamate exposure may be considerably higher than anticipated. Mr. Chef (26.5%) and Bean seasoning (11.8%) contained relatively low MSG levels, suggesting reduced reliance on synthetic flavour enhancers. From a public health perspective, these products may present a higher risk of excessive MSG intake, particularly for populations with high seasoning consumption patterns.

Sodium Ion (Na^{2+}) Content in Selected Seasoning Samples

The sodium ion (Na^{2+}) contents was determined using flame atomic emission spectroscopy (FAES) and the results obtained are presented in Table 1.1

Table 1.1 Percentage MSG in samples using flame spectrometry

Sample	Percentage MSG
Ajinomoto	67.4
Vedan	67.4
Maggi Star	62.2
Royco	60.6
Onga	60.4
Mr chef	60.3
Locust bean	37.4

The sodium ion (Na^{+}) content of the analyzed seasoning samples (Table 1.1) reveals consistently high sodium levels across most brands, with values ranging from 37.4% to 67.4%. Sodium is an essential dietary mineral involved in nerve transmission, muscle contraction, and fluid balance; however, excessive intake is a well-established risk factor for several non-communicable diseases. The results of this study therefore raise important nutritional and public health considerations when evaluated against World Health Organization (WHO) and National Agency for Food and Drug Administration and Control (NAFDAC) guidelines. Ajinomoto and Vedan recorded the highest sodium ion content (67.4%), indicating a substantial contribution of sodium-based compounds, particularly monosodium glutamate and possibly sodium chloride, in their formulations. These findings are expected, as both products are heavily MSG-based, and MSG dissociates in aqueous media to release sodium ions. The high sodium levels imply that frequent or excessive use of these seasonings could significantly increase total daily sodium intake, especially in populations where seasoning cubes or powders are used repeatedly in meal preparation. Maggi Star (62.2%), Onga (60.6%), Mr. Chef (60.4%), and Royco (60.3%) also exhibited comparably high sodium ion contents, suggesting that sodium is a major constituent across most commercially available seasonings. Although these products are often perceived as composite spice blends, the results indicate that sodium-containing additives remain central to flavour enhancement. Given that these brands are widely consumed in Nigerian households, their cumulative contribution to

sodium intake may be substantial. The Locust Bean seasoning sample recorded the lowest sodium ion content (37.4%), markedly lower than all other samples. This suggests reduced inclusion of sodium-based flavour enhancers or salt and potentially greater reliance on natural spices or non-sodium flavouring agents. From a nutritional standpoint, this product may represent a relatively healthier option for individuals seeking to limit sodium consumption. From a regulatory perspective, the WHO recommends a maximum sodium intake of less than 2,000 mg per day, equivalent to 5 g of salt (NaCl), to reduce the risk of hypertension and cardiovascular diseases. Similarly, NAFDAC aligns with international food safety standards by permitting sodium-containing additives, including MSG, provided their use complies with Good Manufacturing Practices (GMP) and that products are clearly labeled to inform consumers. While the sodium ion percentages observed in this study do not necessarily imply regulatory non-compliance, they highlight the potential for dietary sodium intake to exceed recommended limits, particularly when multiple sodium-rich foods are consumed within the same day. The health implications of high sodium intake are well documented. Chronic excessive sodium consumption is strongly associated with hypertension, stroke, coronary heart disease, and kidney dysfunction. In Nigeria, where the prevalence of hypertension is increasing, high-sodium seasonings may represent a hidden but significant contributor to dietary sodium burden. Furthermore, when high sodium intake from seasonings is combined with processed foods, salted snacks, and traditional soups prepared with seasoning cubes, the cumulative risk becomes more pronounced. Although MSG contains less sodium by weight than common salt, its frequent use in large quantities can still meaningfully increase sodium exposure. Therefore, seasonings with high sodium ion content, such as Ajinomoto, Vedan, and Maggi, may indirectly exacerbate sodium-related health risks if not used in moderation. Vulnerable populations, including individuals with hypertension, cardiovascular disease, renal disorders, and pregnant women, may be particularly affected.

Conclusion and Recommendations

Conclusion

In conclusion, monosodium glutamate (MSG) was extracted using formic acid and the MSG and sodium ion (Na^+) contents of selected seasoning brands were also evaluated.

The results revealed notable variations among the samples, with Ajinomoto and Vedan consistently recording the highest levels of both MSG and Na^+, confirming their strong reliance on sodium-based flavour enhancers. Other widely consumed seasonings such as Maggi Star, Onga, Royco, and Mr. Chef contained moderate but still substantial amounts, while Locust Bean seasoning showed comparatively lower MSG and sodium contents.

Although MSG use in foods is permitted under WHO/JECFA guidelines and regulated by NAFDAC, the high Na^+ levels observed across most samples raise public health concerns. Frequent consumption of these seasonings may significantly contribute to excessive dietary sodium intake, which is associated with hypertension, cardiovascular diseases, and renal disorders. The combined presence of MSG and other sodium-containing additives further increases the potential health risk, particularly for vulnerable populations.

Overall, the findings highlight the need for moderation in seasoning consumption, improved consumer awareness, and sustained regulatory monitoring to minimize the health risks associated with excessive MSG and sodium intake.

Recommendations

Based on the findings of this study, the following recommendations are made:

1. **Consumer Awareness:**

Consumers should be educated on the potential health implications of excessive MSG and sodium intake and encouraged to use seasonings in moderation, particularly those with high MSG and sodium contents.

2. **Regulatory Monitoring:**

NAFDAC should strengthen routine surveillance and laboratory verification of MSG and sodium levels in commercial seasonings to ensure compliance with labeling regulations and Good Manufacturing Practices.

3. Improved Labeling:

Manufacturers should clearly and accurately declare MSG and sodium content on product labels to enable informed consumer choices, especially for individuals with hypertension or other sodium-sensitive conditions.

4. Product Reformulation:

Seasoning manufacturers are encouraged to explore formulation strategies that reduce sodium and MSG levels, such as the use of natural flavour enhancers and spices, without compromising product quality.

5. Public Health Policy:

Public health agencies should integrate seasoning consumption into national salt reduction strategies in line with WHO recommendations to reduce the prevalence of diet-related non-communicable diseases.

6. Further Research:

Future studies should assess daily intake levels, consumer usage patterns, and the cumulative dietary contribution of MSG and sodium from multiple food sources, as well as investigate possible long-term health effects.

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DETERMINATION OF HEAVY METALS IN SELECTED COSMETIC PRODUCTS SOLD IN SOKOTO OLD MARKET, NIGERIA: CONCENTRATIONS AND HEALTH RISK ASSESSMENT

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ABSTRACT

The presence of heavy metals in cosmetic products poses potential public health concerns due to chronic dermal exposure. This study determined the concentrations of selected heavy metals and evaluated their associated health risks in cosmetic products sold in Sokoto Old Markets, Nigeria. Representative samples of jellies, creams, lotions, face powders, and lipsticks were collected and analyzed for lead (Pb), cadmium (Cd), chromium (Cr), and nickel (Ni) using Atomic Absorption Spectrophotometry. The measured concentrations of all metals were below the permissible limits set by the World Health Organization and the National Agency for Food and Drug Administration and Control. Despite regulatory compliance, health risk assessment based on the United States Environmental Protection Agency dermal exposure model revealed important toxicological implications. Hazard Quotient and Hazard Index values indicated negligible non-carcinogenic risk for adults, whereas cumulative exposure in children exceeded the acceptable threshold, primarily due to nickel and chromium contributions. Carcinogenic risk assessment showed that cadmium and chromium accounted for the major proportion of total cancer risk, which marginally exceeded the recommended acceptable range for lifetime exposure. These findings demonstrate that concentration-based regulatory limits alone may underestimate health risks associated with long-term cosmetic use, particularly among vulnerable populations. The study underscores the need for routine monitoring of cosmetic products and the integration of risk-based assessment approaches into cosmetic safety regulation in informal markets.

Key Words: Cosmetics, Heavy Metals, Risk Management, Carcinogenic

ISOTOPIC AND HYDROCHEMICAL ANALYSIS OF THE GHIS-NEKOR AQUIFER MOROCCO: ORIGIN OF SALINITY AND GROUNDWATER QUALITY

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ABSTRACT

The chemical characterization of the Ghis-Nekor aquifer has attracted significant attention from researchers in Morocco. It is a crucial indicator of the environmental situation and the socio- economic development of this Moroccan region. Indeed, it helps decision makers to conduct a conscious and sustainable management. The primary objective of this study is to investigate the origin of salinity using isopoly elements such as Stronstium and Bromide and to evaluate the physicochemical quality of groundwater in the Ghis-Nekor aquifer region and to determine the sources of pollution in order to establish maps of the qualities of the Ghis-Nekor water table.

For this reason, of Ghis-Nekor aquifer 19 samples were examined during the month of July 2023, in terms of isotopic elements such as bromine (Br) and strontium (Sr) et tantalum (Ta) (03 samples), and in terms of physico-chemical parameters such as pH, temperature, electrical conductivity (EC), Chlorides, Nitrates, Ammonium, Nitrite, Sulfates, Sodium, Potassium, Bicarbonates, Calcium, orthophosphates and Magnesium . The spatial distribution of the results was visualized through thematic maps generated using a Geographic Information System (GIS), offering crucial insights for decision-making processes related to water resource management in the region.The water temperature varies between 15.1 and 49°C. The pH is close to neutral, varying between 6.65 and 7.86.

The waters are classified into three distinct chemical facies: chlorinated and sulfated calcic-magnesium facies, bicarbonated calcic-magnesium facies, and chlorinated sodium-potassium facies.The degradation of water quality in the aquifer of the basin of

Ghis-Nkour could have geological and anthropogenic origins.

The analysis of bromide and strontium contents allows to discriminate the origin of salinity anomalies. Molar ratios such as Cl/Br, Br/Cl, and Sr/Ca are employed to distinguish areas influenced by geological factors, such as the leaching of salt formations and facies, from those impacted by anthropogenic activities.

Keywords : Groundwater - Quality - Pollution - GIS - Ghis-Nekor, water table -Morocco.

EFFECTS OF E-AGRICULTURE EXTENSION SERVICE USAGE AMONG POULTRY FARMERS IN NIGER STATE, NIGERIA

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ABSTRACT

Agriculture remains a critical sector for economic development, food security, and poverty reduction in Nigeria. Thus, this study was conducted to assess e-agricultural extension Service delivery for enhancing poultry production in Niger State. Specifically, the study aimed at; determine the factors influencing poultry farmers usage of e-agricultural extension services; and assess the challenges associated with e-agricultural extension service usage in the study area. A multi-stage sampling technique was used to select 226 poultry farmers. Data were collected from primary sources using a semi-structured questionnaire and analysed using descriptive statistics and operationalized using 5-point Likert scale. The results showed that access to information on improved breeding techniques and genetic information had a mean value of (4.33) with 62.9%. Digital platforms provided effective brooding information with a mean of (2.76) with 46.2%, but indicators for growing and rearing stages showed that not all conditions were adequately covered online with a mean value of (4.44) at 96.7%. Online record-keeping tools had a mean value of (2.42) 89.9%.The study concluded that e-agriculture extension service usage positively influence poultry production practices in feeding, housing, marketing, and management. It therefore recommended that government and development partners strengthen farmers access to cooperatives, credit facilities, and tailored e-agricultural extension

Keywords: E-Agriculture, Extension Service Delivery, Poultry Farming, Information Communication Technology ICT in agriculture, Digital tools in Poultry Extension.

INTRODUCTION

Agriculture remains a critical sector for economic development, food security, and poverty reduction in Nigeria, with poultry production playing a vital role in improving nutrition, creating employment, and generating income for rural households (Food and Agriculture organization (FAO) 2020). Niger State, located in the North-Central region of Nigeria, has substantial agricultural potential, with poultry farming being one of the most promising enterprises. However, despite its potential, poultry production in the state faces several challenges, including limited access to updated agricultural information, poor veterinary services, disease outbreaks, and inefficient management practices.

Agricultural extension services are essential for bridging the gap between research and farmers by disseminating improved practices and innovations. Traditionally, extension services in Nigeria have been delivered through face-to-face methods, which are often characterized by limited coverage, high costs, and logistical challenges, especially in rural areas (Agwu *et.al* 2019). This situation has necessitated the exploration of alternative methods for delivering agricultural information effectively and efficiently.

E-agriculture, which involves the use of Information and Communication Technology (ICTs) for agricultural development, presents a viable solution to these challenges. Tools such as mobile phones, social media, online platforms, and SMS-based advisory services have emerged as promising innovations for improving extension service delivery (Filli *et al.*, 2021). E-agricultural extension services can provide poultry farmers in Niger State with timely information on disease prevention, vaccination schedules, feeding practices, and market opportunities, thus enhancing productivity and profitability (Oladupe and Olaniyi, 2020).

Despite the growing relevance of e-agriculture, its adoption and impact on poultry production in Niger State remain underexplored. There is a need to assess how digital extension services are currently utilized by poultry farmers, the challenges encountered, and the potential for scaling up such interventions to enhance poultry production in the region. Understanding these dynamics is essential for developing strategies that leverage ICTs to improve agricultural extension service delivery and promote sustainable poultry farming practices in Niger State.Based on the foregoing, the study was conducted to achieve the set objectives.

i. examine the effects of e-agricultural extension service usage on poultry production.

Methodology

The study was conducted in Niger State, the State was created out of defunct North Western State and became a fully autonomous State on 3rd February, 1976, with headquarter at Minna. Niger State is in the North-central region of Nigerią and lies between longitude 3^0 $3^0$1 and 7^0 $2^0$1 East of the Greenwich Meridian and latitude 8^0 $2^0$1 and 11^0 $3^0$1 North of the equator (Niger State Bureau of Statistics (NSBS), 2022). Three stage sampling procedure was used to select 226 poultry farmers. The data collected was analysed using descriptive statistics such as; mean, frequency and percentage.

In this study, a list of factors were provided to the respondents to indicate their interest this factors are as follows; breeding, brooding, growing and rearing, production, health management, feeding and nutrition, and marketing and processing. This was operationalized using 5-point Likert rating scale of strongly agreed (5) Agreed (4) neutral (3) Disagree (2) and strongly disagree (1) This was aggregated as 5+4+3+2+1=15 divided by 5 to get the mean score value of 3.0. This value greater than 3.0 was adjudge agreed, while less than 3.0 was adjudge disagree.

Results and discussion

The results obtained from the analyses carried out to achieve the objective of the research.

Breeding

The results in table 1 reveal that access to improved breeding techniques and genetic information were with effective (35.2%) strongly agreeing and (62.9%) agreeing, while the mean score of (4.33). Secondly, faster access to information sharing was strongly validated by (73.3%) agreeing and (24.8%) strongly agreeing. However, (97.1%) acknowledged the risk of misinformation if sources are unreliable. This shows that e-agricultural platforms are critical in disseminating breeding innovations, such as improved stock selection and genetic upgrades, which directly impact poultry productivity. The strong reliance on digital platforms means farmers benefit from timely access to genetic knowledge and breeding programme that enhance flock performance. These findings are consistent with Krell *et al.* (2020), who noted that smallholder farmers in Kenya used mobile training modules to access breeding innovations, though challenges of misinformation were common.

Brooding

The results in table 1 shows that only a small proportion (20.0%) of respondents agreed that digital platforms provide effective guidelines on brooding (temperature, lighting, ventilation), with (46.2%) neutral and over (33.0%) disagreeing or strongly disagreeing. The mean score of (2.76) reflects low effectiveness in this aspect. In contrast, a significant 91.4% agreed or strongly agreed that overreliance on digital information can lead to neglect of practical experience. This suggests that while farmers may occasionally receive useful brooding tips online, many find them either insufficient or not tailored to their specific farm conditions. Practical brooding often requires hands-on demonstration, which digital platforms cannot adequately provide. The e-agricultural extension service are less effective in brooding management, and over-dependence can hinder practical learning. This aligns with Shehu *et al*. (2022), who reported that poultry farmers in Borno state found extension services inadequate for practical brooding, and with Jiriko and Amah (2018), who highlighted that face-to-face extension support is irreplaceable in sensitive stages like brooding.

Growing and Rearing

The results in table 1 revealed that in terms of advice on housing, feeding, and vaccination schedules, most farmers were neutral (42.4%) or disagreed (35.7%), resulting in a low mean of 2.73. Similarly, growth monitoring via apps had limited support, with only (15.7%) agreeing, while (46.2%) disagreed or strongly disagreed, giving a mean of (2.47). However, (96.7%) strongly agreed or agreed that not all local conditions are covered online, which had a mean of (4.44). This indicates that while digital tools offer general advice, they often fail to account for the diverse climatic and environmental conditions in Niger State. This is similar to findings by Groher et al. (2020), who stated that adoption of digital rearing technologies is highly context-specific, with poor adaptability across varying climates. Olayiwola *et a*l. (2023) also affirmed that ICT tools were widely accessed in Taraba State but often failed to address local realities, such as seasonal disease outbreaks and climatic stress.

Table 1: Effects of e-agricultural Extension service usage on Poultry Production

Variable	Strongly Agree (Freq %)	Agree (Freq %)	Neutral (Freq %)	Disagree (Freq %)	Strongly Disagree (Freq %)	Weighted Sum (WS)	Mean (X)
Breeding							
Access to improved breeding techniques and genetics information	74(35.2)	132(62.9)	4(1.9)	0(0.0)	0(0.0)	910	4.33
Faster access to information sharing	52(24.8)	154(73.3)	4(1.9)	0(0.0)	0(0.0)	888	4.23
Risk of misinformation if sources are unreliable	78(37.1)	126(60.0)	6(2.9)	0(0.0)	0(0.0)	912	4.34
Brooding							
Provide guidelines on temperature control, lighting, and ventilation during brooding	13(6.2)	29(13.8)	97(46.2)	36(17.1)	35(16.7)	579	2.76
Over- reliance on digital information may lead to neglect of practical experience	105(50.0)	87(41.4)	14(6.7)	3(1.4)	1(0.5)	922	4.39
Growing and Rearing							
Advice on housing, feeding and vaccines schedules	18(8.6)	28(13.3)	89(42.4)	30(14.3)	45(21.4)	574	2.73
Growth monitoring through apps or online platforms	8(3.8)	25(11.9)	80(38.1)	42(20.0)	55(26.2)	519	2.47
Not all local conditions are covered online	101(48.1)	102(48.6)	6(2.9)	1(0.5)	0(0.0)	933	4.44

Source: Field Survey, 2025

Production

The results in table 2 shows that online record-keeping tools, which should enhance productivity, were not widely supported. Only (10.0%) strongly agreed, while (89.9%) were neutral with a mean score of

(2.42). This suggests that respondents either do not use such tools effectively or lack the technical capacity to manage them. On the other hand, 91.5% of respondents agreed or strongly agreed that over-dependence on technology may reduce hands-on production skills, with a mean of (4.32). This agrees with Olanrewaju *et al.* (2023), who found that only 18.4% of poultry farmers used computers for record-keeping, showing poor adoption despite clear benefits in Nigeria. **Health Management**

The results in table 2 further reveal mixed perceptions of health management practices. Only (15.8%) agreed or strongly agreed that e-agricultural extension service provide early disease detection and veterinary advice, while (84.3%) were neutral or disagreed, the mean of (2.95). Similarly, wrong diagnosis was identified as a concern, with (42.4%) agreeing, while (31.4%)disagreed. This shows that e-agricultural platforms have potential in health management such as providing vaccination schedules, detecting symptoms, and connecting farmers to veterinarians, but the trust in such services remains low among farmers. The effect on poultry production is that farmers still face challenges in relying on digital veterinary advice, likely due to the risk of self-medication or incorrect application without physical verification by experts. These findings affirmed with Sadique *et al.* (2023), who stated that physical extension agents were more effective than ICT alone in livestock health, and with Pousga *et al.* (2022), who found that livestock health often received less attention in extension services compared to crops.

Feeding and nutrition

The results table 2 revealed that access to feed formulation guidelines and cost-effective feeding strategies had moderate adoption, with (36.6%) agreeing or strongly agreeing and 33.8% disagreeing, giving a mean of (3.80). This indicates that digital platforms were somewhat helpful in guiding feeding decisions, especially in balancing nutrients and managing feed costs. More strongly, (73.3%) of respondents agreed or strongly agreed that standardised advice often does not align with local feed resources or flock conditions, with a mean of (4.10). This highlights the critical limitation of generalised digital feeding recommendations, which may not address local realities such as feed shortages, high costs, or flock variability. Similar limitations were reported by Eleke *et al.* (2024), who found ICT-based training to improve feeding practices but was constrained by local feed availability. Jiriko and Amah (2018) also identified high cost of feed and scarcity as major barriers to poultry farmers, showing that ICT tools alone cannot solve resource-based challenges.

Marketing and processing

The results in table 2 revealed that marketing and processing show strong positive effects of e-agricultural extension service. A total of (84.8%) agreed or strongly agreed that platforms provide wider market access, price updates, and digital sales opportunities, reflected in a mean of (4.10). Similarly, (92.4%) recognised the risk of cyber fraud and market saturation, with a mean of (4.24). These findings show that farmers benefit significantly from digital marketing platforms, gaining access to wider networks and improved bargaining power, thereby increasing income and profitability. However, they also face risks such as fraud and high competition. The effect on poultry production is substantial, as digital marketing and processing directly connect farmers to buyers, reduce middlemen exploitation, and expand opportunities for processed products. This aligns with Ekokogbe *et al.* (2024), who highlighted that WhatsApp adoption significantly improved marketing and communication for poultry farmers.

Waste Management

The results in table 2 indicate that e-agricultural platforms were least effective in waste management. Only (19.6%) of respondents agreed or strongly agreed that they provide innovative ideas on waste recycling, composting, and biogas production, while (44.7%) disagreed or strongly disagreed, with a mean of (2.42). Similarly, (51.9%) strongly disagreed or disagreed that online platforms provide effective waste management support, giving a low mean of (2.36). This suggests that respondents either access or do not access useful information on digital platforms regarding poultry waste utilisation. These findings of Wongsim *et al.* (2018), who noted that ICT adoption in agriculture in Thailand focused more on production than waste management, leaving gaps in environmental sustainability. Likewise, Mohammed *et al.* (2019) stated that while ICT improved livestock production in Tunisia, it contributed little towards waste utilisation or sustainable recycling practices.

Table 2: Effects of e-agricultural Extension service usage on Poultry Production

Variable	Strongly Agree (Freq%)	Agree (Freq%)	Neutral (Freq%)	Disagree (Freq%)	Strongly Disagree (Freq%)	Weighted Sum (WS)	Mean
Production							
Online record keeping tools enhance productivity	8(3.8)	13(6.2)	96(45.7)	36(17.1)	57(27.1)	509	2.42
Over dependency on technology may reduce hands-on skills	90(42.9)	102(48.6)	15(7.1)	2(1.0)	1(0.5)	908	4.32
Health Management							
Provide early disease detection online veterinary services and vaccines	6(2.9)	27(12.9)	79(37.6)	29(13.8)	69(32.9)	502	2.39
Wrong diagnosis if farmers self-medicate based on online information without expert verification	17(8.1)	72(34.3)	55(26.2)	15(7.1)	51(24.3)	619	2.94
Feeding and Nutrition							
Access to feed formulation guidelines, nutritional requirements and cost-effective feeding strategies	20(9.5)	57(27.1)	62(29.5)	18(8.6)	53(25.2)	603	2.87
Standardized advice may not locally feed resources or specific flock condition	38(18.1)	116(55.2)	39(18.6)	9(4.3)	8(3.8)	797	3.79
Marketing and Processing							
Wider market access, prices update online sales platforms digital marketing skills	64(30.5)	114(54.3)	24(11.4)	5(2.4)	3(1.4)	861	4.10
Cyber fraud risk, market saturation due to increased competition online	71(33.8)	123(58.6)	13(6.2)	1(0.5)	2(1.0)	890	4.24
Waste Management							
Online innovative ideas on waste recycling composting and biogas production	10(4.8)	31(14.8)	71(33.8)	23(11.0)	75(35.7)	508	2.42
Online challenges without physical demonstrate or technical support	14(6.70	37(17.6)	50(23.8)	18(8.6)	91(43.3)	495	2.36

Source: Field Survey, 2025

Conclusion

The study revealed that e-agricultural extension services significantly enhance poultry production in Niger State by improving farmers' knowledge and practices in feeding, housing, marketingand processing, and waste management.

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DIFFERENTIAL EQUATIONS AND THEIR APPLICATIONS IN ENGINEERING

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ABSTRACT

Differential equations form the backbone of mathematical modeling in engineering, providing powerful tools to describe dynamic systems and predict their behavior. They are widely applied in diverse fields such as mechanical vibrations, electrical circuits, fluid dynamics, and control systems. Despite their importance, many engineering students and practitioners face challenges in understanding the practical applications of differential equations due to the abstract nature of the subject.

The objective of this paper is to explore the role of differential equations in engineering applications and to highlight how various types—ordinary and partial differential equations—are employed in solving real-world problems. The study emphasizes classical solution techniques as well as modern computational approaches, including numerical simulations. Case studies are presented to demonstrate applications in mechanical oscillations, heat transfer, and electrical networks.

The results indicate that differential equations not only provide theoretical insights but also serve as essential tools for designing and optimizing engineering systems. It was observed that computational methods significantly enhance the ability to solve complex problems that are otherwise analytically intractable.

This study contributes to bridging the gap between mathematical theory and engineering practice. The findings are useful for students, researchers, and engineers seeking to understand the practical significance of differential equations in applied sciences.

EVALUATION OF PROXIMATE COMPOSITION , FUNCTIONAL AND SENSORY PROPERTIES OF *GARRI* FROM BLENDS CASSAVA AND SWEET POTATO FORTIFIED WITH AFRICAN YAM BEAN

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ABSTRACT

The study aimed at evaluating proximate composition functional and sensory properties of *garri* from blends cassava and sweet potato fortified with African yam bean. Cassava, sweet potato and African yam bean were formulated in the ratio of 100:0.0, 70:30:0, 55:35:10 and 45:40:15 which were coded as OG1, OG2, OG3 and OG4 respectively. Sample OG1 served as control. The result of proximate composition revealed that moisture content ranged from 1021 to 1.369% protein content from 1;20 to 536%, fat content 0 20 to 060% fibre from 234 to309%ash content from 0 87 t114% and carbohydrates from 8032 to 8168 %increasing proportion of African yam bean significantly (P<005) increased protein , fat and as content the functional properties result showed that water Absorption ranged from 34880 to 41470%, swelling index from 477 to 680%, , bulk density from 057 to 064 g/m and viscosity from 5141, 85 to 7655 m pas the sample OG4 (45% cassava, 40% sweet potato and 15% African yam bean) was more preferred by panelist in term of taste mouldability and aroma to other formulated *garri* sample t although *garri* samples were accepted this study recommend that 15% African yam should be in cooperated in *gar*ri produced from either cassava or sweet potatoes or blend of cassava and sweet potatoes

STRATEGIC SYNERGIES IN THE INDO – PACIFIC: THE SIGNIFICANCE OF INDIA – JAPAN ECONOMIC RELATIONSHIP

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ABSTRACT

This study attempts to examine the political economy of the relations between India and Japan along with broader aspect of Indo-Pacific region. In past few years Indo-Pacific emerged as a centre region for economic cooperation among the countries, strategic competition and most importantly regional stability. India and Japan both regards each other as trusted partners in the region. Hence, we can see this partnership resulting to cooperation like "special strategic and global partnership" in 2014. The partnership attempts to cover many aspects such as economic cooperation, defence engagements and most importantly people-to-people exchange. While we can already see a lot of existing sources explaining the economic and strategic aspect of India-Japan relations which leaves less scope of it to study in a combined manner.

The very main objective of this entire research is to analyze how economic cooperation and strategic cooperation between both the countries are interconnected in Indo-Pacific. Looking at the economic perspective, the study focuses on the key areas such as trade and infrastructure cooperation, development assistance, maritime security etc. It also looks from the regional framework such as Indo-Pacific strategy, ASEAN and QUAD led mechanism in shaping the bilateral cooperation between both the countries.

The respective study follows a qualitative and descriptive research methodology. It attempts to include the combination of both primary as well as secondary sources. Primary sources including the official government reports released by MEA (Ministry of External Affairs of India) and MOFA(Ministry of Foreign Affairs of Japan). Secondary source including the academic books, journals articles, policy papers. Along with this, semi structured interviews and questionnaire survey involving both Indian and Japanese respondents both so as to give the perspective on the Indo-Japan relations.

The study aims to give a clear and complete understanding of India-Japan relations and to contribute to the research of political economy and strategic cooperation in Indo Pacific.

1. INTRODUCTION

The area of Indo Pacific has become one of the important region in the world both economically and strategically. Along with the presence of important maritime routes, rich natural resources and presence of important and emerging powers , this region plays a crucial role in global trade, security and most importantly politics. There is strong and trusted partnership between both India and Japan and that too in the different sectors such as trade, defence, development, Along with it they have strategic, regional and economic relationship between each other. Taking it ahead, the partnership was formally upgraded to "Special strategic and global partnership" showing the shared interest in regional stability, sustainable development and in much more. Both the countries consider each other as trusted partners in the whole region and that is why try to collaborate on many other areas in order to increase the collaboration and cooperation between India and Japan.

Tracing back in past we could see that both the countries have immensely worked in the areas of economy such as trade and infrastructure along with the development assistance which is ODA (official development assistance of Japan) which is the policy of granting aid of Japan to help the developing countries grow their economies. But from the last two decades both the countries have tried to focus on the different dimensions such as strategic cooperation as well as defence cooperation. It could be seen

particularly in the areas of the regional stability, maritime security and much more. Both the countries focused on the regional cooperation through the framework such as Indo-Pacific strategy, QUAD and ASEAN - led initiatives. Along with this people-to-people exchange, cultural diplomacy and development program between both the countries have laid down a foundation of interconnectedness between the natives of the country. It strengthens mutual understanding as well as trust between both the nations. This has actually led both the countries come close to each other for more and tries to cooperate in economic and strategic sectors even more.

If we look at the review of existing literature, we could examine that the relation between India and Japan could be largely seen in the terms of economic cooperation, strategic partnership and diplomatic relations. These studies offer a valuable insight in the areas of trade, development assistance and security cooperation. However it could be seen that very less attention has been given to people-to-people cooperation especially in the areas of culture, education, science and technology. These aspects are often given less attention even though they help to build trust, encourage technology exchange, and supporting long term relations. This limited attention often creates a gap in understanding the relationship between India and Japan in broader context.

2. STATEMENT OF PROBLEM

The region of Indo pacific is becoming a crucial centre for economic growth and strategic competition. Both India and Japan collaborates through infrastructure, trade, development assistance, investment but little research shows how these efforts strengthen strategic influence. Hence, the impact of people-to-people exchange on education, science and technology is still not well studied, clearly examines the gap study address.

3. SCOPE OF RESEARCH

The study attempts to understand the political economy between India and Japan relations in Indo Pacific. It covers insight collected from respondents in India and Japan through questionnaire and survey. The views of different people related to the topic were taken by interviewing them. The scope of the study is based on the research objectives and it focuses on the main areas related to the topic.

4. AIM

The main aim of the research is to understand the relation between India and Japan, Their different aspects and the main areas of collaboration and cooperation related to the research problem.

5. OBJECTIVES

1. To examine the evolution of the region of Indo Pacific through the lens of political economy perspective.

2. To view how economic cooperation helps enhance the strategic partnership in Indo Pacific?

3. To study how trade, investment, development trade and even Infrastructure projects help in strategic cooperation between India and Japan.

4. To see how development assistance strengthen the long term relations between India and Japan.

5. To look how People-to-people cooperation in education, science and technology supports economic cooperation.

6. To study how regional institution plays an important role in maintaining the relationship between both the countries in the Indo Pacific region.

7. To help identify the institutions included in enhancing the economic and strategic cooperation between both India and Japan.

8. To examine the main challenges coming in the path of economic, strategic and People-to-people cooperation in working together in the region effectively.

6. RESEARCH QUESTIONS

1. How can we see the partnership of India and Japan evolving in Indo-Pacific framework from a political economy perspective?

2. In order to strengthen the strategic partnership between both the countries, highlight the role of economic cooperation in it?

3. How does the trade, investment, development assistance between both the countries play a crucial role in maintaining the strategic engagement in Indo-Pacific region?

4. How does development assistance play an important role in the relationship of India and Japan?

5. How does People-to-People program in education, science and technology play an important role in supporting economy between India and Japan?

6. What institutions are included in coordinate economic and strategic cooperation between both the countries?

7. What role does regional platforms plays in influencing cooperation in the Indo pacific framework?

8. What issues restricts the economic, strategic and people-to-people cooperation from working together between India and Japan?

7. HYPOTHESIS

H_1

Economic cooperation between India and Japan plays a very important role in strengthening the strategic partnership in Indo-Pacific region.

H_2

Trade, investment, infrastructure initiatives, development assistance contribute in enhancing the strategic cooperation between India and Japan in Indo-Pacific.

H_3

People-to-people cooperation in education, science and technology supports long term economic and strategic cooperation between India and Japan.

8. CENTRAL QUESTION

How do economic cooperation and people-to-people engagement play a significant role in shaping the strategic partnership between India and Japan in Indo Pacific?

9. RELATED QUESTIONS

1. How does trade, investment and other infrastructure projects between India and Japan helps to increase the influence in Indo Pacific?

2. How does people-to-people cooperation focuses on maintaining long term strategic partnership between India and Japan.

3. How well do regional institutions and platforms helps in strengthening the economic and strategic cooperation between India and Japan?

4. What restrictions could be viewed in working of economic, strategic and people-to-people cooperation together between India and Japan?

10. METHODOLOGY

11.1 RESEARCH APPROACH

This study adopts the Mixed Method including both qualitative as well as quantitative approach to analyze the relationship between India and Japan in the Indo Pacific Framework. The mixed method proves out to be appropriate method as it attempts to include both measurable method through data, survey as well as helps to dive deep into the insight and knowledge of the particular topic through interviews and discussions. Quantitative data provides patterns and perceptions wile qualitative provides us with contextual understanding of institutional, regional, economic and strategic dimensions.

11.2 RESEARCH DESIGN

The Research design is analytical and descriptive. The descriptive method is used to understand the ongoing economic, strategic and institutional cooperation between India and Japan. The analytical method is applied to view how these engagements influence peace, stability and regional influence in the Indo-Pacific. A comparative perspective is added to consider both Indian as well as Japanese context.

11.3 DATA SOURCES

The study includes both Primary as well the Secondary source of data.

1. PRIMARY DATA - It includes interviews, questionnaire, survey providing the first hand insight about the research topic.

2. SECONDARY DATA - It is generally collected from books, academic journals, articles, various think tank reports which generally help us to study the insight from the existing literature.

These sources help us to gain useful insights and supporting the analysis of the research.

11.4 METHOD OF DATA COLLECTION

A combination of Quantitative and Qualitative technique has been used :-

1. QUALITATIVE - Semi structured Interview and discussion allows exploration of experts insight, policy coordination and people-to-people engagement.

2. QUANTITATIVE - Structured surveys records public perception and trends related to India-Japan relations.

The use of these methods generally helps to understand the research problem in ever more broader way.

11.5 DATA COLLECTION METHODS AND PROCEDURES

The data collected is both primary as well as secondary data. Primary data is collected through questionnaire (conducted online for easy participation) and interviews (conducted offline for better understanding). Secondary data was collected through books, academic journals and credible online sources in India-Japan relations.

The data collection process was carries out in an organized manner. Firstly all the secondary sources were read to understand the topic. After understanding the topic, questionnaire was prepared so as to share with the suitable respondents. The collected data is then combined and used for analysis.

11.6 SAMPLING FRAMEWORK

This study uses purposive sampling which means sources and people were chosen because they were related to the India Japan relations. This actually helped to gain the useful information instead of random opinion. Different types of people were chosen to understand the topic in a much better way.

11.7 SAMPLE SIZE JUSTIFICATION

The number of people chosen for this study is suitable for the research. Since the study aims to understand the opinions and experiences in details, a small but relevant sample was sufficient. This also fits the limited time and scope of the research.

11.8 IDENTIFICATION OF VARIABLES

The two types of variables can be indentified in the study :-

1. INDEPENDENT VARIABLE – The independent variable includes economic cooperation, infrastructure projects and strategic partnership between both the country India and Japan.

2. DEPENDENT VARIABLE - The dependent variable is the impact of these factors on regional influence and cooperation in the Indo Pacific.

11.9 DATA ANALYSIS PLAN AND VISUALIZATION

The collected through questionnaire and interviews will be analyzed in a simple and systematic way. The responses will be arranged question wise and it will be groups to understand and common views and differences among respondents during the collection. Interview responses will be given more emphasized to understand the opinions in details. The key findings will be shown clearly wherever it will be needed so that it will be easy to understand. The full analysis will be done in the analysis chapter.

11.10 ETHICAL CONSIDERATION

Ethical guidelines were followed during the conduction of interview and survey. The respondents were already informed and everything was done voluntary by them. The personal information will be kept confidential and the data extracted will only be used for the academic purpose.

ASPECT	DESCRIPTION
Research Approach	Mixed-Method approach
Research Design	Descriptive and Analytical
Data Type	Primary and Secondary Data
Primary Data	Interview, Survey, Focus Group Discussion
Secondary Data	Books, Journal, Articles and Policy Papers
Unit of Analysis	Indo Japan Relation in Indo-Pacific
Data Analysis	Qualitative and basic Quantitative analysis
Ethical Consideration	Informed consent, confidentiality maintained

11. LIMITATION

The study has few limitations. Most of the respondents were from India and very less were from Japan, due to the practical difficulties. Along with that reaching and identifying the suitable and right candidate for the interview was challenging which limited the number of interview responses.

QUESTIONS CHALLENGE IDEAS , DEEPEN UNDERSTANDING , AND TURN KNOWLEDGE INTO PROGRESS . KEEP QUESTIONING . THAT IS HOW LEARNING TRULY MOVES FORWARD

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ABSTRACT

Questioning plays a pivotal role in advancing knowledge, fostering critical thinking, and transforming learning into meaningful progress. In contemporary educational and professional contexts, where information is abundant but deep understanding is often limited, the capacity to formulate and engage with purposeful questions has become increasingly significant. This study examines how structured and sustained questioning enhances cognitive development and supports intellectual growth.

The primary aim of this paper is to analyze the function of questioning as a pedagogical and epistemological tool that deepens understanding and promotes active knowledge construction. Adopting a qualitative, theory-based approach, the study draws upon contemporary educational literature, inquiry-based learning models, and cognitive science research to explore the relationship between questioning, metacognition, and learner engagement.

The analysis indicates that environments that encourage open-ended, reflective, and analytical questioning significantly improve comprehension, critical reasoning, and problem-solving skills. Furthermore, questioning stimulates metacognitive awareness, enabling learners to monitor their thinking processes and refine their conceptual frameworks. The findings suggest that when questioning is systematically integrated into teaching and learning practices, it transforms passive information acquisition into dynamic intellectual engagement.

In conclusion, questioning is not merely a supportive educational technique but a fundamental mechanism for generating progress. By cultivating a culture of inquiry, educational institutions and professional settings can promote deeper understanding, innovation, and lifelong learning. Continuous and purposeful questioning remains the driving force through which knowledge evolves into sustainable intellectual advancement.

Keywords: Questioning; Critical Thinking; Inquiry-Based Learning; Knowledge Construction; Metacognition; Intellectual Growth; Lifelong Learning; Educational Innovation.

GOLD NANOPARTICLE–BASED LATERAL FLOW IMMUNOASSAYS FOR TUBERCULOSIS DIAGNOSIS: MECHANISTIC INSIGHTS, OPTIMIZATION STRATEGIES, AND TRANSLATIONAL PROSPECTS

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ABSTRACT

Tuberculosis (TB), caused by *Mycobacterium tuberculosis*, remains one of the leading causes of infectious mortality worldwide, with the greatest burden in low- and middle-income countries where access to centralized molecular diagnostics is limited. Although nucleic acid amplification platforms such as GeneXpert have improved case detection, their infrastructure requirements and cost restrict widespread deployment. Lateral flow immunoassays (LFIAs) offer a rapid, low-cost, and field-deployable alternative; however, conventional antibody-based TB serological tests have demonstrated inconsistent diagnostic performance, resulting in limited clinical acceptance. Gold nanoparticles (AuNPs), owing to their localized surface plasmon resonance properties, tunable size-dependent optical behavior, and ease of surface functionalization, have emerged as promising signal reporters for next-generation TB LFIAs. This review critically synthesizes current advances in AuNP-based LFIA development for TB diagnosis, with emphasis on the mechanistic determinants of assay performance. We examine how nanoparticle synthesis methods, size control, surface charge modulation, conjugation chemistry, and antibody orientation influence immunorecognition kinetics, signal amplification, and analytical sensitivity. The role of antigen selection, including ESAT-6, CFP-10, Ag85 complex proteins, and lipoarabinomannan (LAM), is evaluated in the context of TB immunopathology and HIV co-infection. Additionally, we analyze membrane flow dynamics, hook effects, and stability challenges that contribute to historical limitations of TB serology. Translational considerations such as cross-reactivity, differentiation of active versus latent TB, clinical validation in high-burden settings, and regulatory pathways are also discussed. By integrating insights from nanotechnology, immunodiagnostics, and clinical microbiology, this review proposes a rational engineering framework for optimizing AuNP-based TB LFIAs. We highlight emerging strategies, including signal amplification approaches, multiplex detection architectures, and digital readout integration, that may overcome prior performance barriers. This synthesis offers a path forward for the set up of clinically sound, cost-effective, and robust point-of-care TB diagnostics that are suited for environments with limited resources.

PHYTOCHEMICAL CONSTITUENTS, ANTIBACTERIAL, AND ANTIOXIDANT PROPERTIES OF *VITELLARIA PARADOXA* ROOT EXTRACT

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ABSTRACT

Background: Medicinal plants are rich sources of bioactive compounds with potential antibacterial and antioxidant effects. *Vitellaria paradoxa* (shea butter tree) is traditionally used for managing several diseases, but scientific evidence on the therapeutic potential of its root extract remains limited. This study evaluates the antibacterial and antioxidant activities of shea butter root extract as a natural alternative to synthetic agents. **Methods:** Roots of *V. paradoxa* were collected from Aliero (May 2025) and authenticated (Voucher No: AFUSTA/PSB/H/Voucher No: 832). The dried roots were pulverized and extracted using 70% ethanol by cold maceration. Qualitative phytochemical screening was performed using standard protocols. Antibacterial activity against *Escherichia coli* and *Staphylococcus aureus* was evaluated using a broth dilution assay to determine minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC). Antioxidant activity was assessed using the DPPH radical scavenging method. **Results:** Phytochemical screening confirmed the presence of alkaloids, flavonoids, tannins, saponins, steroids, terpenoids, glycosides, and phenols. The extract showed potent antibacterial activity against *S. aureus* (MIC: 6.25 mg/mL; MBC: 12.50 mg/mL) than *E. coli* (MIC: 12.5 mg/mL; MBC: 25 mg/mL). Antioxidant findings revealed an IC_{50} of 40 µg/mL for the root extract, indicating moderate radical-scavenging activity. The observed antibacterial and antioxidant effects are likely linked to phenolic and flavonoid compounds, which can disrupt bacterial membranes and donate electrons to neutralize free radicals. **Conclusion:** Ethanolic root extract of *V. paradoxa* possesses measurable antibacterial and antioxidant activities, supporting its potential as a natural source of bioactive compounds for therapeutic development.

Keywords: *Vitellaria paradoxa*, medicinal plants, Antibacterial activity, Phytochemicals, antioxidant activity.

SOCIAL PROTECTION OF OLDER PERSONS IN PUNJAB, PAKISTAN

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ABSTRACT

This study is to analysis the social protection of older people in Pakistan. Social protection is a major arena of government activity aimed at ensuring that vulnerable population groups receive appropriate and effective public support to ensure their financial security and to safeguard their health. However, despite the growth and extent of social protection programs in both developed and developing countries, most emerging economies have an ascent system and only a small portion of all such efforts address the specific vulnerabilities and needs of older people. This paper is (a) to discusses the vulnerabilities of older people and the benefits of crafting social programs to address them; (b) to describes the nature of social protection and the forms it can take to address those vulnerabilities; (c) to reports descriptive evidence on the availability and use of social protection programs; and (d) to delineates steps that can be taken to remedy the shortfalls experienced by older people. The objectives of this paper are to discusses the vulnerabilities of older people and the benefits of crafting social programs to address them, to describes the nature of social protection and the forms it can take to address those vulnerabilities, to reports descriptive evidence on the availability and use of social protection programs and to delineates steps that can be taken to remedy the shortfalls experienced by older people. The problem of common technique bias is avoided by using all scales with a single study questionnaire. This study is not without limitations. The study is primarily limited to one Tehsil Okara. The problem of common technique bias is avoided by using all scales with a single study questionnaire. A sample of 200 people is chosen at random for this study. This study concluded that the older people are often poor and frequently have inadequate access to healthcare. ANOVA test was also used in this study. The health is very important for all the people at it also effects that the freedom, decisions and movement of the elderly people. Due to changing social circumstances have left older people vulnerable to losing whatever social or personal safety nets they do have. This study also found that there is lack of old age house in Punjab, Pakistan. So, the government should establish the old houses that provide the shelter to poor old and helpless people.

Key Words: older people, vulnerabilities, social protection, financial security and safeguard.

DEVELOPMENT AND EVALUATION OF CALCIUM-ENRICHED COOKIES FORTIFIED WITH EGGSHELL POWDER

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ABSTRACT

Calcium deficiency remains a significant public health concern in India, contributing to osteoporosis, reduced bone mineral density, and increased fracture risk across different age groups. The recommended dietary allowance (RDA) for calcium in adults is approximately 600 mg/day; however, habitual diets often fail to meet this requirement. Food fortification offers a practical and sustainable approach to improving calcium intake at the population level. Eggshell powder (ESP), a by-product of the poultry industry, is a rich and economical source of calcium carbonate ($CaCO_3$), containing approximately 38–40% elemental calcium. The present study aimed to develop and evaluate calcium-enriched cookies fortified with eggshell powder and to assess their physicochemical, nutritional, and sensory characteristics.

Eggshells were collected, cleaned, boiled for sterilization, oven-dried, and finely ground to obtain standardized eggshell powder. The elemental calcium content of ESP was considered as 38%, and fortification levels were calculated based on the Indian RDA for calcium. Cookies were formulated using refined wheat flour with ESP incorporated at varying levels (0%, 3%, 4%, and 5% per 100 g flour), corresponding to approximately 20–30% of the RDA per serving. The prepared cookies were evaluated for proximate composition, calcium content, physical properties (diameter, thickness, spread ratio), texture profile analysis, and sensory attributes using a semi-trained panel.

Results indicated a significant increase in ash and calcium content with increasing levels of eggshell powder incorporation. Calcium content increased proportionally with fortification level, confirming the efficiency of ESP as a natural calcium source. However, higher fortification levels slightly affected physical properties, with a marginal reduction in spread ratio and increased hardness due to mineral interaction with the gluten matrix. Sensory evaluation revealed that cookies fortified up to 4% ESP were acceptable in terms of color, taste, texture, and overall acceptability, whereas 5% incorporation resulted in a slight chalky mouthfeel.

The optimized formulation (4% ESP per 100 g flour) provided approximately 150–170 mg calcium per serving, contributing around 25–28% of the adult RDA. This level aligns with recommended fortification practices while maintaining desirable sensory quality. The study demonstrates that eggshell powder can serve as an effective, low-cost, and sustainable calcium fortificant in bakery products. Additionally, the utilization of eggshell waste supports environmental sustainability by reducing agro-industrial by-products.

In conclusion, calcium-fortified cookies developed using eggshell powder represent a nutritionally enhanced functional food with potential for addressing dietary calcium insufficiency. Further studies on bioavailability, storage stability, and consumer acceptability at a larger scale are recommended to support commercial application.

THE CLINICAL SIGNIFICANCE OF NORMAL PHYSIOLOGICAL BLOOD PARAMETERS IN HEALTH ASSESSMENT

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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 INFLUENCE OF FOOD CULTURE ON IDENTITY, HEALTH, AND COMMUNITY CONNECTIONS

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ABSTRACT

In recent years, the key role of food culture in forming identity, health, and community connections has received growing attention. Food is far more than simple sustenance; it represents cultural heritage, nurtures social bonding, and plays a key role in health outcomes. This study considers how food practices serve as a medium for expressing cultural identity, forging social ties, and influencing health. A comprehensive literature review analyzes the relationship between food practices and cultural heritage, showing how traditional foods serve as anchors of identity. Recipes and cooking methods are often passed along through generations, developing a sense of affiliation and continuity. Group meals, characteristic of many cultures, support both the body and social bonds, generating an atmosphere of inclusion and bonding among varied backgrounds. Observational studies of communal dining practices show that these occasions are pivotal for collective morale. They act as social equalizers, enabling cultural sharing and reciprocal support. (Dunbar, 2017) Interviews with community members more clearly explain local food dynamics, offering qualitative knowledge of how food choices reflect cultural identities. (A Qualitative Study of the Meaning of Food and Religious Identity, 2024) Stakeholders such as farmers and chefs highlight the significance of culturally significant foods for health and well-being, while likewise addressing the pressures of globalization that threaten traditional practices. Significantly, dietary habits are changing due to the rise of processed foods, associated with increased rates of obesity and other health issues. (Juul et al., 2025) However, the study notes the strength of food cultures, showing how communities adapt to modern-day challenges by promoting traditional cooking practices and communal meals. (Alrhmoun et al., 2025) Initiatives supporting the inclusion of traditional foods—like cooking classes and local food festivals—emerge as crucial recommendations. (Cultural Influence of Local Food Heritage on Sustainable Development, 2022) Ultimately, the research stresses the importance of food culture for public health and social cohesion, advocating strategies that recognize the complex relationship among food, culture, and community. (Defining social gastronomy: Multidisciplinary viewpoints and a new paradigm for positive social impact through food and gastronomic practices, 2025)

Keywords: Food Culture, Identity, Health, Community, Traditions, Social Bonds, Globalization, Obesity, Food Heritage, Public Health.

Introduction: Understanding the connection between food culture, health, and community is crucial in today's rapidly changing world. This study considers how traditional and modern eating habits influence personal and collective identities and their impact on public health. The primary finding is that appreciating food culture may lead to healthier food choices and stronger community relationships. Food culture encompasses the beliefs, practices, and emotions surrounding food, determined by social, economic, and environmental elements. Research demonstrates that food plays a vital role in expressing identity, preserving traditions, and encouraging connections among people. As communities evolve, their eating habits too change. Traditional foods frequently promote health and well-being, but globalization and urbanization are shifting diets towards processed and convenience foods, negatively affecting public health (Mingay et al., 2021). With obesity rates on the rise—over 2.2 billion people worldwide were reported as overweight in 2016—there is a strong need for healthy food systems (Mingay et al., 2021).

Past studies have shown that individual efforts to change behaviour often fail, underscoring the need for a broader examination of food culture and its impact. (Parks et al., 2025) Meals are essential for cultural communication and social connection. Events like celebrations, festivals, and communal dining help preserve traditions and strengthen social ties. However, as city life becomes increasingly busy, people may lose cooking skills and cultural practices, leading to a reliance on unhealthy processed foods (Mingay et al., 2021). The media and globalization create a complex food landscape, granting easy access to diverse cuisines but also bringing challenges in making healthy choices. It is important to understand the food environments that promote healthy eating. This study intends to fill a knowledge gap on how food culture affects health outcomes and to suggest practical ways to improve community health. By exploring how traditional foods can fit into modern diets and influence social behaviour and health, this research intends to clarify how food heritage can revive community values. (Yasmeen & Fischer, 2024) Reconnecting with our food roots can help create inclusive communities and improve personal well-being. (Bellin et al., 2025, pp. 492-497) This study argues that understanding and appreciating food culture is an effective way to promote better health and build community connections. By examining how food practices shape our identities and affect our health, this research adds a valuable perspective to the existing literature, highlighting the key role of food in public health discussions. While societies face challenges arising from globalization and the growing dependence on processed foods, our findings offer practical strategies to improve local health programs. We believe that celebrating food culture, such as traditional recipes and group meals, can lead to improved lifestyles and stronger social ties, encouraging a view of health that connects culture, identity, and well-being. (Kapelari et al., 2020)

Literature Review: Food is a key part of culture. It helps people express their backgrounds and connect with others. According to Evans (2023), food represents cultural values and traditions, forming an essential part of family and community relationships. UNESCO recognizes many culinary traditions, showing how dishes like Jordan's Al-Mansaf and Japan's sushi contribute to cultural identity. This illustrates the role of food in showing a nation's history and spirit, as seen in national dishes such as Spain's paella and America's hamburgers (Evans, 2023). Immigration greatly affects food culture. Immigrants carry their traditional dishes to new areas, mixing regional cuisines and expanding cultural diversity. Evans (2023) notes that this mix celebrates the particular contributions of different cultural groups. Meals often become common experiences that fortify social bonds during celebrations and gatherings. Food also serves an essential role in health and well-being. Community groups like the SLO Food Bank understand the significance of culturally relevant foods for health and nutrition, especially for marginalized populations (SLO Food Bank, n.d.). By providing fresh produce and culturally significant food options, these organizations aim to ensure that everyone can access nutritious meals that reflect their cultural identity.

Sharing recipes and helping nutrition education safeguard cultural traditions while encouraging a healthier community (SLO Food Bank, n.d.). From a public health perspective, food consumption patterns have changed significantly over the years, resulting in health problems such as obesity and chronic diseases. Mingay et al. (2021) report that, as of 2016, over 2.2 billion people were overweight, with this number expected to rise to 3.28 billion by 2030. Poor food choices, frequently due to more ultra-processed foods, are linked to 11 million deaths in 2017. This shows the immediate need to address food culture in health conversations (Mingay et al., 2021). The relationship between food culture and public health is complex. Many social and environmental elements shape food beliefs, practices, and feelings.

Media and community shape what we consider normal to eat, and the places where we eat—like homes, workplaces, and schools—are important (Mingay et al., 2021). Economic and community factors also affect our food choices and behaviours, rendering it essential to understand food culture to tackle health difficulties effectively. Globalization, urbanization, and technology have changed how we consume food over time. Although globalization provides more food options, it also leads to unhealthy choices, as convenience frequently takes priority over nutrition (Mingay et al., 2021). Urban lifestyles, with busy schedules and less time or ability to cook, usually lead to a dependence on quick, processed meals. Such reliance can undermine a healthy food culture and harm health. Food plays a vital role in our cultural fabric and strongly affects public health. Looking at food culture through a socio-cultural perspective helps us understand dietary behaviours, the impact of our surroundings, and the need to preserve

traditional cooking practices, especially in the face of modern public health challenges. This stresses the complex relationship among food, culture, and health, stressing the need for a just approach that honours traditions while supporting healthier choices.

Methodology: My research methodology starts by outlining the main objectives of my study, which explores the relationship between food culture and individual identities. To establish a solid foundation, I review the existing literature on food culture, including scholarly articles, books, and case studies that examine how cultural backgrounds influence food practices. This thorough examination helps me identify gaps within current research and provides context for my study. I use a qualitative research approach to explore personal experiences and cultural characteristics. To collect detailed data, I conduct semi-structured interviews and focus groups with participants from diverse backgrounds. These sessions are intended to be conversational, motivating participants to share their food narratives. I create open-ended questions designed to prompt respondents to reflect on their experiences in a way which invites storytelling. For example, I might ask, "Can you describe a memorable meal from your childhood and what it meant to you?" This format elicits individual insights and emotions, creating a richer dataset. Creating a comfortable setting is essential during these communications.

I strive to build rapport with participants, ensuring they feel protected and honoured, which encourages more candid sharing of their thoughts and feelings about their relationship with food. I employ thematic analysis to detect common themes and patterns across responses, coding the data and identifying recurring themes and experiences. I also pay attention to unique stories that offer valuable insights into cultural practices. To improve the credibility and validity of my findings, I use member checking by asking participants to review my interpretations of their input. This feedback loop confirms that my understanding corresponds with their lived experiences, strengthening the reliability of my conclusions. My research seeks to clarify how food culture shapes individual identities and influences public health programs. By underscoring these connections, I hope to give insights that inform policies and programs promoting health and well-being throughout diverse communities.

Results: Food is not just something we eat; it represents our culture, heritage, and community values. Dishes like Al-Mansaf from Jordan and pasta from Italy show how food connects us to our identity and each other. Although globalization has given us more food options, it has also led to poorer choices. Many people now prefer convenient, ultra-processed foods due to their hectic urban lifestyles. This shift in what we eat relates to the growing problems of obesity and chronic diseases. Studies show a clear link between eating processed foods and health issues. This illustrates the need for public health campaigns that promote healthy eating. Community organizations, like the SLO Food Bank, help provide access to nutritious food while honouring cultural tastes. They source culturally essential foods and provide nutrition education, supporting community health and inclusion. Group meals foster social connections and a sense of belonging, especially for immigrants adjusting to new environments. Festivals and communal dining remind us of food's role in building relationships and cultural identity. While societies change, food culture also evolves, mixing traditional dishes with new trends. This shifting food landscape shows broader social changes and stresses the importance of celebrating diversity in cooking. It is important to pass down culinary traditions through education and common experiences to preserve our cultural legacy and strengthen community connections. (D'Andrea & D'Ulizia, 2023) We also recognize the link between food culture, health, and environmental protection. (EAT-'Lancet' commission outlines fairer global diet for feeding planet sustainably, 2025) Social standards and financial factors heavily influence our food choices. (Higgs, 2015, pp. 38-44) To improve public health and eating habits, we should examine these factors together. (Atac, 2025) Understanding the reasons behind our dietary habits will help us create better nutritional strategies. (Kowalczewska et al., 2025) Overall, this research illustrates the many roles food plays in our lives and the need for a just approach which respects traditions while promoting health and wellness in our communities. (Wright et al., 2021, pp. 701-715)

Discussion: Food is an essential element of culture, permitting us to express ourselves and connect with others (Evans, 2023). It reflects our traditions and principles, often carried down through generations. UNESCO recognizes several culinary traditions, such as Al-Mansaf from Jordan and sushi from Japan (Evans, 2023). Traditional foods like pasta from Italy and ramen from Japan showcase our cultural character and feeling of community. [1]National dishes, including Spain's paella and hamburgers in the

U.S., capture a country's spirit and history. Food has a central role in preserving culture and supporting diversity, with immigrants (Evans, 2023) contributing their traditional dishes to American cuisine, forming a rich mix of regional foods. This diversity is more than a collection of dishes; it is an homage to the unique cultural contributions of each group (Evans, 2023). Meals bring people together and are central to celebrations. Cultural foods can also promote better health. To keep our traditions alive, we must share recipes and teach about them. [2]Food banks, like the SLO Food Bank, focus on sourcing culturally significant foods, providing nourishment and comfort while supporting community inclusion. [3]At SLO Food Bank, we believe everyone should have access to nutritious food. We gather fresh produce from local farms and help our Agency Partners offer food choices that respect traditional preferences. [4]The mission includes sharing recipes, promoting nutrition education, and connecting the community to critical resources such as [5] CalFresh. [6]The aim is to reduce hunger and improve health, especially in rural areas. Anyone can volunteer or donate to help bring health and happiness to [7]San Luis Obispo County. Food culture shows who we are and reflects our traditions. [8]It affects our health and the way we interact with each other. As societies change, our diets do too, incorporating new foods alongside traditional ones. When we eat together, it highlights our values and helps us connect. [9] Food is a key way to express our personal and cultural identities. Family traditions and local favourites influence it.[10] Food also shows our beliefs about health and the environment. Traditional meals link us to our heritage and history, passing down recipes from generation to generation. [11]For immigrants, food helps create a feeling of belonging in new communities. Sharing meals brings people together and fortifies social ties. Festivals and communal dining accentuate the importance of food in building friendships. Our food choices affect our health. Diets rich in fresh ingredients can lower the risk of disease, while processed foods may cause health problems. Food connects to our feelings and recollections, and cooking for others shows love and care. Overall, food culture forms our identity, influences our health, and impacts our community. Food consumption patterns have changed significantly, resulting in health problems such as obesity and chronic diseases (Mingay et al., 2021). [12]In 2016, more than 2.2 billion people were overweight, and this number might reach 3.28 billion by 2030. [13]Poor diets caused 11 million deaths in 2017, demonstrating the need to move from just treating diseases to promoting healthy and sustainable food systems. We need to consider social and cultural factors on eating habits, as past efforts focused on individuals have been ineffective (Mingay et al., 2021). Redefining food culture is key to improving public health and nutrition (Mingay et al., 2021). [14]Food culture includes the beliefs, practices, and feelings people have about food, influenced by social and surrounding factors. Relationships and media shape how we interact with food, forming social norms through our experiences (Mingay et al., 2021). The places where we eat—like homes, workplaces, and schools—also matter. [15]Societal rules inform our food behaviours, and knowledge about food is transmitted across generations and is influenced by culture, location, and economic resources. Food production and waste are affected by policies, economics, and sustainability (Mingay et al., 2021). [16]Food culture is part of our identity and affects our health and well-being, connecting our diets to larger social and ecological influences. It is vital to examine food culture in our environments to understand how it promotes healthy food choices and community values (Mingay et al., 2021). By studying food culture, we can understand the complex reasons behind our choices, recognizing that food behaviours change and depend on cultural context. [17]Food consumption has shifted due to globalization, urbanization, and technology, affecting health and eating habits. [18]Globalization has increased food options but often leads to poor nutritional choices, with convenient, ultra-processed foods becoming popular. Urban lifestyle and long work hours drive people toward quick, unhealthy meals, leading to a loss of cooking skills over generations (Mingay et al., 2021). The internet adds confusion with mixed nutrition advice and unrealistic body images, which can cause dissatisfaction and unhealthy eating patterns. Fad diets complicate healthy eating by overshadowing reliable nutrition guidance (Mingay et al., 2021). The decline in food culture illustrates the need for public health campaigns that promote healthy eating and shift our attitudes toward food. Focusing on treating health problems has often taken precedence over promoting health, even though healthier habits can reduce long-term healthcare costs (Mingay et al., 2021). Global calls for change highlight the need for policy updates, cross-sector collaboration, supportive environments, education, early interventions, and support for at-risk groups (Mingay et al., 2021). (Mingay et al., 2021) Climate change also impacts food production, requiring a new approach to our food habits. [19]Key efforts, such as the UN Decade of Action on Nutrition and the EAT-Lancet Commission, aim to make healthy, sustainable diets available to

everyone. [20]Recent dietary guidelines, such as the Dietary Guidelines for Americans 2020–2025, promote healthy eating patterns throughout all life stages and emphasize nutrient-rich choices customized to individual needs. [21] Brazil's Dietary Guidelines show how joint action can support healthy eating, while [22] Canada's 2019 guidelines highlight the significance of mindful eating and social meals. These strategies seek to improve food culture and general well-being. Food is more than nutrition; it forms our identities, cultures, and environment. [23]When we consider food, various ideas come to mind. We regularly prioritize nutrition, taste, and ease of preparation. However, food is more than simply a necessity. [24]It reflects our identities, cultures, and the world around us. Each meal we prepare reveals who we are, formed by our cultural backgrounds, cooking styles, traditions, and shopping habits.

[25]Food connects us to our communities and strengthens our identities. [26]By exploring the world of food, we can uncover its connections to social identity, environmental sustainability, and food politics. (Kenefick,2025) Our objective is to foster a healthier relationship with food and approach eating more mindfully. Through this exploration, we will (Kenefick, 2025) develop a deeper understanding of the cultural meanings of the food we eat and comprehend the connections within our global community. By the end of this journey, we will perceive our meals differently, considering the stories behind our ingredients and the impact of our food choices on the world (Kenefick, 2025). [27]Food culture is formed by history, geography, community relations, and economics, revealing stories and values in our diets. [28]Historical events influence dishes, while geography dictates ingredient availability. [29]Food connects people socially and mirrors cultural identity. Financial elements affect access and choices, impacting food security. Understanding food culture improves our appreciation of diversity while encouraging eco-friendly practices. [31]Food culture maintains traditions and biodiversity.[32]Traditional diets are often healthier than processed foods. [33]Traditional farming supports environmental equilibrium and sustainability. [34]Food culture is broader, including social and historical aspects. It can enrich or threaten traditional food practices. Examples include the Japanese tea ceremony and [35]Hindu offerings. [36]It influences food through food regulations and rituals. Ceremonies.[37]Examples include kosher laws in Judaism, halal dietary guidelines in Islam, and vegetarianism in Hinduism and Buddhism. [38]Food tourism involves travelling to a destination specifically to experience its food culture. It provides opportunities to learn about local ingredients, cooking methods, and culinary traditions, supporting an enhanced understanding and appreciation of diverse food cultures. [39]Food sovereignty is the right of peoples to healthy and culturally appropriate food produced through ecologically sound and sustainable methods, and their right to define their own food and agriculture systems, to local control over food production and distribution, and to promote food security and cultural conservation. We can promote and preserve traditional food cultures by supporting local farmers and producers, learning traditional cooking techniques, documenting oral histories of food traditions, and endorsing policies that safeguard food sovereignty and biodiversity. [41]Media, including cookbooks, television shows, and social media, strongly influence food culture. They can popularize certain foods and cooking styles, promote awareness of food-related issues, and mould public perceptions of different cuisines and food traditions. [42]Food advertising often promotes processed and packaged foods, which can negatively affect our understanding and appreciation of traditional food cultures.[43]It can generate unrealistic expectations about food, normalize unhealthy eating habits, and weaken local food systems. Ethical aspects related to food culture include fair trade, sustainable agriculture, animal welfare, and food security. Tackling these issues is key to creating a fairer and more equitable food system. [45]Understanding food culture can broaden our gastronomic horizons, encourage us to explore new ingredients and cooking techniques, and support a more mindful, sustainable approach to eating.[46]It can also help us reconnect with our own cultural heritage and appreciate the social and cultural meaning of food. Future trends in food culture include rising emphasis on sustainability, local sourcing, plant-based diets, and customized nutrition. There is also a resurgence of interest in traditional food practices and a greater awareness of the social and environmental impacts of our food choices.

Conclusion: The exploration of food culture reveals its considerable significance, showing that food transcends mere nourishment to become a vital expression of cultural heritage and social connection. Research in this area highlights the multiple roles that traditional foods and communal dining practices play in fostering a sense of belonging and permanence within communities. Evidence suggests that these

practices both create common experiences and strengthen familial and community relationships. Conversely, the rise of processed foods, frequently associated with the convenience of modern life, correlates with alarming health challenges, particularly obesity and related diseases. Interviews with community members—from local farmers to chefs—point out the significance of culturally significant foods as integral to health and well-being. These discussions also reveal the challenges posed by globalization, which can dilute traditional food practices and disrupt local culinary landscapes. The research supports a range of initiatives, including cooking classes and food festivals, to promote traditional gastronomic practices.

Such moves not only recognize cultural heritage but also contribute considerably to public health and social cohesion. Understanding food culture functions as a crucial element in the quest for better lifestyles. The research shows that reconnecting with our culinary roots can lead to better nutritional decisions and stronger community relationships. In an era distinguished by rapid modernization and urbanization, it is necessary to recognize and preserve traditional eating habits that have long been part of our identity. The findings show that food not only meets nutritional needs but also plays a fundamental role in shaping social connections and community identity. As globalization continues to reshape diets and threaten culinary traditions, cooperative efforts are needed to support healthier food choices and safeguard our cultural heritage. By celebrating and nurturing food culture, communities can promote stronger interpersonal relationships, support healthier living habits, and strengthen their connection to their roots. Programs that incorporate culturally relevant foods into eating habits can greatly improve nutrition, especially for marginalized groups. Initiatives like those led by the SLO Food Bank emphasize this point, demonstrating the benefits of combining traditional foods with contemporary dietary needs. To address the rising prevalence of processed food consumption and the resulting obesity epidemic, it is fundamental to support policies that foster healthy food environments. These policies should ensure that nutrition education is accessible and provide communities with chances to engage in social gatherings that honour cultural traditions surrounding meals. Understanding and appreciating food culture can bridge the gap between public health and public involvement, resulting in more integrated societies that esteem both health and identity. (Kneale et al., 2025) The study shows the essential interplay among food culture, identity, and health, stressing the need for a holistic approach to nutrition that fully considers social and cultural dimensions. (Integrating culture in Human–Food Interaction: A study of cultural and creative food experiences and technological interactions, 2025) Unlike other studies that focus on individual food choices, this research stresses the importance of community participation and collective eating practices for cultivating healthier eating habits. (Morales-Garzón et al., 2025) While the study yields important insights, a major limitation is its reliance on existing literature, which may not adequately capture individual experiences or emerging trends in food culture. Future research endeavours should incorporate qualitative methodologies, such as interviews or focus groups, to gain a fuller understanding of how varied communities navigate their food identities in a constantly changing environment. This all-encompassing approach may yield culturally appropriate methods for promoting healthy eating.

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[3] Food As Culture: Cuisine, Food Customs, And Cultural Identity. About The Slo Food Bank. Paragraph 1st.

[4] Food As Culture: Cuisine, Food Customs, And Cultural Identity. About The Slo Food Bank. Paragraph 1st.

[5] Food As Culture: Cuisine, Food Customs, And Cultural Identity. About The Slo Food Bank. Paragraph 2nd.

[6] Food As Culture: Cuisine, Food Customs, And Cultural Identity. About The Slo Food Bank. Paragraph 2nd.

[7] Food As Culture: Cuisine, Food Customs, And Cultural Identity. About The Slo Food Bank. Paragraph 2nd.

[8]How Food Culture Shapes Our Lives: Identity, Health, and Community Impact. Paragraph 1st.

[9]How Food Culture Shapes Our Lives: Identity, Health, and Community Impact. Food's Impact on Identity. Paragraph 1st.

[10]How Food Culture Shapes Our Lives: Identity, Health, and Community Impact. Food's Influence on Health. Paragraph 1st.

[11]How Food Culture Shapes Our Lives: Identity, Health, and Community Impact. Community Building through Food. Paragraph 1st.

[12] Why We Eat the Way We Do: A Call to Consider Food Culture in Public Health Initiatives. Introduction. Paragraph 1st.

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[14] Why We Eat the Way We Do: A Call to Consider Food Culture in Public Health Initiatives. Introduction. Paragraph 2nd.

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[17] Why We Eat the Way We Do: A Call to Consider Food Culture in Public Health Initiatives. Detrimental Changes to Food Culture. Paragraph 1st.

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[19] Why We Eat the Way We Do: A Call to Consider Food Culture in Public Health Initiatives. Health promotion, Not Disease Deficit. Paragraph 2nd.

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[22] Why We Eat the Way We Do: A Call to Consider Food Culture in Public Health Initiatives. Health promotion, Not Disease Deficit. Paragraph 4th.

[23] How food shapes identity, culture and the world. Paragraph 1st.

[24] How food shapes identity, culture and the world. Food as a reflection of identity. Paragraph 1st.

[25] How food shapes identity, culture and the world. Exploring food beyond the plate. Paragraph 1st.

[26] How food shapes identity, culture and the world. Exploring food beyond the plate. Paragraph 1st.

[27] What is a Food Culture? Historical Roots. Paragraph 1st.

[28] What is a Food Culture? Historical Roots. Paragraph 1st.

[29] What is a Food Culture? The Social Fabric. Paragraph 1st.

[30] What is a Food Culture? The Economic Realities. Paragraph 1st.

[31] What is a Food Culture? Preserving Heritage. Paragraph 1st.

[32] What is a Food Culture? Promoting Health and Well-being. Paragraph 1st.

[33] What is a Food Culture? Fostering Sustainability. Paragraph 1st.

[34] What is a Food Culture? How does religion influence food culture? Paragraph 1st.

[35] What is a Food Culture? How does religion influence food culture? Paragraph 1st.

[36] What is a Food Culture? How does religion influence food culture? Paragraph 1st.

[37] What is a Food Culture? How does religion influence food culture? Paragraph 1st.

[38] What is a Food Culture? What is “food tourism,” and how does it contribute to understanding food culture? Paragraph 1st.

[39] What is a Food Culture? What is “food sovereignty,” and why is it important? Paragraph 1st.

[40] What is a Food Culture? How can we promote and preserve traditional food cultures? Paragraph 1st.

[41] What is a Food Culture? What is the role of media in shaping food culture? Paragraph 1st.

[42] What is a Food Culture? How does food advertising impact our understanding of food culture? Paragraph 1st.

[43] What is a Food Culture? What are some ethical considerations related to food culture? Paragraph 1st.

[44] What is a Food Culture? What are some ethical considerations related to food culture? Paragraph 1st.

[45] What is a Food Culture? How can understanding food culture improve our own diets and eating habits? Paragraph 1st.

[46] What is a Food Culture? What are the future trends in food culture? Paragraph 1st.

MULTIPLE INTEGRALS AND CHANGE OF ORDER OF INTEGRATION – AREA ENCLOSED BY CARTESIAN COORDINATES IN ENGINEERING APPLICATIONS

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ABSTRACT

Multiple integrals form an essential part of engineering mathematics and are widely used to analyze physical systems involving more than one independent variable. Double and triple integrals are applied to compute areas, volumes, mass distributions, centroids, and moments of inertia in mechanical, civil, and electrical engineering. One of the most important techniques associated with multiple integrals is the change of order of integration, which allows a difficult integral to be simplified by interchanging the sequence of integration. This technique is particularly useful when evaluating areas enclosed by curves expressed in Cartesian coordinates. In many cases, the original limits of integration are complicated or lead to integrals that are difficult to evaluate, whereas changing the order of integration transforms the region into a simpler form. This paper presents a detailed study of multiple integrals, focusing on double integrals and the method of changing the order of integration. The geometric interpretation of regions bounded by curves is emphasized, along with step-by-step procedures for determining new limits of integration. Engineering-oriented examples are included to demonstrate the practical significance of these concepts in real-world applications such as area estimation, load distribution, heat transfer, and material analysis.

Keywords: Multiple Integrals, Double Integrals, Change of Order of Integration, Area, Cartesian Coordinates, Engineering Applications

INTRODUCTION

Engineering problems frequently involve quantities that depend on two or more variables. Examples include temperature distribution over a surface, pressure variation across a plate, and material density varying within a region. Single-variable calculus is insufficient to analyze such systems, and multiple integrals provide a natural extension. Double integrals enable engineers to compute areas and accumulated quantities over planar regions, while triple integrals are used for volume-related calculations in three-dimensional domains. Among these, double integrals play a particularly important role in determining the area enclosed by curves in Cartesian coordinates.

In practical applications, the region of integration is often bounded by curves such as parabolas, straight lines, or circles. Setting up the limits of integration correctly is a crucial step in evaluating a double integral. However, the initially chosen order of integration may lead to complicated limits or integrands. The method of changing the order of integration provides a systematic approach to overcome this difficulty by redefining the region of integration and simplifying the evaluation process.

THEORY OF MULTIPLE INTEGRALS

A double integral of a function f(x, y) over a region R in the xy-plane is defined as the limit of a Riemann sum as the partition size approaches zero. Geometrically, a double integral represents the volume under the surface z = f(x, y) above the region R. When f(x, y) = 1, the double integral reduces to the area of the region R. This interpretation forms the basis for using double integrals to compute areas enclosed by curves.

Regions of integration are broadly classified into rectangular regions and non-rectangular regions. In rectangular regions, the limits of integration are constants, whereas in non-rectangular regions, at least one limit is a function of the other variable. Most engineering problems involve non-rectangular regions bounded by curves, making the choice of limits an important consideration.

CHANGE OF ORDER OF INTEGRATION

The change of order of integration involves interchanging the sequence of integration in a double integral. For example, an integral of the form ∫[a to b] ∫[g1(x) to g2(x)] f(x, y) dy dx can be rewritten as ∫[c to d] ∫[h1(y) to h2(y)] f(x, y) dx dy, provided the region R remains the same. This requires a clear understanding of the geometry of the region.

To change the order of integration, the region of integration must first be sketched in the Cartesian plane. By analyzing the boundaries of the region, new limits of integration can be determined. This process often simplifies the integral, especially when the integrand is easier to integrate with respect to one variable before the other.

AREA ENCLOSED BY CURVES IN CARTESIAN COORDINATES

The area enclosed by curves in Cartesian coordinates can be evaluated using double integrals by integrating the constant function 1 over the region of interest. For regions bounded by curves of the form y = f(x) and y = g(x), the area is given by the integral ∫[a to b] ∫[g(x) to f(x)] 1 dy dx. When the region is more conveniently described in terms of x as a function of y, changing the order of integration leads to a simpler expression.

Common examples include regions bounded by straight lines, parabolas, and combinations of linear and quadratic curves. In such cases, changing the order of integration reduces the problem to evaluating standard integrals with simpler limits.

ENGINEERING APPLICATIONS

Multiple integrals and change of order of integration are widely used in engineering practice. In civil engineering, they are applied to determine the area of irregular land sections and load distributions over structural elements. In mechanical engineering, these techniques are used to compute mass, centroid, and moment of inertia of plates with variable density. In electrical engineering, double integrals are employed to analyze charge distributions and electric flux over surfaces.

In heat transfer and fluid mechanics, double integrals help evaluate total heat flow or fluid quantity across a surface when the flux varies with position. The ability to change the order of integration allows engineers to choose the most efficient computational approach, reducing time and minimizing errors.

RESULTS AND DISCUSSION

The study demonstrates that changing the order of integration significantly simplifies the evaluation of double integrals in many practical problems. Complicated regions bounded by curves can often be transformed into simpler regions with straightforward limits. This not only reduces computational effort but also enhances conceptual understanding of the geometric nature of integration.

The examples discussed highlight the importance of sketching the region of integration and carefully analyzing its boundaries. A clear geometric interpretation ensures correct limits and accurate results, which are essential in engineering design and analysis.

CONCLUSION

Multiple integrals and the change of order of integration are powerful tools in engineering mathematics. They provide an effective framework for evaluating areas enclosed by curves and other accumulated quantities over complex regions. A strong understanding of these concepts is essential for solving real-world engineering problems and for advanced studies in applied mathematics, numerical methods, and engineering analysis.

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TRENDS IN PYTHON FOR DATA ENGINEERING

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ABSTRACT

Python continues to be the dominant language in AI development due to its readability, extensive libraries (e.g., TensorFlow, PyTorch), and supportive ecosystem. This article examines Python's impact on fringe AI innovators, educators, and startups, outlining how Python tooling and community contributions lower barriers to entry for complex model training, deployment, and interpretability. The research also explores Python's integration with emerging AutoML frameworks and ethical AI toolchains, emphasizing its role in democratizing AI capabilities while addressing computational efficiency and scalability challenges.

Keywords: Python, AI democratization, machine learning, AutoML, ethical AI

PYTHON'S EXPANDING ROLE IN GENERATIVE AI SYSTEMS

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ABSTRACT

Generative AI represents one of the most transformative technological movements of the decade, and Python remains central to its advancement. This article explores how Python supports the development of large language models, diffusion systems, and multimodal AI through frameworks such as PyTorch and Hugging Face. It evaluates Python's efficiency in model training, fine-tuning, and deployment pipelines. The study also addresses performance optimization, ethical AI tooling, and distributed computing integration. Findings suggest that Python's ecosystem maturity and interoperability continue to make it the dominant language for generative AI innovation.

Keywords: Python, edge computing, IoT, Micro Python, performance

PYTHON AND EDGE COMPUTING CHALLENGES AND OPPORTUNITIES

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ABSTRACT

Edge computing demands lightweight, efficient software capable of processing near data sources. This article explores Python's adoption in edge environments, focusing on frameworks like Micro Python and Circuit Python, optimizations using C-extensions, and strategies for maintaining Python's usability without compromising performance. The study discusses case uses in IoT devices, autonomous sensors, and decentralized analytics.

Keywords: Python, edge computing, IoT, Micro Python, performance

ENHANCING THE OPTICAL AND DIELECTRIC CONSTANTS OF CU-GE-S FILMS FOR SOLAR CELL WINDOWS

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ABSTRACT

This work concerns the optical characteristics of ternary $Cu_xGe_{25}S_{75-x}$ ($0.0 < x \leq 12.0$ at.%.) films. The transmission spectra ($T(\lambda)$) of $Cu_xGe_{25}S_{75-x}$ (CGS) films display interference fringes with low absorption coefficients (α) in the transparent region of 0.5–2.5 μm. The film refractive index (n) and optical density (x) have been precisely determined without any dependence on the film thickness using only the lower envelope of the measured film transmittance (T_m). The film thickness (t) is determined using the interference fringe main equation ($2nt = m\lambda$ where m is the order number). The phenomenon of absorption edge redshift is a fascinating occurrence that can be attributed to variations in the concentrations of copper (Cu) contents. vs. plots are used to compute bandgap energy (E_g) and the band tail parameter (B). Indicators of the Cu addition effect on polarization and electromagnetic wave interactions include the complex dielectric constant (ε^*), optical conductivity (σ^*), and the dielectric loss factor ($\tan\delta$). The effects of Cu contents on charge carrier mobility and energy losses are emphasized by the energy loss functions (VELF and SELF) and electric modulus (M^*). Moreover, relaxation mechanisms and impedance variations are investigated, producing distinctive Nyquist diagrams. This thorough characterization improves our comprehension of CGS films for possible optoelectronic applications.

Keywords: Physical properties, Metallization character, Non-linear optics, Chalcogenide glasses

MODELING HONORS COURSE ENROLLMENT USING POISSON DISTRIBUTION FOR ACADEMIC RESOURCE PLANNING

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ABSRACT

Modeling uncertainty in real-world systems is a fundamental objective of applied mathematics and statistics. In higher education management, forecasting student enrollment represents a discrete stochastic problem characterized by randomness and variability within fixed admission cycles. Accurate prediction of enrollment is essential for effective faculty allocation, laboratory scheduling, infrastructure planning, and optimal utilization of institutional resources. Traditional deterministic forecasting methods often fail to capture the inherent probabilistic fluctuations in student admissions, leading to inefficient planning decisions. This study proposes the application of the Poisson distribution as a stochastic framework for modeling annual enrollment in a Civil Engineering Honours program. Since student registrations can be interpreted as independent events occurring within a fixed time interval at an approximately constant average rate, the Poisson model provides a mathematically appropriate and statistically consistent representation. The model parameter, representing the average enrollment rate, is estimated using historical admission data. The Poisson probability mass function is then employed to determine the likelihood of observing different enrollment levels in a given academic year. The proposed

framework enables quantitative evaluation of scenarios such as enrollment exceeding infrastructural capacity or falling below minimum operational requirements. Simulation analysis is conducted to validate the distributional assumptions and to illustrate variability across multiple admission cycles. The results indicate that enrollment frequencies concentrate around the estimated mean while maintaining measurable probabilities of deviation. The study demonstrates that probabilistic modeling offers a reliable and scalable tool for academic resource planning and can be extended to broader applications in educational analytics and institutional decision-making.

Keywords: Poisson distribution, Students enrollment in Honours program, Faculty allocation, Simulation analysis, academic resource planning.

EXPLORING FUNDAMENTAL DESIGN PRINCIPLES IN VISUAL LANGUAGE: INSIGHTS FROM ANIMATION STUDENTS

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ABSTRACT

Fundamentals of design form the theoretical and practical foundation of animation education. However, many animation students tend to prioritise technical software proficiency over the development of visual literacy, leading to inconsistencies in visual language and creative identity. This study examines the role of fundamental design principles in shaping the visual language of animation students from pedagogical and theoretical perspectives. The objectives are to explore students' understanding of design elements and principles, analyse their application in animation projects, and evaluate their influence in animation storytelling.

Using a qualitative research, the study integrates visual content analysis of selected student works and interviews with students and lecturers. Thematic analysis was employed to identify patterns in design application and conceptual articulation. Findings indicate that students with stronger element of design are better able to construct consistent visual narratives and distinctive stylistic identities. Limited grounding in design often results in fragmented visual communication despite technical competence. The study concludes that fundamentals of design function as a visual grammar essential for creative consistency and narrative clarity in animation education.

EXPLORING CRIME PREVENTION THROUGH ENVIRONMENTAL DESIGN (C.P.T.E.D) PRINCIPLES IN THE DESIGN PROPOSAL OF A BUS TERMINAL, NASARAWA STATE, NIGERIA

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ABSTRACT

Escalating insecurity in Nigeria's transport hubs, ranging from theft to insurgency, necessitates architectural interventions surpassing traditional fortification. This study evaluates the efficacy of Crime Prevention through Environmental Design (CPTED) in the North-Central zone using a pragmatic mixed-methods approach. Data was triangulated from a quantitative survey of 248 users and ISO 22341 observational audits of representative terminals. The empirical results expose a critical "Resilience Gap," with an aggregate audit compliance of only 59%. This score highlights a failure in operational maintenance rather than structural integrity. Crucially, this "Operational Decay" creates a gendered safety disparity, confirmed by a significant T-Test gap ($p=0.001$) where female users reported drastically lower safety perceptions. Furthermore, regression analysis ($R^2=0.645$) established Natural Surveillance ($\beta=0.620$) as the primary driver of safety, statistically outweighing Access Control ($\beta=0.110$). This finding challenges the local reliance on physical barriers, proving that "Visual Permeability" is significantly more effective at reducing fear than fencing alone. Synthesizing these findings, the study proposes a context-adaptive design for the Keffi Bus Terminal. The proposal operationalizes "Passive Surveillance" through high-durability glazing and a panoptic Watch Tower. Additionally, it introduces gender-responsive measures, such as 300-Lux lighting in vulnerable zones, and utilizes spatial segregation to buffer passengers from informal "Agbero" activities. The study concludes that resilient transport architecture in Nigeria requires a paradigm shift from "Fortress Design" to "Visually Permeable" environments.

AN ANALYSIS OF 12 PRINCIPLES OF ANIMATION AND EVALUATING THE EFFECTIVENESS AMONG 2D ANIMATION STUDENTS KEPALA BATAS COMMUNITY COLLEGE

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ABSTRACT

This study was conducted to analyse the effectiveness of applying the 12 Principles of Animation on the knowledge level and animation quality produced by Semester 2 students of the 2D Animation Certificate at Kepala Batas Community College. Although animation principles such as squash and stretch, anticipation, timing, arcs, follow through, and slow in and slow out are introduced in the syllabus, initial observations showed that some students still produced animations that appeared stiff, lacked expression, and had inappropriate timing. This study employed a quantitative pre-test and post-test research design involving 19 students as the sample. Two main instruments were used: a knowledge test/questionnaire related to the 12 principles of animation and an animation quality assessment rubric evaluating aspects such as timing & spacing, squash and stretch, anticipation, arcs, follow through, and appeal. Data were analysed using descriptive statistics such as mean, percentage, and comparison of scores before and after the intervention. The findings indicated that students' knowledge improved after the application of animation principles, while the quality of their animations also showed a significant improvement, particularly in terms of more natural movement, more accurate timing, and reduced stiffness. This study is expected to strengthen 2D animation teaching methods and enhance student performance through more systematic and structured practice of animation principles.

ANTIHYPERLIPIDEMIC POTENTIAL OF ZINC OXIDE NANOPARTICLES FROM *PUNICA GRANATUM*

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ABSTRACT

Hyperlipidemia is a medical condition with a variation in blood cholesterol levels characterized by increased low-density lipoprotein (LDL) cholesterol and decreased levels of high-density lipoprotein (HDL) cholesterol. This study aims to focus on the anti-hyperlipidemic potential of green-synthesized ZnO nanoparticles from the peel extract of Punica granatum. The bioactive components of Punica granatum, such as phenols and flavonoids, possessed anti-hyperlipidemic activity against 30% high-fat diet (HFD) induced hyperlipidemia in rats. The 30 rats were divided into five groups, first was normal control (normal feed diet), second was a hyperlipidemia control (hyperlipidemia was induced by HFD), the third was standard group (Atorvastatin 10mg/kg), fourth and fifth group was treatment groups of low dose (5mg/kg) and high dose (10mg/kg) of ZnO nanoparticles of Punica granatum peels extract (ZnOPG) respectively. Zeta size, zeta potential, SEM and FTIR analysis was done to analyze the green synthesized nanoparticles. On the 49th day of the experimental trial, rats were decapitated; blood was collected and tissue sampling was performed. Physical parameters and lipid markers (TC, HDL, LDL, TG) were used to determine the efficiency of the treatment. One and two-way analysis of variance (ANOVA) was used to analyze the final data. The results showed a significant improvement in the lipid profiles as well as in other parameters in treatment group compared to disease control in which no treatment was given.

PASSPORT VERIFICATION USING ZIGBEE TECHNOLOGY

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ABSTRACT

The technique of passport verification which is currently used in the airports involves manual checking and it is time consuming. Another major issue with the conventional paper passport is that, it can be forged or duplicated easily. The proposed system consists of two level of authentication. In the first level of authentication, the RFID (Radio Frequency Identification) module is used which involves both RFID tag and RFID reader. The second level of authentication is the face recognition. In this the passport holder's face is captured and is verified. The two levels of authentication increase the level of security and safety. This system is proposed in order to decrease the duplicating of the passports which leads to various illegal activities. Also, the verification duration is reduced with the use of e-passport. The face recognition is implemented which increase the efficiency of the e-passport. The technologies such as RFID can be used effectively to replace paper passports by portable e-passports.

DETERMINANTS OF FINANCIAL GAPS IN THE HOUSEHOLD CAUSING DOMESTIC ECONOMIC VIOLENCE

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ABSTRACT

Economic violence is one of the most insidious manifestations of coercive control, based on the restriction, surveillance, or deliberate deprivation of material and financial resources. Far from being an isolated phenomenon in the private sphere, its analysis from a sociocultural perspective reveals how macroeconomic structures and collective norms create an environment conducive to its perpetuation. In societies characterized by profound gender, class, and ethnic inequalities, unequal access to capital becomes a tool of domination that systematically undermines individual autonomy. The maintenance of these dynamics is largely due to the legacy of a patriarchal culture that naturalizes financial hierarchy. Under this system, the centralization of income in men is not only accepted but institutionalized, stripping women of their agency. This asymmetry is exacerbated in contexts of social stratification, where precarious employment and the absence of inclusion policies drastically limit opportunities for upward mobility for marginalized groups. Consequently, economic dependence is not merely a lack of funds, but a "patrimonial prison" that prevents breaking cycles of abuse. From an operational standpoint, economic violence manifests itself when a dominant actor monopolizes the management of resources, limiting access to basic goods or sabotaging the labor market integration of other family members. Factors such as financial illiteracy and a lack of independent income act as critical barriers that erode the bargaining power of victims. Ultimately, the intersection of structural inequality and traditional gender roles transforms money from a means of subsistence into a mechanism of social control, consolidating a vulnerability that transcends the economic sphere to affect the psychological integrity and fundamental freedom of the individual.

AI-OPTIMIZED MINIATURIZED MICROSTRIP ANTENNA ON ROGERS RT5880 for Sub-6 GHz 5G/6G APPLICATIONS

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ABSTRACT

The rapid deployment of 5G and the emergence of 6G wireless communication systems have increased the demand for compact, wideband, and efficient antennas operating in the sub-6 GHz frequency range. This paper presents an AI-optimized miniaturized microstrip antenna designed on a Rogers RT5880 (lossy) substrate with a thickness of 1.588 mm. The proposed antenna operates over a wide frequency band from 2 to 10 GHz, with a targeted resonance around 5.8 GHz, making it suitable for sub-6 GHz 5G/6G applications.

Applied mathematical modeling and full-wave electromagnetic simulations are carried out using CST Microwave Studio to analyze the antenna behavior and guide the design process. An artificial intelligence-based optimization algorithm is employed to optimize the antenna geometrical parameters, aiming to achieve antenna miniaturization while enhancing impedance matching, bandwidth, and radiation efficiency. Simulation results demonstrate that the proposed antenna exhibits wide impedance bandwidth and stable radiation characteristics, making it a strong candidate for 5G/6G communication systems, smart infrastructure, and sustainable IoT applications.

Keywords: Miniaturized antenna, Microstrip antenna, Sub-6 GHz, 5G/6G, Artificial intelligence, Rogers RT5880, CST Microwave Studio.

HEALING THROUGH LEARNING: THE ROLE OF PRESCHOOL EDUCATION IN TRAUMA RECOVERY FOR CHILDREN IN SOUTHERN PART OF KADUNA STATE, NIGERIA

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ABSTRACT

Addressing childhood trauma in Southern Kaduna State's conflict-affected areas is extremely difficult. This study examined how preschool education can foster resilience and support trauma healing. Trauma-informed preschool education programmes can provide a secure, supportive atmosphere in which children can manage their emotions, re-establish trust, and learn coping skills. Play-based learning, community involvement, and fostering connections with caregivers are important elements. The effectiveness of implementation depends on contextual elements like educator training and cultural sensitivity. The authors highlight the potential of preschool to aid in healing and advance long-term educational success in their suggestions for including trauma-informed practice in preschool settings.

Keywords: Trauma Recovery, Preschool Education, Resilience,

HOW TO END THE WAR IN UKRAINE AND CREATE A SECURITY ZONE FOR MANY YEARS

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ABSTRACT

Today, negotiations to end the war in Ukraine are fruitless, because Putin demands that Russia must get the territory of Donbas, which Ukraine will not agree to do because the transfer of the territory of Ukraine to another country contradicts its constitution. The way out of this impasse may be the leasing of four border regions with Russia and Crimea to the United States. Today this is the most realistic possible way to end the war and guarantee the post-war security of Ukraine and Europe for many years. This involves Ukraine leasing border regions with Russia and Crimea to the United States under a Treaty that has the following main conditions:

1. Border regions with the Russian Federation (Sumy, Kharkiv, Luhansk, Donetsk regions) and Crimea (hereinafter referred to as the Leased Territories) are provided to the United States under a Lease Agreement for a period of 49 years or more.

2. The State Border Service of Ukraine is responsible for protecting the state border of the Leased Territories.

3. The Leased Territories shall be subject to the legislation and legal system of US state that prohibits the death penalty, such as the state of New York, with police units and the state National Guard stationed in the Leased Territories to ensure law and order.

4. The property of Ukraine and Ukrainian citizens illegally appropriated by the occupiers in the period from 2014 to the date of the conclusion of the Agreement shall be returned to their previous owners.

5. Citizens of Ukraine have the right to freely enter, leave, reside and work in the Leased Territories.

6. The property rights of citizens, legal entities and the state of Ukraine in the Leased Territories shall be retained by them.

7. Disputes under the Agreement shall be resolved by the Parties in the High Court of London.

8. A Supervisory Board consisting of representatives of Ukraine and the United States may be established to monitor the implementation of the terms of the Agreement.

To create interest in such a lease for private US business, Ukraine is starting negotiations on granting concessions for mineral deposits in accordance with the Minerals Agreement concluded with the US as well as roads, railways and other facilities that will interest investors.

After the Parties conclude the proposed Lease Agreement, the Russian Federation will be forced to leave the occupied territories in order not to enter into conflict with the US, and the Leased Territories will become a real security zone at least for the term of the lease.

In the event of the conclusion of the Agreement Ukraine announces the postponement of its accession to NATO for the term of the lease, since the Leased Territories will become a de facto security zone against Russian aggression.

In the event of the conclusion of the proposed Lease Agreement, the Parties will receive at least the following benefits:

Benefits of Ukraine:

1. Receiving payment for the lease from the US;

2. Reconstruction in the Leased Territories will be carried out by the US;

3. Ukrainians who fled the war will return to the Leased Territories. The incentives for this will be a much higher level of wages in the Leased Territories than in Ukraine (the minimum wage in New York State is $17 per hour versus UAH 52 ($1.21) in Ukraine, mortgages are provided at 6.2–6.9% for 30-year loans, and living conditions will be close to the US level.

4. The level of corruption in the Leased Territories which the Ukrainian authorities have not overcome in 35 years will decrease to the US level as a result of the action of the American legal system, in particular through the elimination of corruption at customs, in the courts, etc., as well as the absence of a value-added tax in the taxation system in the Leased Territories (there is no such tax in the US) which has become one of the sources of corruption in Ukraine. The Leased Territories will be able to rise to 29th place, which the US occupies in the Corruption Perceptions Index, while Ukraine is currently in 105th place among 180 countries.

5 Ukraine does not need to hold a referendum on Russia's territorial concessions, which is the main obstacle in negotiations to end the war, since the Leased Territories remain the territory of Ukraine and are not transferred to the ownership of another state.

6. The withdrawal of Russian troops from Ukraine will make it possible to end martial law and hold elections for the president and parliament of Ukraine.

1. Benefits of the USA:

1. D. Trump will become a real peacemaker and will be nominated by Ukraine for the Nobel Prize.

2. The USA will receive a huge field for investment and qualified cheap labor for development in the leased territories.

3. The USA will receive an "unsinkable aircraft carrier" in the center of Europe, which will strengthen the geopolitical position of the USA in solving the China problem.

4. The USA will receive grounds for using Russian funds frozen in the USA for reconstruction in the leased territories.

Putin's benefits:

1. Since Ukraine will refuse to join NATO at least for the term of the Treaty, Putin will be able to declare his victory and achievement of the goal of the “special military operation”.

2. Putin will be able to present as his victory the fact that he forced Ukraine to elect a new president instead of President Zelensky whom he considers illegitimate.

3. Putin will be able to present as his victory the fact that he forced Europe to refuse to deploy its troops in Ukraine in a security zone along the border with Russia.

The author is confident that these proposals can become a real basis for negotiations between interested parties and invites to discuss them.

EFFECT OF MANURE AND POTASSIUM ON GROWTH AND YIELD OF TOMATO

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ABSTRACT

The experiment was conducted in the Horticultural Farm of Sher-e-Bangla Agricultural University, Dhaka during the period from October, 2015 to March 2016 to find out the effect of different manures and potassium on growth and yield of tomato. The experiment consisted of two factors: Factor A: Three levels of manures. The treatments are Mo: 0 (control), M_1: cowdung 15 t ha^1 and M2: vermicompost 3.75 t ha^1. Factor B: Four levels of potassium. The treatments are Ko: (control); K_1: 200 kg MOP ha^1; K2: 220 kg MOP ha'and K3: 240 kg MOP ha^1. There were 12 treatment combinations. The experiment was laid out in Randomized Complete Block Design with three replications. Data on different growth and yield contributing characters and yield were recorded to find out the optimum level of manure and potassium on tomato. In case of manure, maximum yield hectare (69.10 t/ha) were recorded from M_2 treatment while the minimum result was from the control. For potassium, the maximum yield hectare (69.43 t/ha) were recorded from the K2 treatment while the minimum from control. Due to interaction effect of manure and potassium application, the maximum yield hectare (79.96 t/ha) was recorded from the MK2 treatment combination and the minimum from control. So, it can be concluded that, the combination of 3.75 t/ha vermicompost with 220 kg MOP ha^1 is the appropriate practice for tomato production.

Keywords: Tomato,Potassium(K),Manure,Growth,Yield,Vermicompost,Cowdung,MOP(Muriate of Potash)

COMPENSATORY PENSION HOW DOES IT WORK IN MEXICO?

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ABSTRACT

in Mexico, compensatory alimony is a concept in family law that seeks to balance the economic disadvantage that may arise after a divorce, especially when one spouse dedicated themselves to household duties and childcare. There is no fixed mathematical formula to calculate it; each case is analyzed individually.

To determine the amount, factors such as the duration of the marriage, dedication to the home, the age and work capacity of the applicant, health, professional training, and the financial situation of both spouses are considered. In some cases, it may reach up to 50% of the assets acquired during the marriage, even under a separate property regime.

Keywords: Marriage, Alimony, Household Duties, Mexico, Home, and Duration.

DISCRETE p(k)-Laplacian PROBLEMS WITH ROBIN BOUNDARY CONDITIONS

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ABSTRACT

This work investigates the existence and multiplicity of solutions for a Robin problem driven by the p(k)-Laplacian without assuming the classical Ambrosetti–Rabinowitz growth condition. In addition, uniqueness of solutions is established under new sufficient conditions.

Keywords: p(k)-Laplacian; Robin boundary conditions; existence and multiplicity of solutions; uniqueness; variational methods; nonstandard growth conditions.

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MEETCON-X II. ULUSLARARASI BİLİMSEL ARAŞTIRMALAR KONGRESİ 17-19 Şubat 2026 tarihleri arasında Ankara, Türkiye'de 14 farklı ülkenin akademisyen/araştırmacılarının katılımıyla gerçekleşmiştir. Kongre kapsamında sunumu yapılan 76 bildirinin 35 adeti Türkiye'den katılımcılar tarafından; 41 bildiri ise 14 ülkeden katılımcılar tarafından sunulmuştur. 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,

Prof. Dr. Hasan ÇİFTÇİ

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Gereğini rica ederim.

Prof. Dr. Mahmut Nedim BAYUK
Dekan

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