GOVERNMENT DEGREE COLLEGE : KOVVUR : E.G.Dt.

Academic & Administrative Audit : 2023-2024

Format-II (Institutional Data Cum Academic Advisor's Grading)

III-RESEARCH, INNOVATIONS AND EXTENSION

A- Promotion of Research and Facilities

ADIKAVI NANNAYA UNIVERSITY

College of Science & Technology

Rajamahendravaram – 533296, East Godavari District, A.P., India

No. ANUR/UCST/ Ph.D Admissions/2018-19 Date:03-04-2019

PROCEEDINGS OF THE VICE CHANCELLOR

Sub:- ANUR- UCST- Allotment of Ph.D Guides- Reg.

Ref:- 1) Proceedings of the Vice-Chancellor No.ANUR/APRCET-2018/13 Dated :09-11-2018.
2)Proceedings of the Vice- Chancellor No. ANUR/DOA/2019-20/7 Dated:13-02-2019

ORDER:

Having considered the minutes of the meetings of Departmental Research Committees,which have been approved the Vice-Chancellor is pleased to order the allotment of the full time Ph.D students to the Research Guides/Supervisers as stated below.

Sl No	Name of the Scholar	Research Centre / College	Allotted Guide / Supervisor & Address
1	Mr. Kota Gani Raju	Govt. College (A), Department of Botany	**Dr. J Sunitha** Govt. College(A), Department of Botany Rajamahendravaram
2	Ms P Madhuri Santhoshi	Govt. College (A), Department of Physics	**Dr. K Rama Chandra Rao** Govt. College(A), Department of Physics Rajamahendravaram
3	Mr Katkar Sneha Satyapal	Adikavi Nannaya University, Department of Geology	**Dr. K Nooka Ratnam** Department of Geology AdikaviNannayaUniversity, Rajamahendravaram
4	Mr. Khadar Mohammed	Adikavi Nannaya University, Department of Geology	**Dr. K Nooka Ratnam** Department of Geology AdikaviNannayaUniversity, Rajamahendravaram
5	Mr.Marukurthi Abinash	Adikavi Nannaya University, Department of Zoology	**Dr. P Vijaya Nirmala** Department of Zoology AdikaviNannayaUniversity, Rajamahendravaram

(BY ORDER)

(K RAMANESWARI)
PRINCIPAL 03/4/19

Copy to
TheResearch Guides /Supervisors
The Ph.D Students
The Heads of the Departments
The Dean Academic Affairs
The Principal Govt College (A), Rajamahendravaram
The Director of Admissions
PS to VC
PA to R
OOF

ADIKAVI NANNAYA UNIVERSITY
ఆదికవి నన్నయ విశ్వవిద్యాలయం
RAJAMAHENDRAVARAM, ANDHRA PRADESH INDIA - 533296
ISO 9001:2015 Certified

University College of Science and Technology

No.ANUR/UCST/Guide Allot./2021/02 Date: 18.09.2021

PROCEEDINGS OF THE VICE-CHANCELLOR

Sub: UCST- Guide Allotment- FT -Botany- Govt. College(A) - Approved - Orders - Issued - Reg.

Ref: Note Orders of the Vice-Chancellor dated :14-09-2021 through E-office

***

ORDER:

The Vice-Chancellor has approved the resolutions of the Departmental Research Committee of Botany held on 07-09-2021, in regard to allotment of research supervisor for the following research scholar admitted in the department of Botany, Govt. College(A), Rajamahendravaram through APRCET-2019, as detailed below:

Sl.No	Name of the Research Scholar	Admn.No.	Name of the Research Supervisor
01	Ms Yedida Baby	20102501	Dr. J Suneetha, Professor, Dept of Botany Govt. College(A), RJY

(By Order)

P Vijaya Nirmala 18/9/202

(P Vijaya Nirmala)

To:

1. The above said Research Supervisor/Research scholar
2. Principal, Govt. Arts College(A), Rajamahendravaram

Copy to:

1. The Head/CC, Department of Botany, UCST
2. The Dean, Academic Affairs
3. The Convener, BRS
4. The Controller of Examinations
5. PA to Registrar
6. PS to VC
7. OOF

ADIKAVI NANNAYA UNIVERSITY
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ANUR/ BRS / Guide Allotment /2023-3 Dt.30.08.2023

24/8/2023

PROCEEDINGS OF THE VICE-CHANCELLOR

Sub: - ANUR – Dean R & D Cell – BRS – Guide Allotment – Orders – issued.
Ref: - Minutes of the meeting of Board of Research Studies, dated.30.08.2023.

******

ORDER:

With reference to the above, the Vice – Chancellor has approved the minutes of the meeting of the BRS held on 30.08.2023 in regard to allotment of Research guides to the following Research scholars admitted in the Department of Botany, Govt College (A), Rjy in the academic year 2023-24.

S.No	Name of the Candidate	Admission No / Category of Admission	Research Center	Name of the Guide
1	ChittiKumari Penumaka	22202501/ Part Time	Govt College (A), Rjy	Prof J Suneetha
2	Raja Rao Uba	22202502/ Part Time		Dr A. Srinivasa Rao

(BY ORDER)

(K. RAMANESWARI)
DEAN
Research & Development Cell
Adikavi Nannaya University.

Copy to:
The above Ph.D. Scholar,
The above Research Guides
Concerned Head of the Department,
To the Principal UCST,
PS to VC,
PA to R,
OOF.

GOVERNMENT DEGREE COLLEGE : KOVVUR : E.G.Dt.

Academic & Administrative Audit : 2023-2024

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III-RESEARCH, INNOVATIONS AND EXTENSION

C. Research Publicaton and Awards

GOVERNMENT DEGREE COLLEGE : KOVVUR : E.G.Dt.

Academic & Administrative Audit : 2023-2024

Format-II (Institutional Data Cum Academic Advisor's Grading)

III. RESEARCH, INNOVATIONS AND EXTENSION

C. Research Publicaton and Awards

8. Papers Presented for the last two years (International/ National/ State level conferences and seminars)

S.No.	Name of the Faculty	Department	Title of the Conferences/Seminar	Organized by	Date	Title of the Paper
1	Prof. J. Suneetha	PRINCIPAL	One Day National Seminar on “Forest Resources, Diversity, Utilization and Conservation”	Organized by Department of Botany, Gopal Rao Patil Government Degree College, Bhainsa. Dist. Nirmal, Telangana State – 504 103.	05-11-2022	Ecobiology of the Lycaenid Butterfly, Zizula hylax hylax Fabricius.
2	Dr. M. Bhupathi Rayalu	BOTANY	One Day National Seminar on “Forest Resources, Diversity, Utilization and Conservation”	Organized by Department of Botany, Gopal Rao Patil Government Degree College, Bhainsa. Dist. Nirmal, Telangana State – 504 103.	05-11-2022	Ecobiology of the Lycaenid Butterfly, Zizula hylax hylax Fabricius.
3	Sri P. Arun Kumar	Computer Science	1st National Conference on Design Thinking: Trans-Disciplinary Challenges & Opportunities	Organized by Andhra University Transdisciplinary Research Hub, Andhra University, Visakhapatnam.	7-8 July 2023	Application of Machine Learning in Acute Kidney Injury: Detection, Prediction, and Healthcare
4	Sri P. Arun Kumar	Computer Science	One Day National Conference on "Future Challenges and Opportunities in Cyber Security".	CSTS Govt. Kalasala, Jangarddigudem, Eluru Dist. A.P.	07-10-2023	Advancements And Challenges Of Artificial Intelligence And Machine Learning In Cybersecurity

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FOREST RESOURCES, DIVERSITY, UTILIZATION AND CONSERVATION

5th NOVEMBER 2022

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EDITOR

Dr. Velmala Madhu

Gopal Rao Patil Government Degree College,
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NAAC Accredited College with ' B ' Grade
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Contents

Eco Biology of the Lycaenid Butterfly, Zizula hylax hylax Fabricius

M. Bhupathi Rayalu[1], Prof. J.Suneetha[2]

The life history of the Dark grass blue butterfly, Zizula hylax hylax Fabricius and larval performance in terms of food consumption and utilization, and the length of life cycle on its host plant Desmodium triflorum (L.) DC. are described for the first time. The study was carried out at Kovvur(17° 0126' N and 81° 7274' E), Andhra Pradesh, India during the monsoon months (June - August) of the current calendar year. Zizula hylax hylax completes its life cycle in 16 - 18 (17.20 ± 0.84) days (Egg:3; Larva:8-10; Pupa:5days). The values of nutritional indices across the instars were AD (Approximate Digestibility) 66.64-96.10%; ECD(Efficiency of Conversion of Digested food) 3.53, 64.77%; ECI(Efficiency of Conversion of Ingested food) 3.39, 42.77%, measured at the temperature of 28±2°C and RH of 80±10% in the laboratory. These relatively high values of ECD and ECI explain at least partially the ecological success of Zizula hylax hylax in the present study environment.

Keywords: Lifehistory, Zizulahylaxhylax, captiverearing, immature stages, food utilization indices.

[1]Department of Botany, Government Degree College, Kovvur, East Godavari Dist., A.P.
[2]Principal, Government Degree College, Kovvur, East Godavari Dist., A.P.
Email ID: bhupathirayalu@gmail.com

Applications of Statistical Methods and Statistical Designs for Forestry Research

Dr. Ananthula Raghu

In order to develop and protect forest resources, research is crucial. Any scientific research can be built on a solid foundation of statistics. The use of statistical techniques is widespread in practically all fields of study that deal with ambiguous phenomena involving aggregation. They aid in the creation of reliable inferences based on data gathered during the course of an investigation. Any scientific research requires the formation of a few hypotheses, whose viability is assessed using the results from an experiment carried out specifically for the investigation. Experiments are typically conducted to examine the impact of various conditions on a phenomenon or to identify a previously unidentified consequence of a specific process. The creation and upkeep of these resources will benefit greatly from scientific study, and statistics will be essential to this effort. Drawing reliable conclusions from these studies requires choosing an adequate statistical design and doing sound analysis. This paper highlights some significant statistical designs and analytical techniques used in forestry experiments.

Keywords: Experimental Designs, t-Test, ANOVA, SPSS.

Faculty Member, University of Delhi, Delhi-110007

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Application of Machine Learning in Acute Kidney Injury: Detection, Prediction, and Healthcare Implications

P. Arun kumar
Department of Computer Science
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Kallam Haranadhareddy Institute of Technology
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Abstract*—This paper explores the application of machine learning in the context of acute kidney injury (AKI). AKI is a significant medical condition that requires prompt identification and intervention to prevent further complications. Machine learning techniques have shown promise in improving the early detection and prediction of AKI, thereby enabling timely interventions and better patient outcomes. This paper provides an overview of the existing literature on machine learning models for AKI prediction and discusses the challenges and opportunities in implementing these models in clinical settings. Furthermore, it explores the potential of machine learning in personalized treatment strategies and precision medicine for AKI patients. The paper concludes with future directions and recommendations for further research in this domain.

Keywords*— acute kidney injury, machine learning, prediction, early detection, personalized treatment, precision medicine.

I. INTRODUCTION

Acute kidney injury (AKI) is a sudden loss of kidney function that can have severe implications on patient health and outcomes. It is characterized by a rapid decline in kidney function, leading to the accumulation of metabolic waste products and electrolyte imbalances in the body. Early identification and intervention are crucial for preventing further damage and improving patient outcomes.

Machine learning, a subfield of artificial intelligence, has gained considerable attention in healthcare due to its potential to analyze large datasets and extract valuable insights. In the context of AKI, machine learning algorithms can leverage clinical data, biomarkers, and other relevant information to develop predictive models that assist in early detection and risk assessment.

II. MACHINE LEARNING APPLICATIONS IN AKI

A. Data Collection and Preprocessing The first step in utilizing machine learning for AKI prediction and diagnosis is the collection of relevant data. Electronic health records (EHRs), laboratory results, imaging reports, and patient demographics can provide valuable insights for training machine learning models. Data preprocessing techniques, such as data cleaning, normalization, and feature selection, are essential for ensuring data quality and removing irrelevant or redundant information.

B. Feature Extraction and Selection Machine learning models require meaningful features to learn patterns and make accurate predictions. Feature extraction techniques, such as statistical analysis and dimensionality reduction, can identify the most informative variables from the collected data. Feature selection algorithms further refine the feature set, considering factors such as predictive power, redundancy, and computational efficiency.

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C. Model Development and Training Various machine learning algorithms can be employed for AKI prediction and diagnosis, including logistic regression, decision trees, random forests, support vector machines, and neural networks. The choice of algorithm depends on the nature of the data, the complexity of the problem, and the desired performance metrics. The models are trained using labelled datasets, where AKI cases and non-AKI cases are appropriately labelled. The models learn from the data, capturing patterns and relationships between features and the occurrence of AKI.

D. Model Evaluation and Validation To assess the performance of machine learning models, evaluation metrics such as accuracy, sensitivity, specificity, and area under the receiver operating characteristic curve (AUC-ROC) are used. Cross-validation techniques, such as k-fold cross-validation, help validate the models on independent datasets and estimate their generalization ability. External validation using data from different healthcare institutions ensures the robustness and applicability of the developed models in diverse settings.

III. RESULTS AND DISCUSSION

Numerous studies have demonstrated the potential of machine learning in AKI prediction and diagnosis. These studies have shown that machine learning models outperform traditional methods in terms of accuracy, sensitivity, and timeliness. By integrating multiple variables and utilizing advanced algorithms, machine learning models can identify early indicators of AKI, predict its occurrence, and assist in risk stratification. The ability to detect AKI at an early stage enables timely interventions, such as adjusting medication doses, optimizing fluid management, and initiating renal replacement therapy when necessary.

IV. CHALLENGES AND FUTURE DIRECTIONS

Despite the promising results, there are several challenges in the widespread implementation of machine learning in AKI healthcare practices. One major challenge is the availability and quality of data. Access to comprehensive and well-curated datasets is crucial for developing accurate and reliable machine learning models. Furthermore, ensuring the interoperability and compatibility of different data sources remains a challenge.

Another challenge is the generalizability of machine learning models. Models trained on data from a specific population or healthcare setting may not perform well in different contexts. Therefore, robust external validation and the development of transferable models are essential for ensuring the effectiveness of machine learning in diverse clinical scenarios.

Ethical considerations, such as data privacy, security, and algorithmic bias, also need to be addressed. Machine learning models should be developed and deployed in a manner that respects patient privacy and maintains data confidentiality. Additionally, efforts should be made to mitigate bias in the algorithms and ensure equitable outcomes for all patient populations.

Future directions in the field of machine learning and AKI include the integration of real-time monitoring and wearable devices, incorporation of genetic and molecular data, and the development of explainable and interpretable models. Collaborative research efforts and data sharing initiatives can further advance the field, enabling the development of more accurate and reliable machine learning models for AKI management.

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V. Conclusions

This research paper highlights the potential of machine learning as a valuable tool in the field of acute kidney injury (AKI). By leveraging the power of advanced algorithms and large datasets, machine learning models have demonstrated their ability to accurately detect and predict AKI, enabling early interventions and improved patient outcomes. The integration of machine learning in AKI management holds great promise for enhancing diagnosis, treatment, and patient care. However, further research and collaboration are needed to address challenges such as data availability and model generalizability, ensuring the widespread implementation and impact of machine learning in AKI healthcare practices.

Acknowledgment

The authors gratefully acknowledge the invaluable support and contributions of numerous individuals and organizations in the completion of this research paper

References

[1] Ronco C, Bellomo R, Kellum JA. Acute kidney injury. Lancet. 2019;394(10212):1949-1964.
[2] Koyner JL, Garg AX, Coca SG, et al. Biomarkers predict progression of acute kidney injury after cardiac surgery. J Am Soc Nephrol. 2012;23(5):905-914.
[3] Chen S, Lin M, Liu X, et al. Machine learning approaches for clinical data mining. J Healthc Eng. 2018;2018:8387121.
[4] Kashani K, Rosner MH, Ostermann M. Creatinine: From physiology to clinical application. Eur J Intern Med. 2020;72:9-14.
[5] Goldstein BA, Navar AM, Pencina MJ, Ioannidis JP. Opportunities and challenges in developing risk prediction models with electronic health records data: a systematic review. J Am Med Inform Assoc. 2017;24(1):198-208.
[6] Luo Y, Szolovits P. Digging into granular clinical data: a method for inferring temporal disease trajectories from electronic health records. J Biomed Inform. 2018;78:85-95.
[7] Pivovarov R, Elhadad N. Automated methods for the summarization of electronic health records. J Am Med Inform Assoc. 2015;22(5):938-947.
[8] Rajkomar A, Oren E, Chen K, et al. Scalable and accurate deep learning with electronic health records. npj Digit Med. 2018;1:18.

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ADVANCEMENTS AND CHALLENGES OF ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING IN CYBERSECURITY

Potty Arun Kumar
Lecturer in Computer Science, Government Degree College, Kovvur, East Godavari Dist.

Abstract:
Cybersecurity has become a paramount concern in the digital age as cyber threats continue to evolve in complexity and sophistication. To counter these threats, the field has turned to Artificial Intelligence (AI) and Machine Learning (ML) as powerful tools. This research paper seeks to provide a comprehensive exploration of the role of AI and ML in cybersecurity, covering fundamental concepts, applications, challenges, ethical considerations, case studies, future directions, and the imperative need for responsible AI/ML implementation in cybersecurity.

1. Introduction

The digital landscape is constantly under siege from cybercriminals who exploit vulnerabilities in systems and networks to steal data, disrupt operations, and compromise security. The sheer volume and sophistication of cyber threats demand innovative solutions. AI and ML, which were once the domain of science fiction, have now become indispensable in the fight against cyber adversaries. This paper delves into the transformative potential of AI and ML in bolstering cybersecurity defenses.

2. AI and ML Fundamentals

To understand the impact of AI and ML in cybersecurity, it is crucial to grasp the fundamental principles. AI encompasses a range of technologies that enable computers to mimic human intelligence, while ML focuses on algorithms that allow systems to learn from data. This section provides an in-depth explanation of these concepts, highlighting their essential role in cybersecurity.

3. AI and ML Applications in Cybersecurity

AI and ML have found applications across various facets of cybersecurity. Detection and prevention of cyber threats have become more effective through AI-driven approaches. Anomaly detection and behavior analysis empower systems to recognize deviations from normal patterns, thus identifying potential threats. Predictive analysis enables the anticipation of future threats based on historical data, offering a proactive defense strategy.

4. Challenges and Limitations

While AI and ML hold great promise, they are not without challenges. False positives and false negatives in AI/ML-based systems can undermine trust and efficacy. Adversarial attacks pose a significant threat, as malicious actors attempt to manipulate AI/ML models. Ethical concerns surrounding automated decision-making and potential biases in AI algorithms raise important questions that require careful consideration.

5. Case Studies

Real-world case studies showcase the tangible benefits of AI and ML in cybersecurity. From identifying zero-day vulnerabilities to thwarting advanced persistent threats, these examples provide insights into the practical applications and successes of AI and ML.


Cover Page

INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY EDUCATIONAL RESEARCH
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6. Future Directions

The landscape of cybersecurity is constantly evolving, and AI/ML technologies are no exception. This section explores emerging trends in AI/ML for cybersecurity, such as the use of generative adversarial networks (GANs) for threat detection and the integration of AI into autonomous response systems. Additionally, it highlights potential areas for further research and development, such as explainable AI in cybersecurity.

7. Ethical Considerations

The integration of AI/ML in cybersecurity necessitates a critical examination of ethical implications. Ensuring fairness and transparency in AI algorithms is imperative, as automated systems may make consequential decisions. This section addresses the ethical concerns associated with AI and ML in cybersecurity and proposes strategies to mitigate them.

8. Conclusion

In conclusion, the fusion of AI and ML with cybersecurity has ushered in a new era of defense against cyber threats. While challenges and ethical dilemmas persist, the potential for enhanced security is undeniable. As AI and ML continue to evolve, research and innovation are key to harnessing their full potential in safeguarding the digital realm. Responsible AI/ML implementation and a commitment to ethical considerations will be central in this ongoing journey to secure the digital future.

References

1. Moustafa, N., & Slay, J. (2016). A Survey of Machine Learning Techniques in the Detection of Botnets. *Journal of Network and Computer Applications.*
2. Chio, C., & Freeman, D. (2018). Machine Learning and Security: Protecting Systems with Data and Algorithms. *O'Reilly Media.*
3. Goodfellow, I., Shlens, J., & Szegedy, C. (2014). Adversarial Machine Learning. *arXiv preprint.*
4. Islam, R., Abolhasan, M., & Wijesekera, D. W. (2018). Deep Learning for Cybersecurity Threat Detection and Mitigation: Challenges and Opportunities. *IEEE Internet of Things Journal.*
5. Kurakin, A., Goodfellow, I., & Bengio, S. (2016). Evolving Adversarial Attacks Against Deep Learning at Scale. *arXiv preprint.*
6. Marchal, S., Lahmadi, A., & Festor, O. (2017). Machine Learning for Network Security. *IEEE Security & Privacy.*
7. Xu, Z., Zhang, Y., & Tang, X. (2020). AI in Cybersecurity: A Comprehensive Survey. *IEEE Access.*
8. Leite, J. V. de S., Guedes Neto, D. O., & Weigang, L. (2020). Challenges in Data Science for Cybersecurity. *Springer.*
9. Zhou, C., & Pausch, R. C. (2019). Deep Learning for Anomaly Detection: A Survey. *ACM Computing Surveys.*
10. Abbasi, A., Xu, H., & Liu, X. (2017). Cybersecurity and Machine Learning: A Review of Trends, Challenges, and Solutions. *Journal of Cybersecurity and Mobility.*

GOVERNMENT DEGREE COLLEGE : KOVVUR : E.G.Dt.

Academic & Administrative Audit : 2023-2024

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III. RESEARCH, INNOVATIONS AND EXTENSION

C. Research Publicaton and Awards

10. No of Papers published per teacher in the UGC notified journals (SCOPUS, Web of Science, ICI) for the last 2 years

S.No.	Name of the Faculty	Department	Title of the Paper	Journal Name, Year, Volume and Page nos.	ISSN Number	Indexing
1	Sri K. Janardhana Rao	Mathematics	Hypergeometric functions on fuzzy lie groups	Journal of Mathematical Problems, Equations and Statistics. 2022. 3(1): 89-92.	Print: 2709-9393 Online: 2709-9407	Peer reviewed Journal
2	Sri K. Janardhana Rao	Mathematics	A METHOD TO FIND GENERATORS OF A FUZZY LIE GROUP	International Journal of Applied Mathematics & Statistical Sciences (IJAMSS). 2022. Vol. 11, Issue 2, 69–74	Print: 2319–3972 Online: 2319–3980	Peer reviewed Journal
3	Dr. Sadik Ahmed Mohammed	Chemistry	Effect of 0.5Li2O–0.5K2O–2B2O3 glass additive on optical and magnetic properties of YFeO3 nanomaterials	Journal of Materials Science: Materials in Electronics. 2023. 34:2242	Springer Journal	Springer Journal
4	Smt. G.Satya Suneetha	Computer Applications	ENHANCING SECURITY IN THE INTERNET OF THINGS (IOT): CHALLENGES AND SOLUTIONS	International Journal of Multidisciplinary Educational Research. 2023. Vol. 12, Issue: 10(1): 156-159.	2277-7881	Scopus
5	Smt. K. Jyothi	Commerce	CUSTOMERS ATTITUDE TOWARDS BANKING SERVICES--- A STUDY ON SELECTED BANKING ORGANIZATIONS IN KRISHNA DISTRICT OF ANDHRA PRADESH	International Journal of Management, Technology And Engineering. 2024. Vol. XIV, Issue II, page nos. 63-72	2249-7455	Peer reviewed Journal
6	Sri K. Janardhana Rao	Mathematics	L-hypergeometric functions on fuzzy lie groups	International Journal of Physics and Mathematics. 2023. 5(1): 51-55	Print: 2664-8636 Online: 2664-8644	Peer reviewed Journal

7	Sri K. Naga Suryanarayana	Commerce	E-commerce growth and its implications for consumer behavior: A review of recent trends	Asian Journal of Management and Commerce. 2023. 4(1): 366-372	Print: 2708-4515 Online: 2708-4523	Peer reviewed Journal
8	Sri K. Naga Suryanarayana	Commerce	The impact of foreign exchange policies on Indian trade and commerce	International Journal of Foreign Trade and International Business. 2023. 5(1): 54-58	Print: 2663-3140 Online: 2663-3159	Peer reviewed Journal
9	Sri K. Naga Suryanarayana	Commerce	Consumer protection in India: Laws, challenges, and effectiveness	International Journal of Research in Human Resource Management. 2023. 5(1): 94-99	Print: 2663-3213 Online: 2663-3361	Peer reviewed Journal
10	Dr. M. Bhupathi Rayalu	BOTANY	Ecobiology of the Tamil Bushbrown Butterfly, Mycalesis subdita Moore (Lepidoptera: Rhopalocera: Nymphalidae: Satyrinae) from Visakhapatnam, East Coast of Southern India.	Journal of Entomology and Zoology Studies. 2024. 12(3): 232-237.	Print: 2349-6800 Online: 2320-7078	Peer reviewed Journal
11	Smt. I. Laxmi Gayatri	English	Compatible Mappings on a 2-Metric Space	International Journal of Scientific Research and Engineering Development. 2024- 7 (3): 2590 - 2597	2581-7175	Peer reviewed Journal
12	Dr. Sadik Ahmed Mohammed	Chemistry	Enhancement in the Magnetic Properties of Yttrium Orthoferrite Materials by the Addition of BaO–Bi2O3–B2O3 Glass Sintering Aid	Phys. Status Solidi B 2024, 261, 2300313	Wiley-VCH GmbH	Wiley-VCH GmbH
13	Smt. K. Jyothi	Commerce	CUSTOMERS PERCEPTION TOWARDS CORE SERVICES OF PUBLIC AND PRIVATE SECTOR BANKING ORGANIZATIONS --- A STUDY IN GUNTUR DISTRICT OF ANDHRA PRADESH	Mukt Shabd Journal. Volume XIII, Issue II, FEBRUARY/2024: 890 - 902.	2347-3150	Peer reviewed Journal

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Hypergeometric functions on fuzzy lie groups

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Abstract
This research paper explores the integration of hypergeometric functions with fuzzy Lie groups. By extending classical Lie group theories to their fuzzy analogues, we aim to construct hypergeometric functions on fuzzy Lie groups and investigate their properties. The foundation of this study lies in the application of fuzzy set theory to the well-established concepts of Lie groups and hypergeometric functions, thus providing a new dimension to both fields.

Keywords: Hypergeometric functions, fuzzy lie groups, fuzzy set theory, lie groups

1. Introduction
The concept of fuzzy sets, introduced by Zadeh in 1965, has provided a robust framework for dealing with the imprecision inherent in many real-world problems [1]. Fuzzy set theory has been successfully applied in various domains such as computer science, decision making, and differential equations. This paper focuses on the extension of Lie group theory into the fuzzy domain, specifically investigating the construction and properties of hypergeometric functions on fuzzy Lie groups.

2. Preliminaries
2.1 Fuzzy Vector Spaces and Fuzzy Topology
A fuzzy set $\widetilde{A}$ in a universe of discourse X is characterized by a membership function $\mu_{\widetilde{A}}: X \rightarrow [0,1]$ [2].
Fuzzy vector spaces and topological structures extend these concepts to algebraic and topological settings, allowing the treatment of imprecision in vector operations and topological properties.

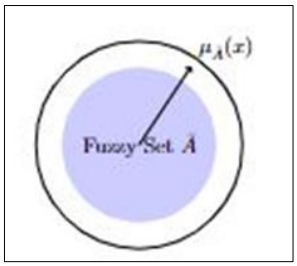

Fig 1: Representation of a Fuzzy Set

2.2 Fuzzy Lie Groups
A fuzzy Lie group $\widetilde{G}$ is a group G equipped with a fuzzy set structure that satisfies the group axioms to a degree defined by membership functions [3]. The fuzzy Lie algebra $\tilde{g}$ associated with $\widetilde{G}$ inherits the properties of the classical Lie algebra, modified to accommodate the fuzziness.

3. Hypergeometric Functions on Fuzzy Lie Groups
3.1 Construction of Hypergeometric Functions
Hypergeometric functions are solutions to hypergeometric differential equations, characterized by parameters that determine their behavior [4]. In the context of fuzzy Lie groups, these

functions can be constructed by defining differential operators that act on fuzzy manifolds and satisfy fuzzy analogues of the classical hypergeometric equations.

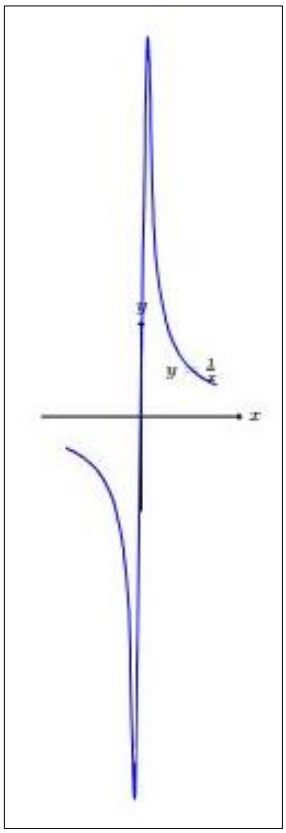

Fig 2: A Sample Hypergeometric Function Plot

3.2 Differential Operators on Fuzzy Lie Groups

Let $\widetilde{G}$ be a fuzzy Lie group and $\tilde{g}$ its associated fuzzy Lie algebra. The differential operators on $\widetilde{G}$, denoted $D_{\widetilde{G}}$, are defined in a manner analogous to classical differential operators but respect the fuzziness of the underlying group structure. These operators act on functions defined on $\widetilde{G}$ and are used to formulate the fuzzy hypergeometric differential equations.

4. Main Results

4.1 Existence and Uniqueness

Theorem 1 (Existence and Uniqueness) Let $\widetilde{G}$ be a fuzzy Lie group. There exists a unique solution to the fuzzy hypergeometric differential equation of the form

$$D_{\widetilde{G}}\phi(x) = 0$$

where $\phi(x)$ is a hypergeometric function defined on $\widetilde{G}$.

Proof. We prove the existence and uniqueness of the solution to the fuzzy hypergeometric differential equation $D_{\widetilde{G}}\phi(x) = 0$ by extending the classical Frobenius method to the fuzzy context [5].

Assume a Solution Form

We assume a solution of the form

$$\phi(x) = \sum_{n=0}^{\infty} a_n x^n$$

where the coefficients a_n are determined recursively.

Substitute into the Differential Equation

Substituting $\phi(x)$ into the fuzzy hypergeometric differential equation, we obtain

$$D_{\widetilde{G}}\left(\sum_{n=0}^{\infty} a_n x^n\right) = 0$$

Expanding the differential operator $D_{\widetilde{G}}$ and applying it to each term in the series, we get

$$\sum_{n=0}^{\infty} D_{\widetilde{G}}(a_n x^n) = 0$$

Obtain Recurrence Relation

The fuzziness of the group modifies the recurrence relation slightly. We obtain a recurrence relation for a_n from the fuzzy hypergeometric differential equation.

Prove Convergence

To ensure convergence of the series, similar techniques as in the classical case can be employed. This guarantees that the series solution exists.

Conclusion

Thus, the fuzzy hypergeometric differential equation has a solution of the form $\phi(x)$, and this solution is unique.

Therefore, by following the Frobenius method in the fuzzy context, we have established the existence and uniqueness of the solution to the fuzzy hypergeometric differential equation.

4.2 Properties of Fuzzy Hypergeometric Functions

Theorem 2 (Orthogonality): The fuzzy hypergeometric functions $\phi_m(x)$ and $\phi_n(x)$ are orthogonal with respect to a suitable inner product on $\widetilde{G}$.

Proof: We aim to demonstrate the orthogonality of the fuzzy hypergeometric functions $\phi_m(x)$ and $\phi_n(x)$ with respect to a suitable inner product on $\widetilde{G}$.

Inner Product Definition

Consider the inner product defined on the space of fuzzy functions [6]. Let $\langle \cdot, \cdot \rangle$ denote this inner product.

Integrating over the Fuzzy Manifold

We proceed by integrating the product of $\phi_m(x)$ and $\phi_n(x)$ over the fuzzy manifold. This integration accounts for the fuzziness inherent in $\widetilde{G}$.

$$\langle \phi_m, \phi_n \rangle = \int_{\widetilde{G}} \phi_m(x)\phi_n(x)\, d\mu$$

Handling Fuzziness

Properties of the membership functions are utilized to handle the fuzziness in the integration process.

Orthogonal Polynomials Theory

We utilize the theory of orthogonal polynomials, adapted to the fuzzy setting, to establish the orthogonality condition.

Conclusion

By integrating over the fuzzy manifold and leveraging properties of membership functions, we have shown that $\langle \phi_m, \phi_n \rangle = 0$ for $m \neq n$. This confirms the orthogonality of

the fuzzy hypergeometric functions $\phi_m(x)$ and $\phi_n(x)$.
Therefore, the theorem holds, and the fuzzy hypergeometric functions are indeed orthogonal with respect to the specified inner product on $\tilde{G}$.

Theorem 3 (Recursion Relations): The fuzzy hypergeometric functions satisfy recursion relations similar to their classical counterparts.

Proof. We aim to establish that the fuzzy hypergeometric functions satisfy recursion relations akin to their classical counterparts.

Step 1: Differentiation and Properties of Fuzzy Operators
We differentiate the fuzzy hypergeometric functions and utilize the properties of the fuzzy differential operators [7]. This differentiation accounts for the fuzziness inherent in the group $\tilde{G}$.

Step 2: Derivation of Recursion Relations
By applying differentiation and leveraging the properties of fuzzy operators, we derive recursion relations for the fuzzy hypergeometric functions. These relations retain a similar structure to their classical counterparts but include additional terms to accommodate the fuzziness.

Step 3: Fuzzy Context Adjustment
We note that the resulting recursion relations involve additional terms that arise due to the fuzziness of the group $\tilde{G}$. These terms modify the classical recursion relations but still preserve their fundamental structure.

Step 4: Conclusion
Through the differentiation process and the use of fuzzy differential operators, we have derived recursion relations for the fuzzy hypergeometric functions. These relations, while modified to accommodate the fuzziness, maintain the essence of their classical counterparts.
Thus, the theorem holds, affirming that the fuzzy hypergeometric functions indeed satisfy recursion relations analogous to their classical counterparts.

Theorem 4 (Integral Representations) Fuzzy hypergeometric functions have integral representations analogous to those in the classical theory.

Proof. We construct the integral representations by defining suitable fuzzy integration measures and adapting the classical integral representations [8]. The fuzziness is incorporated through the membership functions in the integration process, leading to modified but analogous integral forms.

Theorem 5 (Convergence): The series representation of fuzzy hypergeometric functions converges within a certain radius.
Proof. We analyze the series

$$\phi(x) = \sum_{n=0}^{\infty} a_n x^n$$

by considering the fuzzy radius of convergence. Using the ratio test adapted to the fuzzy context, we show that

$$\lim_{n\to\infty} \left|\frac{a_{n+1}}{a_n}\right| < 1$$

within a specified fuzzy radius. This ensures that the series converges within this radius.

4.3 Numerical Examples
Example 1 Consider a fuzzy hypergeometric function defined on a simple fuzzy Lie group $\tilde{G}$. Let the differential operator be $D_{\tilde{G}} = x\frac{d}{dx} + \tilde{\alpha}$. For specific values of $\tilde{\alpha}$, we can compute the first few terms of the series representation of $\phi(x)$:

$$\phi(x) = 1 + \tilde{\alpha}x + \frac{\tilde{\alpha}(\tilde{\alpha}+1)}{2!}x^2 + \cdots$$

By evaluating for $\tilde{\alpha} = 0.5$, we get:

$$\phi(x) \approx 1 + 0.5x + 0.375x^2 + \cdots$$

5. Applications
5.1 Fuzzy Control Systems
Fuzzy hypergeometric functions can be applied to design fuzzy controllers that manage systems with inherent uncertainties. By modeling system dynamics using fuzzy differential equations, controllers can be developed that adapt to changing conditions and imprecise measurements [9].

5.2 Image Processing
In image processing, fuzzy techniques are used to handle noise and ambiguity. Fuzzy hypergeometric functions can enhance algorithms for edge detection, image segmentation, and pattern recognition by providing more flexible mathematical models [10].

5.3 Quantum Mechanics
The fuzziness inherent in quantum mechanics can be modeled using fuzzy hypergeometric functions. These functions allow for the incorporation of uncertainty and imprecision in quantum states and operators, leading to more accurate descriptions of quantum phenomena [11].

6. Future Work
The development of hypergeometric functions on fuzzy Lie groups opens up new avenues for research in both mathematics and applied sciences. Potential applications include further exploration in fuzzy control systems, advanced image processing techniques, and quantum mechanics. Future work will focus on extending the theory to other special functions and exploring their applications in various scientific and engineering fields.

7. Conclusion
This paper presents a novel integration of hypergeometric functions with fuzzy Lie groups, providing a new perspective on both fields. The construction and analysis of these functions pave the way for further research and applications, demonstrating the versatility and power of fuzzy set theory in mathematical analysis.

8. References
1. Zadeh LA. Fuzzy sets. Inf Control. 1965;8(3):338-353.
2. Klir GJ, Yuan B. Fuzzy sets and fuzzy logic: theory and applications. Upper Saddle River (NJ): Prentice Hall; c1995.
3. Turksen IB. Fuzzy Lie groups. J Math Anal Appl. 2006;320(1):97-112.
4. Andrews GE, Askey R, Roy R. Special functions.

Cambridge: Cambridge University Press; c1999.
5. Johnson RA, Wichern DW. Fuzzy differential equations and applications. New York: Springer; c2000.
6. Li X, Pedrycz W. Fuzzy functions and data analysis. Berlin: Springer; c2012.
7. Carmona R, Zhong M. Fuzzy differential equations and applications for engineers and scientists. Hoboken (NJ): John Wiley & Sons; c2017.
8. Nahas R. Fuzzy integrals and applications. Berlin: Springer; c2011.
9. Mendel JM. Uncertain rule-based fuzzy logic systems: introduction and new directions. Upper Saddle River (NJ): Prentice Hall; c2001.
10. Pal SK, King RA. Image enhancement using fuzzy sets. Electron Lett. 1992;28(16):1494-1495.
11. Bucher I. Fuzzy logic in quantum mechanics. Singapore: World Scientific; c2003.

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A METHOD TO FIND GENERATORS OF A FUZZY LIE GROUP

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ABSTRACT

This paper presents a method to find generators of a fuzzy Lie group. By utilizing the algebraic and geometric properties of fuzzy Lie groups, we derive a systematic approach to identify a set of elements that generate the entire group. The methodology is rooted in the theory of fuzzy control sets and fuzzy Weyl group actions on fuzzy homogeneous spaces. Examples from $SL(2,\mathbb{R})$ and $SO(3)$ and applications in theoretical physics and differential geometry are provided to illustrate the utility of the method.

KEYWORDS: *Fuzzy Lie Group*

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INTRODUCTION

A fuzzy Lie group is an extension of a classical Lie group where the membership of elements is described by a fuzzy set. This extension allows for the incorporation of uncertainty and partial membership, which is useful in various applications where systems are not strictly deterministic.

This paper introduces a method to identify generators of a fuzzy Lie group by leveraging fuzzy control sets in fuzzy semigroup actions. The approach is based on the characterization of fuzzy control sets and the actions of the fuzzy Weyl group on fuzzy homogeneous spaces. The importance of such generators can be seen in numerous applications, from symmetry operations in quantum mechanics to transformations in differential geometry under uncertain conditions.

PRELIMINARIES

Let G be a connected fuzzy Lie group, and let $S \subset G$ be a fuzzy subsemigroup with interior points. Consider the fuzzy homogeneous space G/L, where L is a closed fuzzy subgroup of G.

Definition: A fuzzy partial order $\leq$ on G/L is defined by a fuzzy relation such that $x \leq y$ to a degree $\mu(x,y)$, where $\mu: (G/L) \times (G/L) \to [0,1]$ is a membership function indicating the degree of inclusion.

Theorem: The set G/L with the fuzzy partial order $\leq$ induced by the fuzzy semigroup action of S forms a fuzzy poset.

Proof. To show that $(G/L, \leq)$ forms a fuzzy poset, we need to verify that the fuzzy relation $\leq$ is transitive.

Suppose $x, y, z \in G/L$ such that $x \leq y$ with degree $\mu(x, y)$ and $y \leq z$ with degree $\mu(y, z)$.

By the composition rule of fuzzy relations,

the degree $\mu(x, z) \geq \min(\mu(x, y), \mu(y, z))$.

Thus, transitivity is satisfied to a fuzzy degree, and $(G/L, \leq)$ forms a fuzzy poset.

Lemma: If $S \subset G$ is a fuzzy subsemigroup with interior points, then the induced fuzzy partial order $\leq$ on G/L is dense in the sense that for any $x, y \in G/L$, there exists $z \in G/L$ such that $x \leq z \leq y$ with appropriate fuzzy degrees.

Proof. Since S has fuzzy interior points, for any $x \in G/L$ and $y \in Sx$, there exists a neighborhood $U \subset G/L$ such that $U \cap Sx \neq \emptyset$.

Therefore, we can find $z \in G/L$ such that $x \leq z \leq y$ with degrees $\mu(x, z)$ and $\mu(z, y)$, demonstrating the density of the fuzzy partial order.

Definition: A fuzzy control set D is a subset of G/L such that for any $x, y \in D$, there exists $s \in S$ with $y = sx$ to a fuzzy degree $\mu(y, sx)$.

FUZZY CONTROL SETS

Fuzzy control sets are crucial in understanding the dynamics of the fuzzy semigroup action on the fuzzy homogeneous space. These sets are where the fuzzy partial order $\leq$ effectively becomes a fuzzy equivalence relation.

Theorem: Fuzzy control sets can be characterized by the action of the fuzzy Weyl group W on G. Each element $w \in W$ corresponds to a fuzzy control set D_w.

Proof. Consider the action of the fuzzy Weyl group W on G.

Each element $w \in W$ induces a transformation on G/L, resulting in distinct fuzzy subsets of G/L.

These fuzzy subsets, invariant under the action of W, form fuzzy control sets D_w.

The bijective correspondence between elements of W and these fuzzy control sets establishes the characterization.

Proposition: The invariant fuzzy control set D_1 associated with the identity element of the fuzzy Weyl group W corresponds to the fuzzy subgroup $W(S) \subset W$ reflecting the structure and properties of the fuzzy subsemigroup S.

Proof. The invariant fuzzy control set D_1 is defined by the elements of G/L that remain unchanged under the fuzzy action of W.

Since $S \subset G$ has fuzzy interior points, the fuzzy control set D_1 captures the fuzzy subgroup $W(S)$ of the fuzzy Weyl group W that preserves these elements. Thus, D_1 provides insight into the structure of $W(S)$.

METHODOLOGY

To find generators for a fuzzy Lie group G, the following steps are undertaken:

- **Identify Fuzzy Control Sets**: Determine the fuzzy control sets $D_w$for the action of the fuzzy semigroup S on the fuzzy homogeneous space G/L.

- **Determine the Invariant Fuzzy Control Set**: Identify the invariant fuzzy control set D_1, which is directly related to the fuzzy subgroup $W(S)$ of the fuzzy Weyl group.
- **Analyze the Fuzzy Subgroup W(S)**: The structure of the fuzzy subgroup $W(S)$ provides insights into the elements that can serve as generators for G.
- **Construct Generators**: Use the elements associated with the fuzzy subgroup $W(S)$ to construct a generating set for the fuzzy Lie group G.

Theorem 4.1 The set of elements associated with the fuzzy subgroup $W(S)$ generates the entire fuzzy Lie group G.

Proof. Let $\{g_1, g_2, \dots, g_k\} \subset G$ be the set of elements associated with the fuzzy subgroup $W(S)$.

We need to show that any element $g \in G$ can be expressed as a product of these elements. Since $W(S)$ reflects the structure of the fuzzy subsemigroup S, and S acts transitively on G/L, any element of G can be reached by a finite sequence of actions from $\{g_1, g_2, \dots, g_k\}$.

Therefore, these elements generate G.

EXAMPLES

$SL(2, \mathbb{R})$

Consider $G = SL(2, \mathbb{R})$, the group of 2×2 real matrices with determinant 1, extended to a fuzzy context.

- **Fuzzy Control Sets**: The fuzzy Weyl group for $SL(2, \mathbb{R})$ is isomorphic to $\mathbb{Z}_2$. The fuzzy control sets can be identified by examining the action on the fuzzy projective line $\mathbb{RP}^1$.
- **Invariant Fuzzy Control Set**: The invariant fuzzy control set D_1 corresponds to transformations preserving orientation in $\mathbb{RP}^1$.
- **Generators**: The matrices

$$A = \begin{pmatrix} 1 & 1 \\ 0 & 1 \end{pmatrix}, \quad B = \begin{pmatrix} 1 & 0 \\ 1 & 1 \end{pmatrix}$$

Generate the fuzzy Lie algebra $\mathfrak{sl}(2, \mathbb{R})$. Exponentiating these matrices generates the entire $SL(2, \mathbb{R})$ group in the fuzzy context.

Theorem 1 The matrices A and B generate $SL(2, \mathbb{R})$ in the fuzzy context.

Proof. Any element of $SL(2, \mathbb{R})$ can be expressed as a product of exponentials of elements from its fuzzy Lie algebra $\mathfrak{sl}(2, \mathbb{R})$.

The matrices A and B span $\mathfrak{sl}(2, \mathbb{R})$, and their exponentials cover all elements of $SL(2, \mathbb{R})$ in the fuzzy context, thus generating the group.

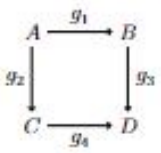

Figure 1: Action of Generators on a Fuzzy Control Set.

SO(3)

Consider $G = SO(3)$, the group of 3×3 orthogonal matrices with determinant 1, extended to a fuzzy context.

- **Fuzzy Control Sets**: The fuzzy Weyl group for $SO(3)$ is isomorphic to $\mathbb{Z}_2 \times \mathbb{Z}_2$. The fuzzy control sets can be understood by analyzing the action on the fuzzy unit sphere S^2.
- **Invariant Fuzzy Control Set**: The invariant fuzzy control set D_1 corresponds to rotations preserving the orientation of S^2 in the fuzzy context.
- **Generators**: The matrices

$$R_x = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta \\ 0 & \sin\theta & \cos\theta \end{pmatrix}, \quad R_y = \begin{pmatrix} \cos\theta & 0 & \sin\theta \\ 0 & 1 & 0 \\ -\sin\theta & 0 & \cos\theta \end{pmatrix}$$

Generate the fuzzy Lie algebra $\mathfrak{so}(3)$. Exponentiating these matrices generates the entire $SO(3)$ group in the fuzzy context.

Theorem: The rotations R_x and R_y generate $SO(3)$ in the fuzzy context.

Proof: The fuzzy Lie algebra $\mathfrak{so}(3)$ is spanned by the infinitesimal rotations around the x- and y-axes. The matrices R_x and R_y generate these infinitesimal rotations, and their exponentials cover all rotations in $SO(3)$ in the fuzzy context, thereby generating the group.

APPLICATIONS

Theoretical Physics

In quantum mechanics, the generators of fuzzy Lie groups are essential for describing symmetries and conserved quantities under uncertainty. For example, the fuzzy $SU(3)$ group is fundamental in the theory of strong interactions in particle physics, with its generators corresponding to the fuzzy Gell-Mann matrices. These generators play a crucial role in understanding the behavior of quarks and gluons under the strong force with inherent uncertainties [6].

Differential Geometry

In differential geometry, the study of fuzzy Lie groups and their generators aids in understanding the structure of smooth manifolds under fuzzy conditions. The tangent spaces of fuzzy Lie groups are spanned by the generators of their corresponding fuzzy Lie algebras, which are crucial in defining geometric properties such as curvature and connections on manifolds under uncertainty. For instance, the generators of the fuzzy Lie algebra $\mathfrak{so}(3)$ are used to study the curvature of surfaces in three-dimensional space with fuzzy conditions [8].

Control Theory

Control theory often utilizes fuzzy Lie groups to describe the state space of dynamic systems under uncertainty. The ability to generate the entire state space through a finite set of fuzzy controls (generators) is critical for the design and analysis of control systems. Techniques involving fuzzy control sets and fuzzy semigroup actions provide powerful tools for understanding the reachability and controllability of these systems under fuzzy conditions [2].

CONCLUSION

The method of utilizing fuzzy control sets and the fuzzy Weyl group provides a systematic approach to identify generators for fuzzy Lie groups. By analyzing the fuzzy semigroup actions and the associated fuzzy control sets, one can derive a generating set that captures the structure of the entire group under fuzzy conditions. This approach offers a unified framework for studying the generators of fuzzy Lie groups, contributing to both theoretical insights and practical applications in the field of fuzzy Lie group theory.

REFERENCES

1. *L. Arnold and W. Kliemann, Invariant Control Sets and Global Attractors, SIAM J. Math. Anal., 1987.*
2. *F. Colonius and W. Kliemann, The Dynamics of Control, Birkhäuser, 2000.*
3. *Y. Guivarc'h and A. Raugi, Products of Random Matrices: Asymptotic Properties of the Lyapunov Exponents, Ann. Inst. H. Poincaré Probab. Statist., 1985.*
4. *J.E. Humphreys, Introduction to Lie Algebras and Representation Theory, Springer, 1972.*
5. *B.C. Hall, Lie Groups, Lie Algebras, and Representations: An Elementary Introduction, Springer, 2015.*
6. *H. Georgi, Lie Algebras in Particle Physics, Westview Press, 1999.*
7. *G.B. Folland, Harmonic Analysis in Phase Space, Princeton University Press, 1989.*
8. *M.P. do Carmo, Riemannian Geometry, Birkhäuser, 1992.*

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Effect of $0.5Li_2O–0.5K_2O–2B_2O_3$ glass additive on optical and magnetic properties of $YFeO_3$ nanomaterials

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ABSTRACT

The orthorhombic crystal structure of $YFeO_3$ (YFO) is well known for photocatalysis and magneto-optical application, as a result, continued efforts are being made to further improve the physical properties (optical and magnetic) of this material via doping of rare earth (more expensive) elements. In this context, we attempted to improve the physical properties of YFO by adding the $0.5Li_2O–0.5K_2O–2B_2O_3$ (LKBO) as a glass additive (inexpensive). The X-ray powder diffraction (XRD) studies show that the maximum 0.5 wt% of LKBO glasses was incorporated into YFO without exhibiting any impurity or secondary phase. FWHM of the main intensity XRD peak (*hkl* = 121) was reduced from 0.173 to 0.145 when LKBO glasses rose from 0 to 1.0 wt%. The existence of each element present in YFOLKBO-0 and YFOLKBO-0.5 samples was confirmed through X-ray photoelectron spectroscopy (XPS). The average particle size of YFO and 0.5 wt% LKBO added YFO samples were found to be ~ 395 and ~ 794 nm respectively, which was observed through scanning electron microscopy (SEM) analysis. The calculated optical band gap was decreased from 2.23 to 2.18 eV with an increase of LKBO content from 0 to 1 wt% in the YFO nanomaterials. The maximum magnetization value of 0.5 wt% LKBO added YFO material reached 4.15 emu/g, ~ 1.2 times higher than pure YFO materials. In conclusion, these findings (0.5 wt% LKBO glasses added into the YFO) bode well for future production of low-cost YFO materials for magnetic applications.

1 Introduction

The wide range of physical characteristics of multifunctional rare-earth orthoferrites nano-materials has drawn attention from the research point of view due to their uses in different applications. These make orthoferrites suitable for a variety of uses, such as magneto-optical devices, biomedical, capacitors, photocatalysis, microwave electronic devices, spintronic devices, and many more applications [1–5]. Masoud groups have extensively worked on ferrite or non-ferrite and composites-based nanomaterial and explained it in different perspective applications, especially hydrogen storage energy, and catalysis [6–13]. Oxides of perovskite with a general formula ABO_3, where A = Pb, Ba, Na, Ni, Co, Zn, Cu, Bi and Y, and B = Ti, Nb, Mo, Fe, etc.,

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are well recognized as a functional inorganic material for different industrial applications, such as gas sensors, piezoelectric, ferroelectric, fuel cells, optical and non-linear optical and metal-air barriers [14–18]. The incorporation of different elements in perovskite leads to three categories of structural distortion: tilting of BO_6 octahedra, polar cationic displacement, and Jahn–Teller distortions. Tilting of BO_6 octahedra is the most common of these three in the *Pmna* space group, to which YFO belongs. YFO belongs to the perovskite structure, and it exhibited multifunctional behavior. Both hexagonal and orthorhombic crystal structures were present in YFO, although, from the perspective of magnetic applications, the orthorhombic crystal structure is preferable to the hexagonal one. Furthermore, the YFO exhibits excellent UV–Vis absorption, a soft ferromagnetic nature with high magnetization value, and a relatively low energy band gap (1.8–2.6 eV), making them more desirable for photocatalysis and magneto-optical applications [19, 20].

Several synthetic routes such as solid-state synthesis, sol–gel, sol–gel auto combustion with a one-step method, hydrothermal, mechanochemical, and a few more methods have been used for the synthesis of YFO nanomaterial and reported in the literature [21–40]. Apart from this, the YFO nanocrystals were also synthesized using different soft chemical routes and reported in the literature [35]. The difference between the multiferroic properties of hexagonal and orthorhombic ion–doped YFO nanoparticles was also studied theoretically and reported in the literature [36]. Previous research has shown that the structural and physical characteristics of rare-earth orthoferrites can be changed by adding magnetic or non-magnetic ions in A-sites or B-sites of YFO material [28, 30, 36–38]. Bharadwaj et al. [28] reported a 2.6 times higher magnetization value for the Sm (15 mol%) doped YFO (1.04 emu/g) when compared to pure YFO (0.4 emu/g). The same group also reported [30] the improved (~ 6.7 times higher) magnetization value for the Nd (15 mol%) doped YFO when compared to pure YFO, however, the coercive field was reduced from 800 Oe (Nd doped YFO) to 34 Oe (YFO). Other groups [36, 38, 39] also reported improved magnetization values of YFO material through doping of rare earth elements. Here we also observed the improved magnetization value for YFO material via the addition of LKBO glass as a sintering aid, as discussed in this article. To the best of the authors' knowledge, no reports on the glass phase-assisted sintering of YFO nanomaterials have been discovered in the literature. As glass melts or liquefies above the glass transition temperature, it facilitates the effective diffusion of ions or molecular units, and this leads to the formation of large grains. Stable LKBO glass is used in this article's investigation of the impact of glass phase-assisted sintering on YFO nanomaterials. The low melting points of the glasses made of borate led to their selection. Recently our group optimized better chelating agents (tartaric acid) and sintering temperature for YFO nanomaterials to realize the optimal physical properties of the material [32, 40]. Hence, the main objective of this study is to improve the magnetization value of YFO nanomaterials with the combination of LKBO glass as a sintering aid. For LKBO glass, Li_2O and K_2O could increase the grain growth of the material, while B_2O_3 modifier oxide could increase the fluidity of the glass. Low-temperature calcination occurs via a viscous flow mechanism in which glass liquidation plays a significant role. In this investigation, we used LKBO glass as an additive to prepare YFO samples to observe further improvements in magnetic and optical properties. The appropriate addition of LKBO glass is expected to promote the grain growth of the YFO. As a result, the optical bandgap will be reduced, which is required for photocatalysis applications. Here we are reporting the structural, optical, and magnetic properties obtained from 0 wt% of LKBO glass (henceforth YFOLKBO-0)-, 0.25 wt% of LKBO glass (henceforth YFOLKBO-0.25)-, 0.5 wt% of LKBO glass (henceforth YFOLKBO-0.50)-, and 1.0 wt% of LKBO glass (henceforth YFOLKBO-1) added in YFO material.

2 Experimental procedure

2.1 Materials and methods

Y_2O_3 (99.99%, Ultrafunction Enterprise CO. LTD), $Fe(NO_3)_3{\cdot}9H_2O$ (98%, SDFCL), (+) − $(CHOH.COOH)_2$ (99.5%, Qualigens) used as a starting material for the synthesis of YFO nanomaterials using sol–gel technique. To begin with, the required amount of Y_2O_3 (0.5 mol ratio concerning Fe $(NO_3)_3{\cdot}9H_2O$) was dissolved in a HNO_3 solution [3 mol of HNO_3 (12 mL) and 1.5 mol of H_2O (5 mL)] at 80 °C for 30 min. The temperature of the solution was brought to room temperature when the clear solution was formed, and then a 1.0 mol ratio of Fe $(NO_3)_3{\cdot}9H_2O$ solution (15 mL) was added to the above solution under continuous stirring.

Then tartaric acid solution (10 mL) as a chelating agent (2.0 mol ratio) was added to the above solution and stirred for 1 h at room temperature. Drop by drop of ammonium solution (25%) was added to the above solution to maintain the pH of ~ 6.5–7 with continuous stirring at room temperature. The above solution was heated at 120 °C with continuous stirring to remove the water molecule in the solution. At this temperature, water molecule was evaporated and formed the gelation. Then the obtained gel was dried and then heated at 250 °C to achieve the YFO precursor. Then the obtained precursor was calcined at 900 °C for 3 h to obtain a pure phase of YFO nanomaterial [40]. However, the conventional melt-quenching technique was used to fabricate the LKBO glasses. To prepare LKBO glasses, the suitable amounts of Li_2CO_3, K_2CO_3, and H_3BO_3 were weighed and mixed with acetone using a mortar and pestle for 1 h. This mixture was taken in a platinum crucible and melted at 1000 °C, and then the melt was quenched to room temperature. The obtained as-quenched glasses were grounded into a fine powder and added to YFO nanomaterials in different wt% (0, 0.25, 0.5, and 1.0). The mixture of these powders was ball-milled in an ethanol medium for 5 h. The obtained mixed powders were dried and uniaxially pressed into pellets (10 mm diameter and ~ 1.5 mm thickness). The pressed pellets were sintered in air at 1000 °C for 3 h with heating and cooling rates of 5 °C/min using a Thermolyne furnace.

2.2 Characterization techniques

XRD technique (CuK_α radiation, $\lambda = 0.154$ nm) (PANalytical Multifunctional X'PertXRD) was used to identify the phase purity of the LKBO added YFO nanomaterial with a scanning rate of 2°/min at room temperature. Dynamic Light Scattering (DLS) Particle Analyzer (Anton Paar, Litesizer™ 500) technique was used to determine the particle size distribution of each sample. The morphology and grain size of each sample were estimated using the SEM (SEM; JEOL-JSM-IT300LV). Raman Microscope (DXR model, Thermo Fischer Scientific) was used to identify the dominant Raman vibrational modes of the LKBO-added YFO nanomaterials at room temperature. For this measurement, the laser excitation-centered wavelength at 780 nm with a laser power of 3 mW was used. UV–Vis NIR spectrophotometer (Perkin-Elmer Lambda 750 UV/Vis/NIR spectrophotometer) was used to record the absorption spectra of LKBO glasses added YFO nanomaterial in the wavelength range of 200 to 800 nm. The bandgap of the LKBO-added YFO samples was estimated using the diffuse reflectance spectrum by using the Kubelka–Munk function. The magnetic properties measurement was carried out by using VSM (Model EZ9, MicroSense, USA). X-ray photoelectron spectrometry (XPS), Shimadzu Axis Ultra DLD, was used to determine the chemical species present in the samples.

3 Results and discussion

The typical powder XRD pattern of LKBO-added YFO samples is shown in Fig. 1; however the powder XRD pattern of as-quenched LKBO glass is depicted in Supplementary data (Fig. S1). The obtained XRD pattern was indexed to orthorhombic structure with *Pmma* (*space group: 62*) using the standard JCPDS Card [98-008-0866]. The diffraction peaks could be indexed to (111), (200), (121), (002), (112), (220), (202), (040), (141), (212), (240) and (042) of orthorhombic structure (enlarged view of XRD 2θ from 20 to 40, and 40 to 70 in Fig. 1). YFO comprising the 0.25 and 0.5 wt% of LKBO glasses showed the pure YFO phase. Above 0.5 wt% LKBO added YFO samples, the presence of impurity or secondary phase was observed (denoted @, #, and & in Fig. 1) which indicates a possible chemical interaction between YFO and LKBO. Indeed the observed impurity peaks were identified as Y_2O_3, α-Fe_2O_3, and $Li_{0.5}Fe_{2.5}O_3$ phases. Furthermore, we performed the Rietveld analysis of the LKBOYFO-0 and LKBOYFO-0.5 samples for further structural confirmation. The obtained refinement graphs are provided in Fig. 2. The satisfactory fit was confirmed through χ^2 values, and it was found to be 2.55 and 2.31 for LKBOYFO-0 and LKBOYFO-0.5, respectively. The obtained lattice parameters of LKBOYFO-0 and LKBOYFO-0.5 samples through Rietveld analysis is mentioned in Table 1. These studies indicate that the maximum 0.5 wt% of LKBO is soluble in the YFO material. FWHM (high-intensity peak (*hkl* = 121) of each sample under this study is provided in Table 2. The decrease of FWHM with the increase of LKBO content indicates that increase in the average grain size of the sample. Table 2 shows the calculated average grain size (D) of each sample using the Scherrer formula with the help of the XRD pattern. To calculate the average D, we used the high-intensity XRD peaks [(111), (200), (121), (002), (220), (202), (040), (141), (240),

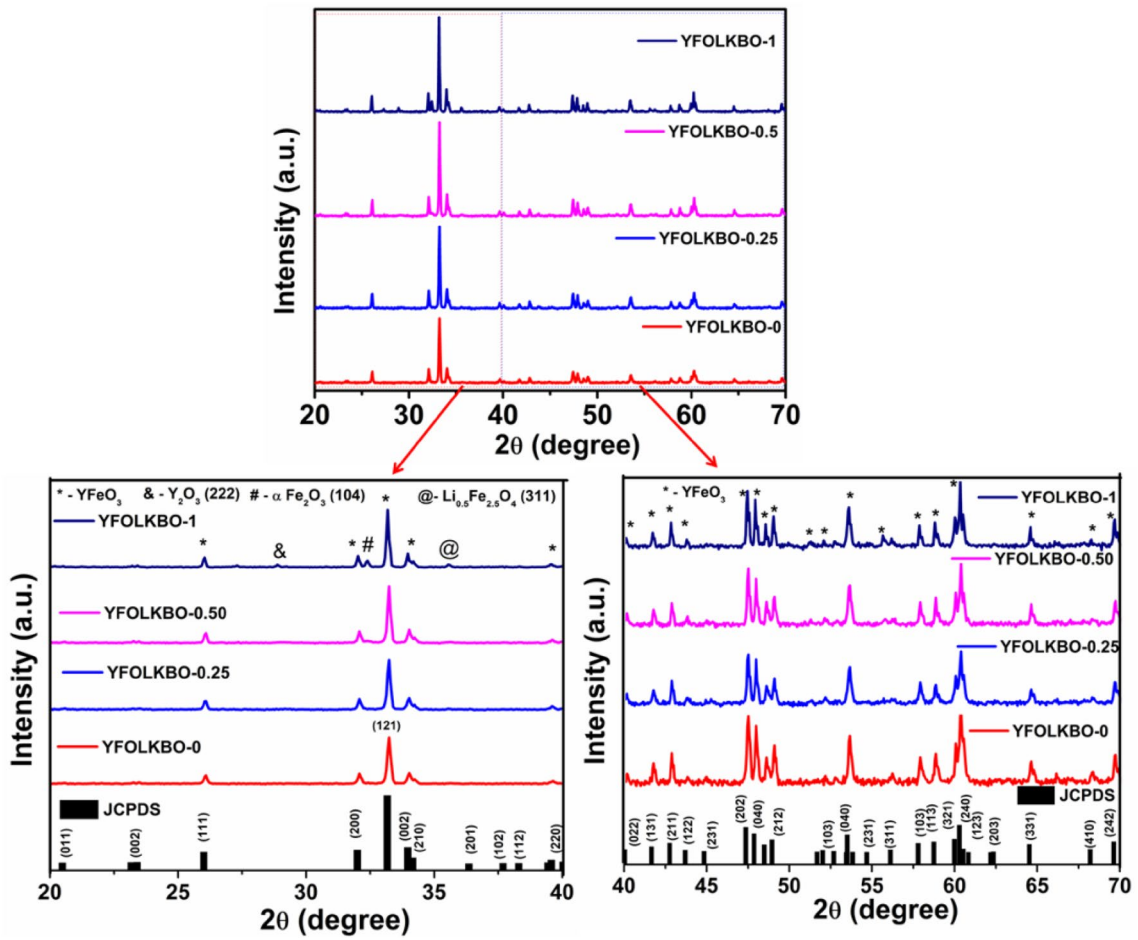

Fig. 1 Experimental observed XRD patterns of JCPDS of YFO and different wt% LKBO glass added in YFO nanomaterials

and (042)]. This table indicating that the increase of D with an increase of LKBO content in the YFO sample. Dislocation density (δ) is also another important factor to explain the crystalline nature of the sample. Hence we calculated the δ of each sample under this study with the help of literature reported [41, 42] equations ($\delta = \frac{1}{D}$), and thus obtained results are provided in Table 2. The decrease in δ value indicates the improved crystallization of the sample [41–43].

Figure 3 represents the size distribution of the YFO and LKBO added YFO material as obtained by the dynamic light scattering (DLS) technique with deionized water as the solvent. The obtained average particle size of each sample is mentioned in Table 1. The average particle size was found to increase with an increase of LKBO wt% in the YFO sample. The size distribution of each sample shows a narrow range, which indicates the formation of uniform-sized particles in all the samples in this study. The uniform particle size distribution is due to the formation of heterometallic polynuclear complexes in the solution.

Raman spectra of YFO and different wt% added LKBO in YFO samples were measured in the range of 100–3100 cm^{-1} at room temperature, and thus obtained results are depicted in Fig. 4. For the first orders, the 12 modes among the 24 Raman active modes ($7A_g + 5B_{1g} + 7B_{2g} + 5B_{3g}$) of YFO orthorhombic structure were assigned in the literature. As per the literature, here we assigned the 8 strong modes for the LKBO (0–1.0 wt%) added in YFO materials [50]. Two bands, one at ~ 152 cm^{-1} and the second one at ~ 182 cm^{-1} were observed in the region of 100–200 cm^{-1} (Fig. 5a). These bands are responsible for the yttrium ion vibrational modes. In the region of 200–400 cm^{-1}, 3 different characteristic bands were observed (Fig. 5b). The observed band ~ 218 cm^{-1} is ascribed to Fe^{3+} ions vibration. The bands ~ 278 and 342 cm^{-1} are responsible for the magnetic Fe^{3+} ions

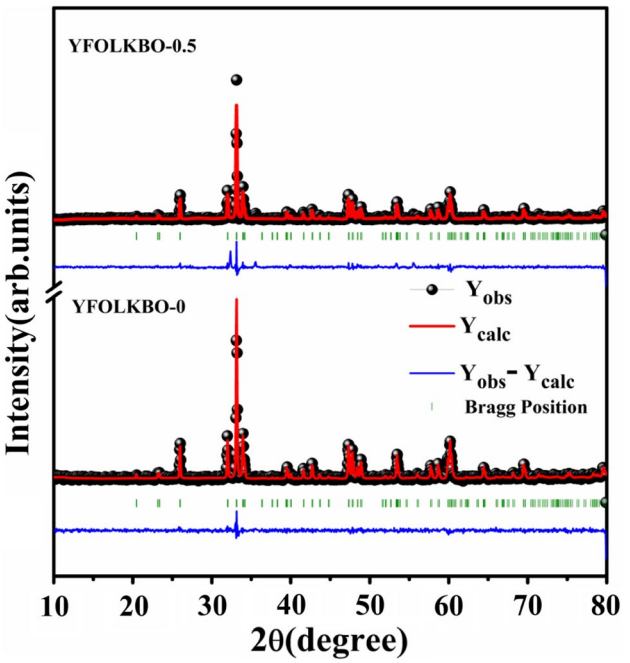

Fig. 2 Rietveld analysis plots of YFOLKBO-0 and YFOLKBO-0.5 samples

excitation. In the region of 400–600 cm^{-1}, two bands (431 and 500 cm^{-1}) were observed (Fig. 5c), and these bands are ascribed to the excitation of magnetic of Fe^{3+} ions. The characteristic of the Fe–O bond (~ 635 cm^{-1}) was observed in the region of 600–700 cm^{-1} region (Fig. 5d). The characteristic of the Fe–O peak was shifted from 632.3 cm^{-1} (YFO) to 634.7 cm^{-1} (LKBOYFO-0.5), and this could be due to the increase in particles. As the particle size increases the polarization of the material will change as a result shift in the peak position was observed. Apart from this, one band ~ 1302 cm^{-1} was observed (Fig. 4), and this band is responsible for the vibration of magnetic Fe^{3+} ions [51, 52]. The observed Raman modes are well matched with YFO orthorhombic structure which was earlier reported in the literature [44, 53].

Reflectance (%) versus wavelength (nm) for each sample under this study in the region of 350–800 nm

Table 2 FWHM, D, δ and average particle size from DLS of YFOLKBO-0, YFOLKBO-0.25, YFOLKBO-0.50 and YFOLKBO-1 samples

Name of the sample	FWHM	D (nm)	δ	Average particle size from DLS (nm)
YFOLKBO-0	0.173	195	0.0051	381
YFOLKBO-0.25	0.169	228	0.0044	597
YFOLKBO-0.50	0.149	283	0.0035	805
YFOLKBO-1	0.145	348	0.0029	1033

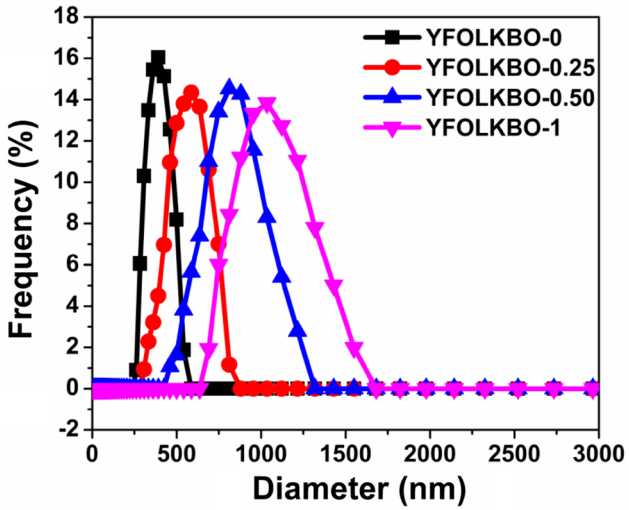

Fig. 3 Size distribution graphs of different wt% LKBO glasses added in YFO nanomaterials measured by the DLS technique

was depicted in Fig. 6. The reflectance spectrum is less than 10% for all the samples under this study in the region of 350–470 nm, which indicates that, these material's ability to absorb the light in the visible region. The decrease of reflectance (%) with an increase of LKBO content in YFO is due to the increase in crystallite size. Crystallite size is increasing, resulting in a decrease in surface area and less scattering from the particles. A strong and wide absorption band

Table 1 Reliability factors of profile fit and lattice parameters of YFOLKBO-0 and YFOLKBO-1 samples obtained from Rietveld analysis

Name of the sample	Reliability factors of profile fit			Lattice parameters (Å)		
	R_P (%)	R_{wP}(%)	GOF	*a*	*b*	*C*
YFOLKBO-0	2.55	2.95	7.43	5.5935	7.6028	5.2842
YFOLKBO-0.50	2.31	2.48	6.08	5.5969	7.6055	5.2859

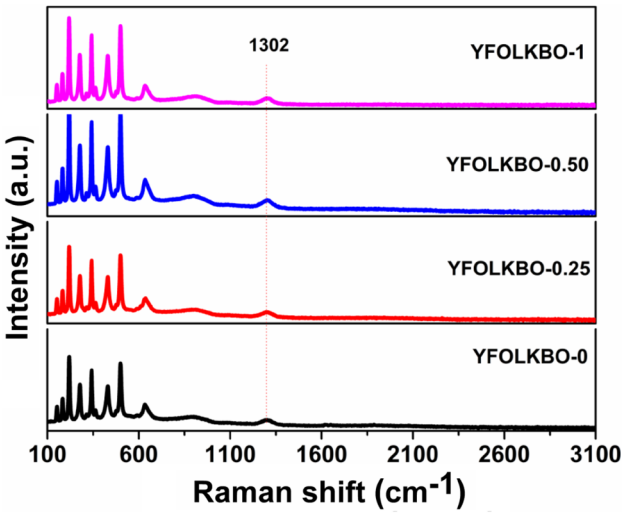

Fig. 4 Room temperature Raman spectra of YFO and different wt% added LKBO glasses in YFO nanomaterial in the region of 100–3100 cm^{-1}

was observed in the region of 575–650 nm for all the samples under this study. This absorption is responsible for the electronic transition between the valance band (oxygen 2p states) to the conduction band (Fe 3d states) [54].

Figure 7 shows the calculated bandgap of each material using the reflectance spectra with the help of the Tauc method [55]. Bandgap estimated from extrapolating the linear portion of hυ versus $(h\upsilon \times F_{KM})^2$. Here *h* is the plank constant, υ is the frequency, and F_{KM} Kubella–Munk function. The estimated energy bandgap of all the materials under this study is provided in Table 2. According to the mass approximation model, the optical band gap is inversely proportional to particle size. As a consequence, we observed a decrease in bandgap with the increase in particle size. The calculated bandgap is smaller than that of the earlier reported YFO-based materials as well as other perovskite materials. The literature reported bandgap of the materials as well

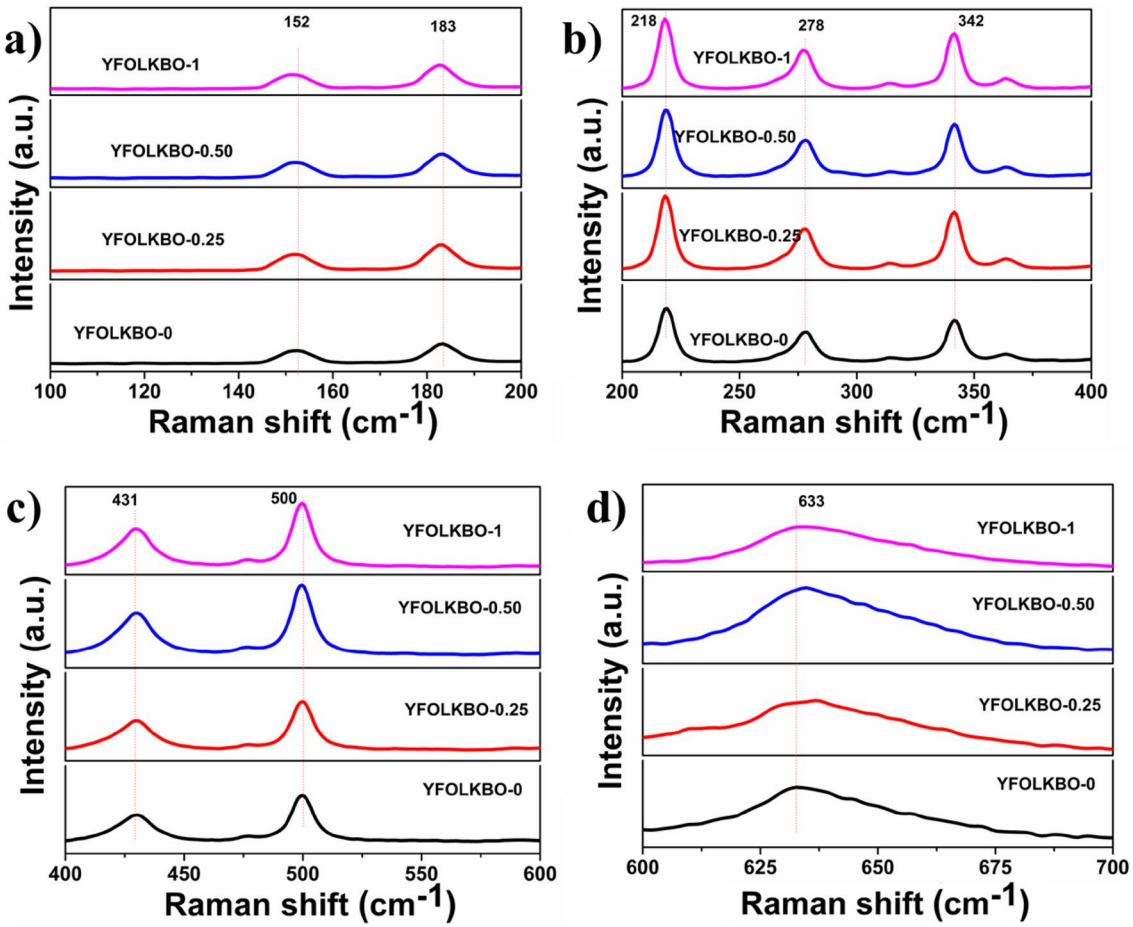

Fig. 5 Enlarged view of Raman spectra **a** 100–200 cm^{-1}, **b** 200–400 cm^{-1}, **c** 100–200 cm^{-1}, and **d** 600–700 cm^{-1}

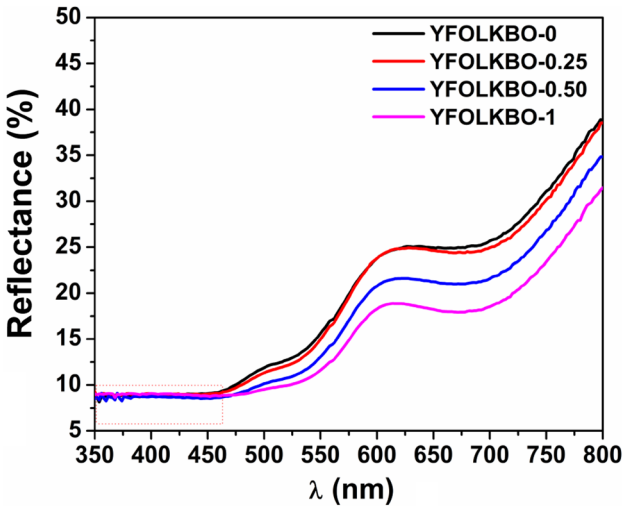

Fig. 6 Reflectance spectra of YFO and different wt% added LKBO in YFO nanomaterials

as the present study is provided in Table 3, for the comparison purpose. The low bandgap result of the present study (Table 3) indicates that these materials could be potential candidates for photocatalysis applications [49, 56].

Room temperature magnetization hysteresis (M–H) loops (an applied field up to 1.8 T) of YFO and different wt% added LKBO in YFO nanomaterials are depicted in Fig. 8a–d. All the samples under this study exhibited the net magnetic moment, and the obtained magnetization (M_s) values for YFOLKBO-0, YFOLKBO-0.25, YFOLKBO-0.50, and YFOLKBO-1 were 3.64, 3.72, 4.14 and 3.62 emu/g and the corresponding coercive field (Oe) values were 67.3, 64.8, 62.6 and 47.7, respectively Fig. 8. The magnetization values depend on many factors, such as the synthetic route used for the preparation, sintering or calcination temperature, particle size, and a few more factors [20, 44, 57–61]. Here the improved magnetization value is due to the increase in particle size. With an increase in particle size, the YFO polarization also changes (due to changes in the Fe–O bond) which leads to the improvement of magnetic property [32]. In Fig. 5d, the characteristic of the Fe–O bond for the YFOLKBO-0.5 is shifted toward a higher wavenumber (2 cm^{-1}, i.e., from ~ 633 to 635 cm^{-1}) when compared to that of the YFOLKBO-0 sample. Furthermore, the coercive field of the sample continuously decreased from 67. 3 to 47.8 Oe when the increase of LKBO wt% from 0 to 1 wt% in YFO nanomaterials (Fig. 9). The decrease in the

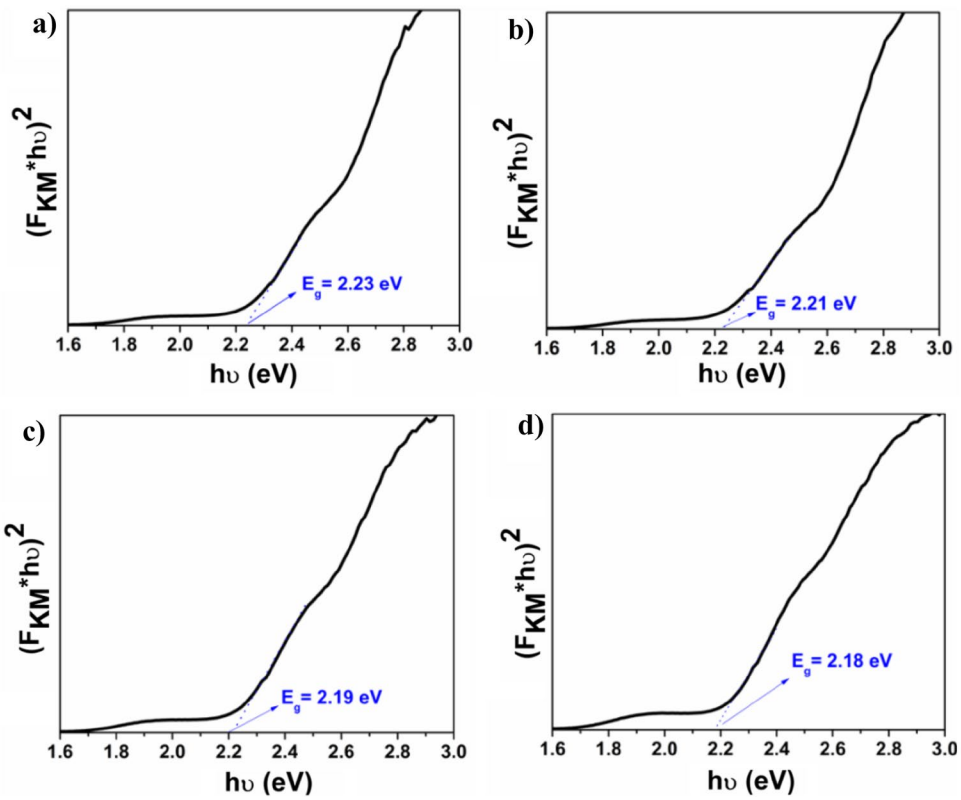

Fig. 7 Tauc plots for **a** YFOLKBO-0, **b** YFOLKBO-0.25, **c** YFOLKBO-0.50, and **d** YFOLKBO-1 nanomaterials

Table 3 Comparative study of the optical bandgap of the present study and previously reported YFO and other perovskite materials

S. No.	Material	Optical band gap (eV)	References number
1.	YFO	2.47	[34]
2.	YFO	2.30	[44]
3.	YFO	2.48	[20]
4.	$BaTiO_3$	3.28	[45]
5.	$LiNbO_3$	3.78	[46]
6.	$CoCr_2O_4$	3.10	[47]
7.	$BiFeO_3$	2.67	[48]
8.	$FeCr_2O_4$	2.90	[47]
9.	$CaCu_3Ti_4O_{12}$ thin films	3.79	[49]
10.	YFOLKBO-0	2.23	Present study
11.	YFOLKBO-0.25	2.21	Present study
12.	YFOLKBO-0.50	2.19	Present study
13.	YFOLKBO-1	2.18	Present study

coercive field may be due to the increase in crystallite size [62].

X-ray photon spectroscopy (XPS) was performed, to estimate the chemical states of the elements present in YFOLKBO-0 and YFOLKBO-0.5 samples. The survey scan spectrum and each element present in YFOLKBO-0 and YFOLKBO-0.5 samples were depicted in Figs. 10 and 11, respectively. The binding energy for $3d_{5/2}$ and $3d_{3/2}$ was observed at 156.8 and 159.2 eV, respectively for the Y atom in both the samples. The difference between these two states is around 2.4 eV, which indicates that Y exists in + 3 oxidation states. The deconvolution of Fe: $2p_{3/2}$ peak has been calculated using the multi-peak method. These deconvolutions yield two different peaks with two binding energies around 710 and 723 eV corresponding to the Fe^{2+} and Fe^{3+} ions respectively (for both samples). This evidence provides that the Fe is the existence of mixed states (Fe^{2+} and Fe^{3+}) in the samples. The deconvolution of two peaks in oxygen around 529 and 532 eV

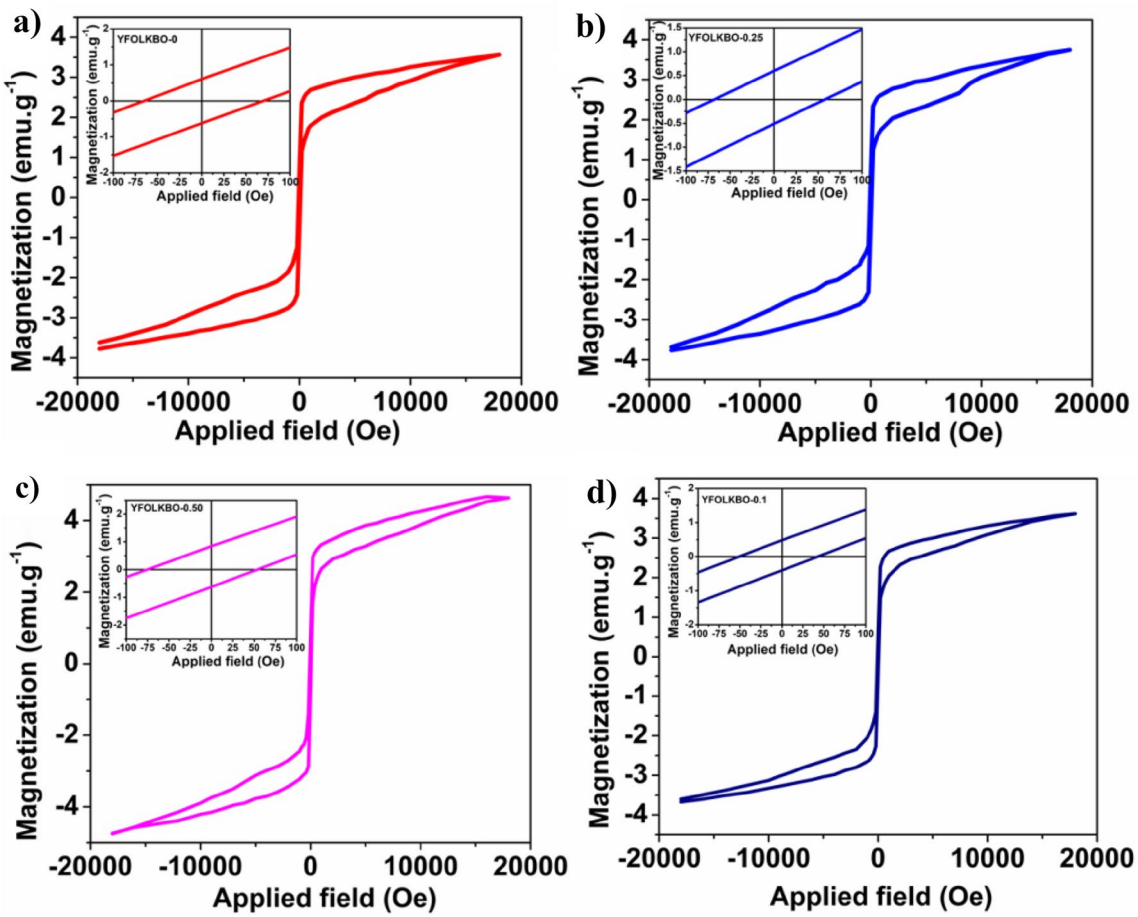

Fig. 8 M-H loops of **a** YFOLKBO-0, **b** YFOLKBO-0.25, **c** YFOLKBO-0.50, and **d** YFOLKBO-1 nanomaterials

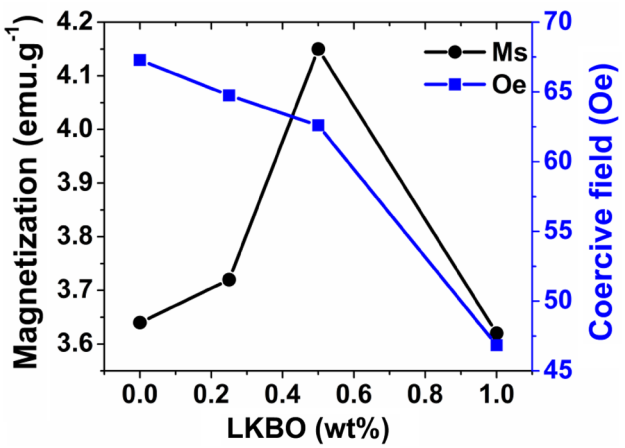

Fig. 9 Comparison of magnetization and Coercive field as a function of wt% of LKBO added in YFO nanomaterials

are attributed mainly to the surface adsorbed oxygen. The peak position of 532 eV is not strong enough as compared to the 529 eV which suggests the loss of an electron, making it O^- from O^{-2} ion thus giving rise to a higher concentration of oxygen vacancies. The peak strengthening therefore decides the position of 529 eV as it belongs to the O^{-2} ion which in turn belongs to lattice oxygen and the position at 532 eV corresponds to the O^- ion which is thus related to the O^{-2} ion. The ratio of O^{-2}/O^-ions within the limit of 2–10 suggests that oxygen deficiency is not in consideration of the structural impact. The binding energy at 55.4, 191.1, and 299.2 eV for Li 1 s, B 1 s, and K 2p, respectively for the YFOLKBO-0.5 samples (Fig. 11).

Finally, to observe the morphology of the YFOLKBO-0 and YFOLKBO-0.50, the SEM analysis was carried out on the surface of the pellet samples. The samples were sputtered with platinum before SEM analyses to prevent the surface charge because they are electrically non-conducting by nature. The SEM images of YFOLKBO-0 and YFOLKBO-0.50 are depicted in Fig. 12a–b. Here both the samples exhibit the regular shape morphology. The line intercept method was used to estimate the average particle size of the samples. The estimated average particle size of the YFOLKBO-0 and YFOLKBO-0.5 samples was found to be 390 and 920 nm, respectively.

4 Conclusions

The current investigations aided in identifying lithium potassium borate (LKBO) glass as an additive for further magnetic properties improvement of YFO material. Rietveld analysis indicates that YFO and 0.5 wt% LKBO added YFO materials are exhibiting the orthorhombic structure. An increase of LKBO concentration in YFO leads to an increase in the particle size of the material. The optical bandgap was decreased from 2.23 to 2.18 eV with an increase of particle size from 195 to 398 nm. The regular shape

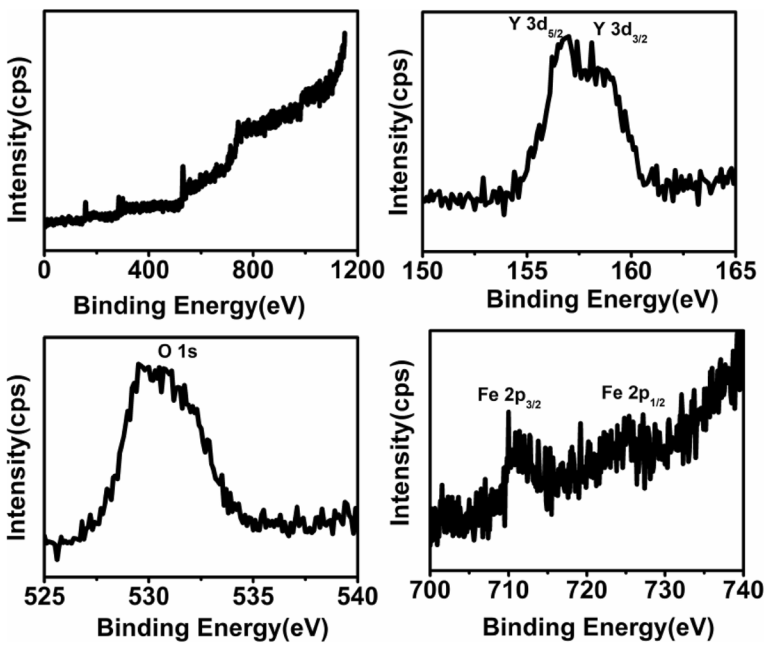

Fig. 10 XPS spectrum of LKBOYFO-0 sample

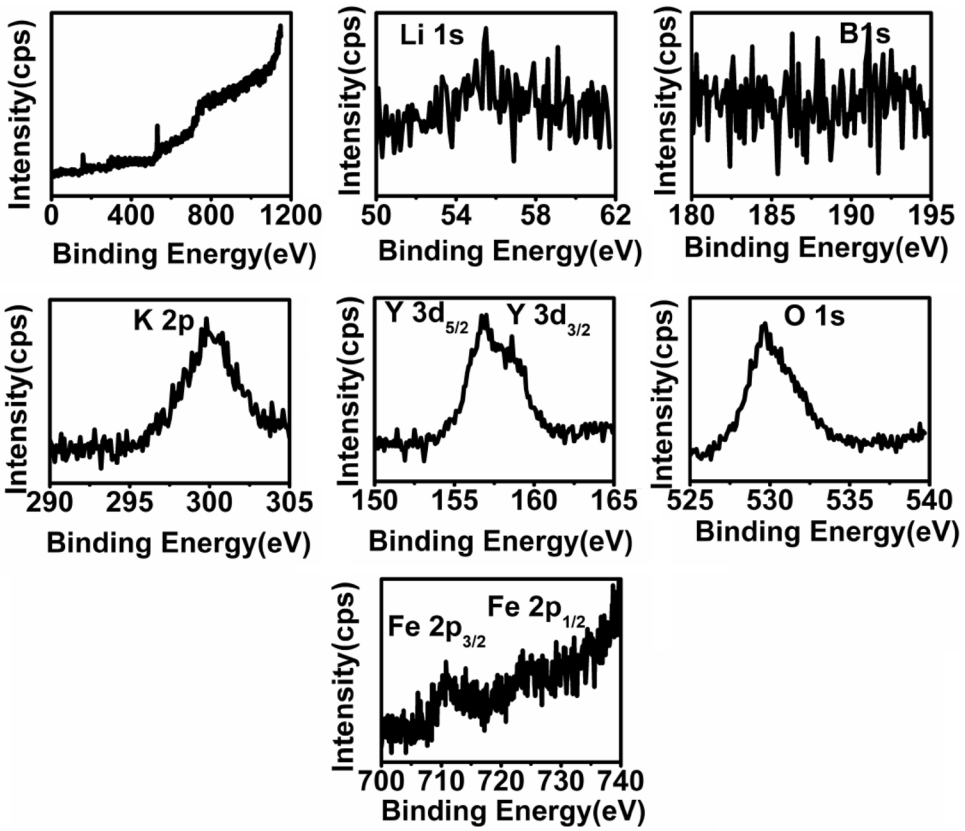

Fig. 11 XPS spectrum of LKBOYFO-0.5 sample

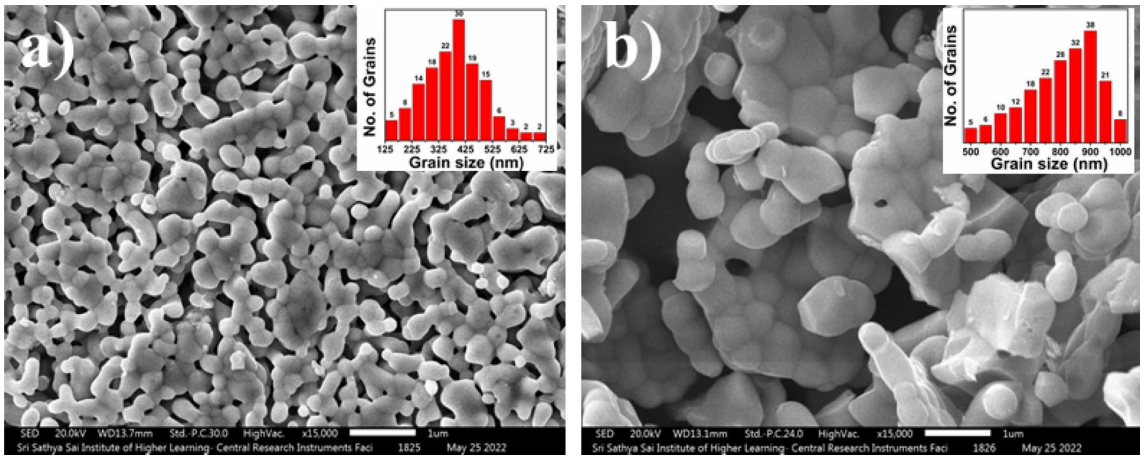

Fig. 12 SEM images of **a** YFO and **b** 0.5 wt% LKBO added YFO (insert shows the histogram of the particle size distribution of each sample)

and uniform-sized particles were observed through SEM and DLS techniques. The oxidation state of each element in YFO and 0.5 wt% LKBO added YFO was estimated using XPS analysis. YFOLKBO-0.50 sample shows the highest magnetization value (4.15 emu/g) and realistic coercive field (62.6 Oe) when compared to that of other samples under this study. Thus, these studies show that 0.5 wt% LKBO glasses added to YFO will be potential candidates for different applications.

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Author contributions

SAM: Sample preparation and their structural characterization and original draft preparation. DRSR: Conceptualization, Reviewing, and editing the manuscript.

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Data availability

The authors declare that all the data generated or analyzed during this study are included in this manuscript.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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References

1. N.A. Spaldin, Multiferroics: past, present, and future. MRS Bull. **42**, 385–390 (2009). https://doi.org/10.1557/mrs.2017.86
2. C.W. Nan, M.I. Bichurin, S. Dong, D. Viehland, G. Srinivasan, Multiferroic magnetoelectric composites: historical perspective, status, and future directions. J. Applied Phys. **103**, 031101 (2008). https://doi.org/10.1063/1.2836410
3. N. Suo, A. Sun, L. Yu et al., Effect of different rare earth (RE = Y^{3+}, Sm^{3+}, La^{3+}, and Yb^{3+}) ions doped on the magnetic properties of Ni–Cu–Co ferrite nanomagnetic materials. J. Mater. Sci. Mater. Electron. **32**, 246–264 (2021). https://doi.org/10.1007/s10854-020-04762-0
4. G. Jayakumar, A.A. Irudayaraj, A.D. Raj, S.J. Sundaram, K. Kaviyarasu, Electrical and magnetic properties of nanostructured Ni doped CeO_2 for optoelectronic applications. J. Phys. Chem. Solids **160**, 10369 (2022). https://doi.org/10.1016/j.jpcs.2021.110369
5. J. Mao, Y. Sui, X. Zhang, Y. Su, X. Wang, Z. Liu, Y. Wang, R. Zhu, Y. Wang, W. Liu, J. Tang, Temperature- and magnetic-field-induced magnetization reversal in perovskite $YFe_{0.5}Cr_{0.5}O_3$. Appl. Phys. Lett. **98**, 192510 (2011). https://doi.org/10.1063/1.3590714
6. H. Zahra, M. Rozita, A.D. Elmuez, S.-N. Masoud, $EuMnO_3$/$EuMn_2O_5$/MWCNT nanocomposites: insights into synthesis and application as potential materials for development of hydrogen storage capacity. Fuel **351**, 128885 (2023). https://doi.org/10.1016/j.fuel.2023.128885
7. S.-N. Masoud, G. Davood, D. Fatemeh, Shape selective hydrothermal synthesis of tin sulfide nanoflowers based on nanosheets in the presence of thioglycolic acid. J. Alloys Compd. **492**(1–2), 570–575 (2010). https://doi.org/10.1016/j.jallcom.2009.11.183
8. M. Rozita, G.-A. Maryam, S.-N. Masoud, Application of ultrasound-aided method for the synthesis of NdVO4 nanophotocatalyst and investigation of eliminate dye in contaminant water. Ultrason. Sonochem. **42**, 201–211 (2018). https://doi.org/10.1016/j.ultsonch.2017.11.025
9. A. Mahnaz, E. Khalil, S.-N. Masoud, Magnetically retrievable ferrite nanoparticles in the catalysis application. Adv. Coll. Interface Sci. **271**, 101982 (2019). https://doi.org/10.1016/j.cis.2019.07.003
10. A. Mahnaz, E. Khalil, S.-N. Masoud, Magnetically retrievable ferrite nanoparticles in the catalysis application. Mater. Res. Bull. **48**(4), 1660–1667 (2013). https://doi.org/10.1016/j.cis.2019.07.003
11. Z.-A. Sahar, B. Mahin, S.-N. Masoud, Enhanced visible-light-driven photocatalytic performance for degradation of organic contaminants using $PbWO_4$ nanostructure fabricated by a new, simple and green sonochemical approach. Ultrason. Sonochem. **72**, 105420 (2021). https://doi.org/10.1016/j.ultsonch.2020.105420
12. A. Mahnaz, S.-N. Masoud, A. Ahmad, G. Tahereh, Removal of malachite green (a toxic dye) from water by cobalt ferrite silica magnetic nanocomposite: herbal and green sol-gel autocombustion synthesis. Int. J. Hydrogen Energy **42**(39), 24846–24860 (2017). https://doi.org/10.1016/j.ijhydene.2017.08.077
13. S.-N. Masoud, D. Mahnaz, D. Fatemeh, Pure cubic ZrO_2 nanoparticles by thermolysis of a new precursor. Polyhedron **28**(14), 3005–3009 (2009). https://doi.org/10.1016/j.poly.2009.06.032

14. A. Sobhani-Nasab, S.M. Hosseinpour-Mashkani, M. Salavati-Niasari et al., Synthesis, characterization, and photovoltaic application of $NiTiO_3$ nanostructures via two-step sol–gel method. J. Mater. Sci. Mater. Electron. **26**, 5735–5742 (2015). https://doi.org/10.1007/s10854-015-3130-0
15. A. Sobhani-Nasab, S.M. Hosseinpour-Mashkani, M. Salavati-Niasari et al., Controlled synthesis of $CoTiO_3$ nanostructures via two-step sol–gel method in the presence of 1,3,5-benzenetricarboxylic acid. J. Clust. Sci. **26**, 1305–1318 (2015). https://doi.org/10.1007/s10876-014-0814-1
16. A. Sobhani-Nasab, Z. Zahraei, M. Akbari, M. Maddahfar, S.M. Hosseinpour-Mashkani, Synthesis, characterization, and antibacterial activities of $ZnLaFe_2O_4/NiTiO_3$ nanocomposite. J. Mol. Struct. **1139**, 430–435 (2017). https://doi.org/10.1016/j.molstruc.2017.03.069
17. R. Bhimireddi, B. Poonraj, K.B.R. Varma, Structural, optical, and piezoelectric response of lead-free $Ba_{0.95}Mg_{0.05}Zr_{0.1}Ti_{0.9}O_3$ Nanocrystalline Powder. J. Am. Ceram. Soc. **99**, 896–904 (2016). https://doi.org/10.1111/jace.14018
18. L. Dhavala, R. Bhimireddi, V.S. Muthukumar, V.S. Kollipara, K.B.R. Varma, Exceptional dielectric and varistor properties of Sr, Zn and Sn co-doped calcium copper titanate ceramics. RSC Adv. **13**, 10476–10487 (2023). https://doi.org/10.1039/D3RA00743J
19. N. Singh, J.Y. Rhee, S. Auluck, Electronic and magneto-optical properties of rare-earth orthoferrites $RFeO_3$ (R = Y, Sm, Eu, Gd and Lu). J. Korean Phys. Soc. **53**, 806–811 (2008). https://doi.org/10.3938/jkps.53.806
20. N.T.K. Chung, N.A. Tien, B.X. Vuong, Optical and magnetic properties of $YFeO_3$ nanoparticles synthesized by a co-precipitation method at high temperature. Chem. Pap. **76**, 923–930 (2022). https://doi.org/10.1007/s11696-021-01913-3
21. Y. Ma, M. Chen, Y.Q. Lin, Relaxorlike dielectric behavior and weak ferromagnetism in $YFeO_3$ ceramics. J. Appl. Phys. **103**, 124111 (2008). https://doi.org/10.1063/1.2947601
22. S. Madolappa, B. Ponraj, R. Bhimireddi, K.B.R. Varma, Enhanced magnetic and dielectric properties of Ti-doped $YFeO_3$ ceramics. J. Am. Ceram. Soc. **100**, 2641–2650 (2017). https://doi.org/10.1111/jace.14809
23. G. King, P.M. Woodward, Cation ordering in perovskites. J. Mater. Chem. **20**, 5785–5796 (2010). https://doi.org/10.1039/B926757C
24. V.G. Nair, A. Das, V. Subramanian, P.N. Santosh, Magnetic structure and magnetodielectric effect of $YFe_{0.5}Cr_{0.5}O_3$. J. Appl. Phys. **113**, 213907 (2013). https://doi.org/10.1063/1.4808459
25. X. Yuan, Y. Sun, M. Xu, Structure and magnetic properties of Y_{1-x} Lu_xFeO_3 ($0 \le x \le 1$) ceramics. J. Appl. Phys. **111**, 053911 (2012). https://doi.org/10.1063/1.3691243
26. W. Zhang, C. Fang, W. Yin, Y. Zeng, One-step synthesis of yttrium orthoferrite nanocrystals via sol–gel auto-combustion and their structural and magnetic characteristics. Mater. Chem. Phys. **137**, 877 (2013). https://doi.org/10.1016/j.matchemphys.2012.10.029
27. Y. Sui, F. Lu, X. Liu et al., A novel hexagonal $YFeO_3$ 3D nanomaterial with room temperature ferromagnetic properties prepared by self-assembling method. Res. Mater. **10**, 100186 (2021). https://doi.org/10.1016/j.rinma.2021.100186
28. P.S.J. Bharadwaj, V.S. Kollipar, Evaluating the structure-property correlation in $Y_{1-x}Nd_xFeO_3$ ($0 \le x \le 0.15$) perovskites. Ceram. Int. **47**, 30797–30806 (2021). https://doi.org/10.1016/j.ceramint.2021.07.260
29. T. Ahmad, I.H. Lone, S.G. Ansari, J. Ahmed, T. Ahamad, Multifunctional properties and applications of yttrium ferrite nanoparticles prepared by citrate precursor route. Mater. Des. **126**, 331–338 (2017). https://doi.org/10.1016/j.matdes.2017.04.034
30. P.S.J. Bharadwaj, S. Kundu, V.S. Kollipar, K.B.R. Varma, Structural, optical and magnetic properties of Sm^{3+} doped yttrium orthoferrite ($YFeO_3$) obtained by sol–gel synthesis route. J. Phys.: Condens. Matter. **32**, 035810 (2020). https://doi.org/10.1088/1361-648X/ab4845
31. D.H.T. Pham, L.T.T. Nguyen, V.O. Mittova et al., Structural, optical and magnetic properties of Sr and Ni co-doped $YFeO_3$ nanoparticles prepared by simple co-precipitation method. J. Mater. Sci. Mater. Electron. **33**, 14356–14367 (2022). https://doi.org/10.1007/s10854-022-08360-0
32. C. Venkatrao, D.R.S. Reddy, R. Bhimireddi, Optimization of sintering temperature for realizing enhanced magnetic properties of $YFeO_3$ ceramic derived from the sol-gel technique. J. Mater. Sci. Mater. Electron. **33**, 20731–20739 (2022). https://doi.org/10.1007/s10854-022-08883-6
33. Y. Li, Y. Ma, Z. Wang et al., Morphologically distinctive $YFeO_3$ with near-infrared reflection and ferromagnetic characteristics. J. Mater. Sci. Mater. Electron. **33**, 11318–11331 (2022). https://doi.org/10.1007/s10854-022-08105-z
34. V.I. Popkov, O.V. Almjasheva, A.S. Semenova, D.G. Kellerman, V.N. Nevedomskiy, V.V. Gusarov, Magnetic properties of $YFeO_3$ nanocrystals obtained by different soft-chemical methods. J. Mater. Sci.: Mater. Electron. **28**, 7163–7170 (2017). https://doi.org/10.1007/s10854-017-6676-1
35. A.T. Apostolov, I.N. Apostolova, J.M. Wesselinowa, Differences between the multiferroic properties of hexagonal and orthorhombic ion-doped $YFeO_3$ nanoparticles. Int. J.

Mod. Phys. B (2023). https://doi.org/10.1142/S0217979223502016

36. A. Apostolov, I. Apostolova, J. Wesselinowa, Multiferroic, phonon and optical properties of pure and ion-doped $YFeO_3$ nanoparticles. Nanomaterials **11**, 2731 (2021). https://doi.org/10.3390/nano11102731
37. A.T. Nguyen, H.D. Chau, T.T. Nguyen, V.O. Mittova, T.H. Do, I.Y. Mittova, Structural and magnetic properties of $YFe_{1-x}Co_xO_3$ ($0.1 \leq x \geq 0.5$) perovskite nanomaterials synthesized by co-precipitation method. Nanosyst. Phys. Chem. Math. **9**, 424–429 (2018). https://doi.org/10.17586/2220-8054-2018-9-3-424-429
38. W. Meng, W. Ting, Structural, magnetic and optical properties of Gd and Co Co-Doped $YFeO_3$ nanopowders. Materials **12**, 2423 (2019). https://doi.org/10.3390/ma12152423
39. J. Lingxian, J. Guojian, W. Dandan, C. Jianbin, Study on the influence of ion doping on the crystal structure and magnetic properties of $YFeO_3$. Mater. Res. Express **7**, 066103 (2020). https://doi.org/10.1088/2053-1591/ab9c5f
40. C. Venkatrao, D.R.S. Reddy, R. Bhimireddi, Optimization of better chelating agent to attain optimal physical properties of $YFeO_3$ nanomaterials obtained via sol–gel technique. J. Mater. Sci. Mater. Electron. **34**, 302 (2023). https://doi.org/10.1007/s10854-022-09691-8
41. M. Ahmadipour, M. Arjmand, A.Y. Le, S.L. Chiam, Z.A. Ahmad, S.-W. Pung, Effects of multiwall carbon nanotubes on dielectric and mechanical properties of $CaCu_3Ti_4O_{12}$ composite. Ceram. Int. **46**, 20313–20319 (2020). https://doi.org/10.1016/j.ceramint.2020.05.119
42. A. Goktas, Role of simultaneous substitution of Cu^{2+} and Mn^{2+} in ZnS thin films: defects-induced enhanced room temperature ferromagnetism and photoluminescence. Physica E **117**, 113828 (2020). https://doi.org/10.1016/j.physe.2019.113828
43. F. Mikailzade, H. Türkan, F. Önal, M. Zarbali, A. Göktaş, A. Tumbul, Structural and magnetic properties of polycrystalline $Zn_{1-x}Mn_xO$ films synthesized on glass and p-type Si substrates using sol–gel technique. Appl. Phys. A **127**, 408 (2021). https://doi.org/10.1007/s00339-021-04519-4
44. M. Wang, T. Wanga, S.H. Song, M. Ravia, R.C. Liu, S.S. Ji, Effect of calcination temperature on structural, magnetic and optical properties of multiferroic $YFeO_3$ nanopowders synthesized by a low temperature solid-state reaction. Ceram. Int. **43**, 10270 (2017). https://doi.org/10.1016/j.ceramint.2017.05.056
45. S.H. Wemple, Polarization fluctuations and the optical-absorption edge in $BaTiO_3$. Phys. Rev. B **2**, 2679–2689 (1970). https://doi.org/10.1103/PhysRevB.2.2679
46. D. Redfield, W.J. Burke, Optical absorption edge of $LiNbO_3$. J. Appl. Phys. **45**, 4566–4571 (1974). https://doi.org/10.1063/1.1663089
47. C. Suchomski, C. Reitz, K. Brezesinski et al., Structural, optical, and magnetic properties ofhighly ordered mesoporous MCr_2O_4 and $MCr_{2-x}Fe_xO_4$ (M = Co, Zn) spinel thin filmswith uniform 15 nm diameter pores and tunable nanocrystalline domain sizes. Chem. Mater. **24**, 155–165 (2012). https://doi.org/10.1021/cm2026043
48. S.R. Basu, L.W. Martin, Y.H. Chu et al., Photoconductivity in $BiFeO_3$ thin films. Appl. Phys. Lett. **92**, 091905 (2008). https://doi.org/10.1063/1.2887908
49. M. Ahmadipour, M. Arjmand, M.F. Ain, Z.A. Ahmad, S.-W. Pung, Effect of Ar:N_2 flow rate on morphology, optical and electrical properties of CCTO thin films deposited by RF magnetron sputtering. Ceram. Int. **45**, 15077–15081 (2019). https://doi.org/10.1016/j.ceramint.2019.04.245
50. B.S. Nagrare, S.S. Kekade, B. Thombare, R.V. Reddy, S.I. Patil, Hyperfine interaction, Raman and magnetic study of $YFeO_3$ nanocrystals. Solid State Commun. **280**, 32–38 (2018). https://doi.org/10.1016/j.ssc.2018.06.004
51. Y. Ma, M. Chen, Y.Q. Lin, Relaxorlike dielectric behavior and weak ferromagnetism in $YFeO_3$ ceramics. J. Appl. Phys. **103**, 124111 (2008). https://doi.org/10.1063/1.2947601
52. B. Deka, S. Ravi, A. Perumal, D. Pamu, Effect of Mn doping on magnetic and dielectric properties of $YFeO_3$. Ceram. Int. **43**, 1323–1334 (2017). https://doi.org/10.1016/j.ceramint.2016.10.087
53. L. Wu, J.C. Yu, L. Zhang, X. Wang, S. Li, Selective self-propagating combustion synthesis of hexagonal and orthorhombic nanocrystalline yttrium iron oxide. J. Solid State Chem. **177**, 3666–3674 (2004). https://doi.org/10.1016/j.jssc.2004.06.020
54. J.H. Jung, M. Matsubara, T. Arima, J.P. He, Y. Kaneko, Y. Tokura, Optical magnetoelectric effect in the polar $GaFeO_3$ ferrimagnet. Phys. Rev. Lett. **93**, 037403 (2004). https://doi.org/10.1103/PhysRevLett.93.037403
55. P. Kubelka, Errata: new contributions to the optics of intensely light-scattering materials, part I. J. Opt. Soc. Am. **38**, 448–457 (1948). https://doi.org/10.1364/JOSA.38.000448
56. M. Ahmadipour, C.W. Kian, M.F. Ain, K.V. Rao, Z.A. Ahmad, Effects of deposition temperatures and substrates on microstructure and optical properties of sputtered CCTO thin film. Mater. Lett. **210**, 4–7 (2018). https://doi.org/10.1016/j.matlet.2017.08.121
57. F.S. Al-Hazmi, A.A. Al-Ghamdi, L.M. Bronstein, L.S. Memesh, F.S. Shokr, M. Hafez, The influence of sintering temperature on the structure, optical and magnetic

properties of Yttrium iron oxide $YFeO_3$ prepared via Lα-alanine assisted combustion method. Ceram. Int. **43**, 8133–8138 (2017). https://doi.org/10.1016/j.ceramint.2017.03.137

58. P.S.J. Bharadwaj, S. Kundu, V.S. Kollipar, K.B.R. Varma, Synergistic effect of trivalent ($Gd3^+$, Sm^{3+}) and highvalent (Ti^{4+}) co-doping on antiferromagnetic $YFeO_3$. RSC Adv. **10**, 22183–22195 (2020). https://doi.org/10.1039/D0RA02532A
59. M.V. Berezhnaya, O.V. Almyasheva, V.O. Mittova, A.T. Nguen, I.Y. Mittova, Sol–gel synthesis and properties of $Y_{1-x}Ba_xFeO_3$ nanocrystals. Russ. J. Gen. Chem. **88**, 626–631 (2018). https://doi.org/10.1134/S1070363218040035
60. N.A. Tien, O.V. Almjasheva, I.Y. Mittova, O.V. Stognei, S.A. Soldatenko, Synthesis and magnetic properties of $YFeO_3$ nanocrystals. Inorg. Mater. **45**, 1304–1308 (2009). https://doi.org/10.1134/S0020168509110211
61. C. Venkatrao, D.R.S. Reddy, K.R. Kandula, R. Bhimireddi, Grain size-dependent structural, optical, dielectric, and magnetic properties of $YFeO_3$ nanomaterials obtained by the sol–gel technique using tartaric acid as a chelating agent. Phys. Status Solidi B **260**, 2200272 (2023). https://doi.org/10.1002/pssb.202200272
62. Y. Liao, F. Xu, D. Zhang, Z. Li, T. Zhou, X. Wang, L. Jia, H. Zhang, Effect of $ZnO–B_2O_3–SiO_2$ glass additive on magnetic properties of low-sintering $Li_{0.43}Zn_{0.27}Ti_{0.13}Fe_{2.17}O_4$ ferrites. J. Mater. Sci.: Mater. Electron. **27**, 811–817 (2016). https://doi.org/10.1007/s10854-015-3821-6

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ENHANCING SECURITY IN THE INTERNET OF THINGS (IOT): CHALLENGES AND SOLUTIONS

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Abstract:

The rapid proliferation of Internet of Things (IoT) devices has ushered in a new era of connectivity, promising transformative benefits across various domains. However, this growth has also given rise to formidable security challenges that must be addressed to unlock the full potential of IoT. This paper presents a comprehensive exploration of the multifaceted security challenges inherent in the IoT ecosystem.The paper subsequently uncover the vulnerabilities commonly found in IoT devices, underscoring the critical importance of strong authentication, encryption, and secure firmware management. Real-world case studies illustrate the consequences of these vulnerabilities, shedding light on the tangible impact of security lapses.It offers an in- depth analysis of security solutions and best practices for mitigating IoT security risks, addressing the roles of encryption, authentication, and security-by-design principles and explore the regulatory and compliance frameworks that govern IoT security, emphasizing their role in establishing baseline security requirements. Through an exploration of emerging trends, including the integration of edge computing, 5G connectivity, and artificial intelligence, it provide a forward-looking perspective on the evolving IoT security landscape.

Keywords: Multifaceted Security Challenges In the IOT, Iot Security Risks, Edge Computing.

1. Introduction:

The Internet of Things (IoT) has emerged as a transformative technological paradigm, ushering in an era where everyday objects are connected to the internet, enabling them to communicate, collect, and exchange data. This interconnectedness has the potential to revolutionize industries, improve efficiency, and enhance the quality of life. However, this rapid proliferation of IoT devices has also given rise to a host of security challenges that must be addressed to realize the full potential of this technology. The growth of IoT has been staggering.

According to industry reports, there were over 30 billion connected IoT devices in 2020, and this number is projected to reach 75 billion by 2025. This exponential growth, while promising, raises significant concerns about the security of these devices and the data they handle. As IoT devices become increasingly integrated into our daily lives and critical infrastructure, the need for robust security measures becomes paramount.This paper aims to delve into the multifaceted security challenges facing the IoT ecosystem. It explores the various threats that IoT devices and networks are susceptible to, delves into the vulnerabilities inherent in IoT device design, discusses security solutions and best practices, examines regulatory and compliance frameworks, presents real-world case studies of IoT security breaches, and looks ahead to emerging trends in IoT security.

2. Background

The roots of IoT can be traced back to the early days of the internet when researchers envisioned a world where devices could communicate and share data seamlessly. The concept has since evolved into a reality, driven by advancements in connectivity, miniaturization of sensors, and the availability of low-cost hardware.
IoT has found applications across various domains, including healthcare, transportation, agriculture, and smart cities. For instance, in healthcare, IoT-enabled wearable devices can continuously monitor vital signs, providing real-time data to healthcare professionals and enabling early intervention. In agriculture, IoT sensors can monitor soil conditions, weather


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patterns, and crop health, optimizing crop yields and resource utilization.As IoT continues to grow, it is poised to play a crucial role in Industry 4.0, where automation and data-driven decision-making are central. Smart factories, for example, leverage IoT to improve manufacturing efficiency, reduce downtime, and enhance product quality.

3. IoT Security Threats

IoT security threats are diverse and constantly evolving, posing significant risks to individuals, organizations, and critical infrastructure. One of the most prevalent threats is the proliferation of IoT-specific malware and botnets. These malicious software entities target vulnerable devices, turning them into a network of compromised devices that can be harnessed for various malicious activities, such as launching Distributed Denial of Service (DDoS) attacks or stealing sensitive data.

Data breaches and privacy violations are also major concerns. IoT devices often collect and transmit personal or sensitive data, making them attractive targets for cybercriminals. Unauthorized access to such data can result in identity theft, financial losses, and reputational damage.Physical attacks on IoT devices cannot be overlooked either. As these devices become embedded in critical infrastructure, physical tampering or tampering with firmware can have far-reaching consequences, including disrupting essential services or compromising public safety. The scale and impact of these threats are substantial. Recent studies indicate that a significant percentage of IoT devices are vulnerable to attack, with a majority of them lacking basic security features.

4. Vulnerabilities in IoT Devices

IoT device vulnerabilities often stem from inadequate security practices during the design and manufacturing phases. One common issue is the use of weak or default credentials. Many IoT devices ship

default usernames and passwords that are rarely changed by end-users, creating an easy entry point for attackers. Manufacturers must implement strong authentication mechanisms and enforce password changes to mitigate this risk.

Another critical vulnerability is the lack of end-to-end encryption. Data transmitted between IoT devices and the cloud is often inadequately protected, making it susceptible to interception and tampering. Robust encryption protocols such as Transport Layer Security (TLS) must be implemented to secure data in transit.

Additionally, firmware updates and patch management are often neglected, leaving devices with known vulnerabilities unpatched. Manufacturers must establish mechanisms for delivering timely updates and patches to IoT devices throughout their lifecycle. Real-world case studies further illustrate the consequences of these vulnerabilities. Notable incidents include the Mirai botnet attack in 2016, which harnessed compromised IoT devices to launch massive DDoS attacks, and the Stuxnet worm, which targeted industrial control systems.

5. Security Solutions and Best Practices

Securing IoT devices and networks requires a multi-pronged approach involving device manufacturers, service providers, and end-users. Strong encryption, authentication, and access control mechanisms are fundamental components of IoT security.

Encryption safeguards data at rest and in transit, preventing unauthorized access. Modern cryptographic algorithms like Advanced Encryption Standard (AES) and secure key management are essential for protecting data integrity and confidentiality.

Authentication mechanisms, such as two-factor authentication (2FA) and biometrics, ensure that only authorized users can access IoT devices and systems. 2FA adds an extra layer of security by requiring users to provide two forms of identification.


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Security-by-design principles should guide IoT device manufacturers. This entails incorporating security features and best practices into the design and development process from the outset. Security assessments and penetration testing should be conducted regularly to identify and address vulnerabilities. Ongoing monitoring and incident response are critical. Security teams should continuously monitor IoT device behavior for anomalies, signifying potential breaches. Rapid response procedures should be in place to mitigate threats and limit damage in case of an incident. End-users also play a vital role in IoT security. They must change default passwords, keep devices updated with the latest firmware and security patches, and use strong, unique passwords. Education and awareness campaigns can empower users to take these actions.

6. Regulatory and Compliance Frameworks

Recognizing the growing importance of IoT security, governments and industry bodies have introduced regulatory frameworks and standards to establish baseline security requirements for IoT devices and services. These regulations are designed to ensure that manufacturers prioritize security in their products and that consumers can trust the devices they use. In the United States, for example, the Cyber security Improvement Act of 2020 establishes guidelines for federal agencies to procure and deploy IoT devices with a focus on security. The European Union's Cyber security Act and GDPR (General Data Protection Regulation) also have implications for IoT security, requiring stringent data protection and security measures. Industry standards such as the IoT Cyber security Improvement Act of 2020 and ISO/IEC 27001 provide guidance and certification processes that IoT manufacturers can follow to demonstrate their commitment to security. Compliance with these standards not only enhances security but also builds consumer trust.

7. Case Studies

Real-world case studies offer valuable insights into the consequences of IoT security failures. These incidents underscore the urgency of addressing IoT security challenges. One notable case study is the 2016 Mirai botnet attack. Mirai malware infected hundreds of thousands of IoT devices, including cameras and routers, turning them into a powerful botnet that launched massive DDoS attacks. These attacks disrupted internet services for millions of users and exposed the vulnerability of IoT devices with default credentials.

Another significant incident involved a casino's high-roller database being breached through an IoT- connected fish tank thermometer. The attacker exploited a vulnerability in the IoT device to gain access to the casino's network, ultimately compromising sensitive customer data. This case demonstrates the unexpected entry points and potential consequences of IoT security breaches.

In the healthcare sector, a case study involving a connected medical device serves as a stark reminder of the risks. In this instance, an insulin pump was compromised by an attacker who gained unauthorized access. The attacker could have potentially manipulated insulin dosages, putting the patient's life at risk. These case studies highlight the wide-ranging impact of IoT security breaches, ranging from service disruptions to privacy violations and even life-threatening situations. They underscore the critical need for robust security measures and proactive risk management in the IoT ecosystem.

8. Future Trends and Conclusion

As the IoT landscape continues to evolve, several emerging trends and challenges warrant attention from stakeholders:

- Edge Computing: The proliferation of edge computing in IoT architectures will bring computation closer to IoT devices. While this enhances real-time processing and reduces latency, it also introduces new security concerns, including the need to secure edge nodes.

- 5G Connectivity: The deployment of 5G networks will further accelerate IoT adoption. However, it also expands the attack surface, requiring enhanced security measures to protect the increased volume of data transmitted over high-speed connections.

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• Artificial Intelligence (AI) and Machine Learning (ML): AI and ML are being increasingly integrated into IoT devices for predictive maintenance, anomaly detection, and automation. However, these technologies also introduce vulnerabilities that can be exploited by malicious actors.

In conclusion, the security challenges in the Internet of Things are multifaceted and ever-evolving. The exponential growth of IoT devices demands a proactive and comprehensive approach to security. Manufacturers must prioritize security-by-design, governments and industry bodies must enact and enforce regulations, and end-users must be educated about IoT security best practices.

The consequences of IoT security breaches are substantial, affecting not only individual privacy and financial well-being but also public safety and critical infrastructure. However, with concerted efforts and continued research and innovation in IoT security, we can harness the full potential of this transformative technology while minimizing the associated risks. This research paper has explored the landscape of IoT security challenges, delving into threats, vulnerabilities, solutions, regulatory frameworks, case studies, and future trends. It is our hope that this paper serves as a valuable resource for policymakers, manufacturers, security professionals, and all those vested in securing the IoT ecosystem for a safer and more connected future.

References

1. “Security and Privacy Concerns of the 'Internet of Things' (IoT) in IT and its Help in the Various Sectors across the World”,International Journal of Computer Trends and Technology (IJCTT) – Volume 68 Issue 4 – April 2020.
2. “IoT Security Study”, International Journal of Engineering Research & Technology (IJERT)
3. “IoT Privacy and Security: Challenges and Solutions”,Appl. Sci. 2020, 10(12), 4102; https://doi.org/10.3390/app10124102
4. “Security on Internet of Things (IOT) with Challenges and Countermeasures” International Journal of Engineering Development and Research, Volume 5, Issue 1.
5. “Baseline Security Recommendations for IoT in the context of Critical Information Infrastructures”, European Union Agency For Network And Information Security.

CUSTOMERS ATTITUDE TOWARDS BANKING SERVICES --- A STUDY ON SELECTED BANKING ORGANIZATIONS IN KRISHNA DISTRICT OF ANDHRA PRADESH

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ABSTRACT

Core Banking is normally the business conducted by a banking institution with its retail and small business customers. Core banking basically is depositing and lending of money. The core banking services in the present day scenario comprises the digitalized and electronic banking transactions. The present study examines the attitude of the customers towards the core banking services offered by the selected banking organizations and it assess the rating scores offered by the customers towards the core banking services in the selected banking organizations. The study further evaluates the relationship between the demographic factors of the customers and their rating scores towards core banking services. The present research study adopts Descriptive Research Design . Both the primary and secondary data sources will be utilized by the researcher in order to draw conclusions from the findings of this study. Primary data will be collected from the selected sample respondents through interview schedule method. The sampling units identified for the present study involves four banking organizations comprising both public and private sector banking organizations located in the Krishna District of Andhra Pradesh and the sample respondents comprises the customers of the selected banking organizations. Two public sectors and two private sector banking organizations were identified as the study units. Selective Random Sampling Technique was applied in order to draw the sample respondents from the identified sampling units in the study area. The sample size fixed for this study purpose was 120 from the selected four public and private banking organizations in the study area. In order to draw the statistical inferences from the data analysis, statistical tools like percentage, Rank score and t-test were applied. The study concludes that the customers are having very high attitude towards the core banking services offered by the selected banking organizations. The study further concludes that there exists a significant relationship between the demographic profile of the respondents and their rating towards the core banking services in the selected banking organizations.

Key Words: Customer, Attitude, Satisfaction level, Core Banking Services

INTRODUCTION

An attitude can be defined as a positive or negative evaluation of people, objects, event, activities, ideas, or just about anything in your environment, but there is debate about precise definitions. Eagly and Chaiken, for example, define an attitude "a psychological tendency that is expressed by evaluating a particular entity with some degree of favor or disfavor."Core banking is the services provided by a group of networked bank branches.

Bank customers may access their funds and other simple transactions from any of the member branch offices. Core Banking is normally the business conducted by a banking institution with its retail and small business customers. Many banks treat the retail customers as their core banking customers, and have a separate line of business to manage small businesses. Larger businesses are managed via the Corporate Banking division of the institution. Core banking basically is depositing and lending of money.

The core banking services in the present day scenario comprises the digitalized and electronic banking transactions comprising national electronic fund transfer, real time gross settlement, electronic clearance service, cheque collection, cheque transaction, clearing, SMS banking, ATMs, internet banking , payment of dividends and utility bills etc,. The present study aims at analyzing the attitude of the customers towards the core banking services offered by the selected public and private sector banking organizations in the Krishna district of Andhra Pradesh.

REVIEW OF LITERATURE

Fozia, M. (2013), The aim of this paper is to determine the customer's perception toward the ebanking services. 196 customers were engaged for the study to derive the conclusions.. Analysis of variance technique is used to study the significant relationship between the occupation and customer perception of e-banking services and significant relationship between the age and customer perception of E-Banking services. The result of the study shows that diverse age group of customer and different occupation group of customers have dissimilar perception toward the e-

banking services. The results also show that the demographic factors have a significant impact on online banking behaviour, especially work and age. Finally, this article suggests that understanding customer perceptions of e-banking in commercial and private banks will help bankers better understand their customers needs.

Surabhi Singh (2017), he examines in his study that, the present examination was intentional with the objective to assess the degree of use of services especially the IT enabled services in these banks and to analyse the component factors affecting client satisfaction with the quality of services. The study was conducted in public, private and foreign banks of Delhi. Multistage random sampling is used for sampling. It was proposed to conduct the study in five areas of Delhi such ass East, West, North, South and Central Delhi in Delhi. One of the above bank branches in each region of Delhi will be randomly selected. While choosing a branch, we pay attention to provision of at least 5 IT support services. This step is compared to Intra Bank. Survey shows that the clients of nationalized banks are dissatisfied with the behaviour and infrastructure of their employees, while respondents of private and foreign banks are dissatisfied with high prices, accessibility and communication.

Sawanth K (2016), This study was assumed by customers of two local and foreign banks in Oman. An effort has been made to learn and analyse the important factors affecting the service quality of banks in Oman. The major discoveries of the study are the level of customer satisfaction of local banks is better than the foreign banks in Oman. The eminence of service provided by local banks is better than foreign banks.

Madhava K (2020), A try has been made by evaluating the services concentrated by banks through the e-banking services. The e-banking service carries lot of convenience, customer centricity, increased service quality and cost effectiveness. This paper scrutinizes the patron satisfaction on the Electronic Banking Services of Public Sector and Private Sector Banks in Puducherry Region. The model size of the study is 478, the data is assembled from both the primary and secondary information. The outcome of the learning shows that customers of Public Sector Banks have lesser perception of the various dimensions of eservice quality compared

with the private sector Banks. This paper recommends that the wider use of ICT based applications in banking services will make better banking solutions.

Yogeswaran G (2015), this study was undertaken on topic customer perception towards amenities provided by public sector and private banks- A comparative study. The services of ICICI Bank and SBI Banks are taken into consideration. According to this study, public sector banks face tough competition from private sector banks for the quality of their services. Public sector banks should focus on providing their clients with up-to-date information on the new services they provide. The study also reveals that, public sector banks need to change their policies, customer service standards and service efficiency.

Dhar K Ravi (2009), this study focuses on the opportunities and perceptions of customers for the quality of banking services in the public and private sectors. The study also identifies two factors that influence customer expectations and perceptions of the quality of banking services. Samples were collected from 400 Madhya Pradesh clients in India. As a result, it can be seen that there is a big difference between the expectations of the clients of commercial and private banks. The results also highlight a significant difference between in the perception of clients by public and private banks. The study also states that, public sector banks must focus on narrowing differences in perceptions of customer expectations and quality of service in order to compete in international markets.

OBJECTIVES OF STUDY

1. To analyze the attitude of the customers towards the core banking services offered by the selected banking organizations.

2. To assess the rating scores offered by the customers towards the core banking services in the selected banking organizations

3. To analyze the relationship between the demographic factors of the customers and their rating scores towards core banking services.

HYPOTHESES

In order to test the mentioned research objectives in the present study, the following Null-hypothesis was proposed and tested for its statistical significance.

Ho1 : There exists no significant relationship between the demographic profile of the respondents and their rating towards the core banking services in the selected banking organizations.

RESEARCH METHODOLOGY

The present research study adopts Descriptive Research Design . Both the primary and secondary data sources will be utilized by the researcher in order to draw conclusions from the findings of this study. Primary data will be collected from the selected sample respondents through interview schedule method and secondary data sources will be gathered from the Reports, Journals , Magazines and other published material pertaining to the research topic.

The sampling units identified for the present study involves four banking organizations comprising both public and private sector banking organizations located in the Krishna District of Andhra Pradesh and the sample respondents comprises the customers of the selected banking organizations. Two public sector banking organizations namely State Bank of India and Indian Bank and two private sector banking organizations namely Axis Bank and ICICI were identified as the study units.

Selective Random Sampling Technique was applied in order to draw the sample respondents from the identified sampling units in the study area. 30 customers from each selected banking organization were identified as the sample respondents and hence, the sample size fixed for this study purpose was 120 from the selected four public and private banking organizations in the study area. In order to draw the statistical inferences from the data analysis, statistical tools like percentage, Rank score and t-test were applied.

DATA ANALYSIS AND INTERPRETATION

Table No.1

Customer attitude towards core banking services in the selected organizations

Demographic factors	Very High	High	Moderate	Low	Very low	Total	Rank
Age	43	47	10	18	2	120	II
Education	49	40	16	9	6	120	I
Occupation	44	40	13	18	5	120	IV
Income	45	41	10	21	3	120	III
Social factor	5	6	31	59	19	120	X
Type of accounts	20	42	31	24	3	120	VI
Expenditure	18	21	28	48	5	120	VII
Encouragement	10	12	26	60	12	120	IX
Awareness about services	41	38	18	20	3	120	V
Savings	15	11	31	58	5	120	VIII
Family status	5	3	28	65	19	120	XI

Source : Primary Data

The table no.1 shows the Customer attitude towards core banking services in the selected organizations. It shows that with regard to the demographic factor of age, majority of the respondents are having high attitude followed by the respondents with very high attitude towards core banking services in the selected organizations. The table further shows that with regard to the demographic factor of education, majority of the respondents are having very high attitude followed by the respondents with high attitude towards core banking services in the selected organizations.

The table depicts that with regard to the demographic factor of occupation, majority of the respondents are having very high attitude followed by the respondents with high attitude towards core banking services in the selected organizations. The table further denotes that with regard to the demographic factor of

income, majority of the respondents are having very high attitude followed by the respondents with high attitude towards core banking services in the selected organizations.

The table denotes that with regard to the demographic aspect of social factor, majority of the respondents are having low attitude followed by the respondents with very low attitude towards core banking services in the selected organizations. The table further shows that with regard to the demographic factor of type of accounts, majority of the respondents are having high attitude followed by the respondents with low attitude towards core banking services in the selected organizations.

The table depicts that with regard to the demographic factor of expenditure, majority of the respondents are having low attitude followed by the respondents with high attitude towards core banking services in the selected organizations. The table further denotes that with regard to the demographic factor of encouragement, majority of the respondents are having low attitude followed by the respondents with very low attitude towards core banking services in the selected organizations.

The table denotes that with regard to the demographic aspect of awareness about services, majority of the respondents are having very high attitude followed by the respondents with high attitude towards core banking services in the selected organizations. The table further shows that with regard to the demographic factor of savings, majority of the respondents are having low attitude followed by the respondents with very high attitude towards core banking services in the selected organizations.

The table depicts that with regard to the demographic factor of the family status, majority of the respondents are having low attitude followed by the respondents with very low attitude towards core banking services in the selected organizations.

Verification of Hypothesis- Ho1

Ho1 : There exists no significant relationship between the demographic profile of the respondents and their rating towards the core banking services in the selected banking organizations.

Test applied : t- test

Table No.2

Relationship between Demographic factors of the customers and their Rating towards core banking services

Sl.No	Demographic factors	t-value	Significant (2-tailed) at 0.05 level of significance
1	Age	75.196	0.000
2	Education	72.482	0.000
3	Occupation	66.159	0.000
4	Income	69.032	0.000
5	Social factor	53.614	0.000
6	Type of accounts	68.972	0.000
7	Expenditure	59.729	0.000
8	Encouragement	52.138	0.000
9	Awareness about services	69.564	0.000
10	Savings	57.295	0.000
11	Family status	53.467	0.000

Source : Computed

The table no.2 shows the relationship between Demographic factors of the customers and their Rating towards core banking services. It shows that all the identified demographic factors were found to be statistically significant at 0.05 level of significance. Thus, the proposed null hypothesis (Ho1) is rejected.

MAJOR FINDINGS

- The result shows that with regard to the demographic factors of age, education, occupation, income, type of accounts and awareness about

services, the respondent customers are having very high attitude towards the core banking services offered by the selected banking organizations in the study area.

- The result denotes that with regard to the demographic factors of the customers like social factors, expenditure, encouragement, savings and family status, the respondent customers are having low attitude towards the core banking services.

- The result depicts that the customers had ranked the demographic factors of education, age, income and occupation in the priority of first, second , third and fourth rank orders respectively.

- The t-test result shows that all the identified demographic factors are significant at 0.05 level of significance. Hence, the proposed null hypothesis (Ho1) stands rejected. Thus, it can be inferred that there exists a significant relationship between the demographic profile of the respondents and their rating towards the core banking services in the selected banking organizations.

CONCLUSION AND SUGGESTIONS

The present study examines the attitude of the customers towards the core banking services offered by the selected banking organizations and it assess the rating scores offered by the customers towards the core banking services in the selected banking organizations. The study further evaluates the relationship between the demographic factors of the customers and their rating scores towards core banking services.

The study concludes that the customers are having very high attitude towards the core banking services offered by the selected banking organizations. The study further concludes that there exists a significant relationship between the demographic profile of the respondents and their rating towards the core banking services in the selected banking organizations. The banking organizations shall extend their customer service departments and grievance redressal mechanism in order to safe guard the interest of their customers.

REFERENCES

- Dhar K Ravi. (2009). Service quality expectations and perceptions of public and private sector banks in India- A Comparative Study. Indore Management Journal, 19(3), 34- 39.

- Fozia, M. (2013). A comparative study of customers' perception towards E-banking services provided by selected private & public sector bank in India. *International Journal of Scientific and Research Publications*, 3(9), 1-5.

- Madavan, K., & Vethirajan, C. (2020). Customer Satisfaction on E-Banking Services of Public and Private Sector Banks in Puducherry Region-An Empirical Analysis. *International Journal of Management (IJM),* 11(6).

- Sawant, K.B. (2016). A comparative study of factors affecting service quality and level of customer satisfaction in Local and Foreign banks in Oman. *Journal of Banking and Finance Management, 2(2), 2016, pp.20-24*

- Singh, S., & Arora, R. (2011). A comparative study of banking services and customer satisfaction in public, private and foreign banks. *Journal of Economics*, 2(1), 45-56.

- Sowmya. K (2017), "Challenges faced by the employees towards E-Banking services, study with reference to ICICI Bank of Mangalore City", *International Research journal of management and commerce*.

- Yogeswaran G. (2015). Customer perception towards services provided by public sector and private sector banks- A Comparative study. *Global Journal of Commerce and Management Perspective*, 4(1), 68-74.

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L-hypergeometric functions on fuzzy lie groups

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Abstract
This research paper explores the integration of L-hypergeometric functions with fuzzy Lie groups. We construct L-hypergeometric functions on fuzzy Lie groups and investigate their properties, providing numerical examples and visualizations to illustrate key concepts.

Keywords: L-hypergeometric functions, fuzzy lie groups, integrations

1. Introduction
Fuzzy set theory, introduced by Zadeh in 1965 [1], has provided a framework for dealing with imprecision in many real-world problems. This paper focuses on extending Lie group theory into the fuzzy domain, specifically investigating L-hypergeometric functions on fuzzy Lie groups.

2. Preliminaries
2.1 Fuzzy Lie Groups
Definition 1 A fuzzy Lie group $\widetilde{G}$ is a group G equipped with a fuzzy set structure that satisfies the group axioms to a degree defined by membership functions [2].

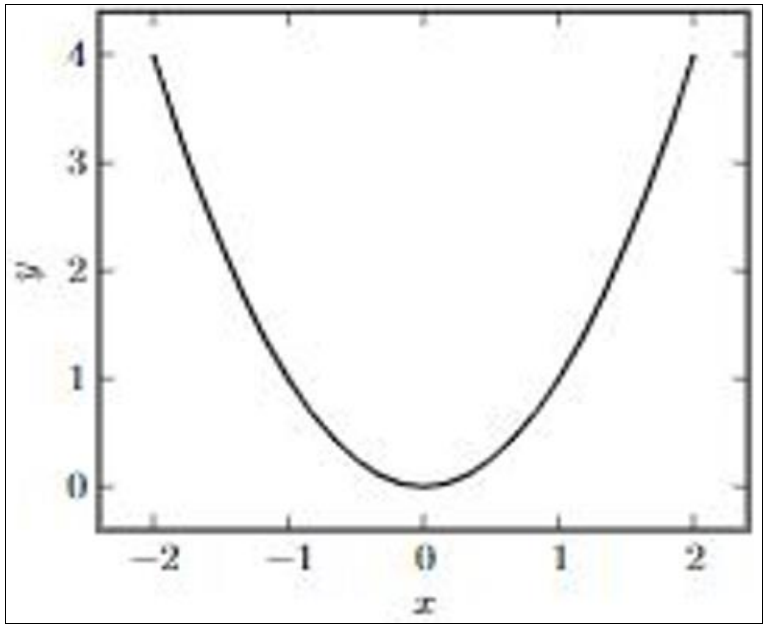

Fig 1: Membership function of a fuzzy Lie group element

2.2 L-Hypergeometric Functions
Definition 2 L-hypergeometric functions are generalizations of classical hypergeometric functions, defined by the differential equation [3]:

$$x(1-x)\frac{d^2y}{dx^2}+[c-(a+b+1)x]\frac{dy}{dx}-aby=0$$

where a, b, and c are complex parameters, and L is a linear differential operator.

3. L-Hypergeometric Functions on Fuzzy Lie Groups

3.1 Construction

We construct L-hypergeometric functions on fuzzy Lie groups by defining differential operators that act on fuzzy manifolds and satisfy fuzzy analogues of the classical L-hypergeometric equations.

Example 1 (Fuzzy L-Hypergeometric Function) Consider a fuzzy L-hypergeometric function defined on a fuzzy Lie group $\tilde{G}$:

$$\phi(x) = {}_2F_1(\tilde{a},\tilde{b};\tilde{c};x) = \sum_{n=0}^{\infty}\frac{(\tilde{a})_n(\tilde{b})_n}{(\tilde{c})_n}\frac{x^n}{n!}$$

where $\tilde{a}$, $\tilde{b}$, and $\tilde{c}$ are fuzzy parameters.

For numerical computation, let's use crisp values: $\tilde{a}=0.5, \tilde{b}=1.5, \tilde{c}=2.0$

We can compute the first few terms:

$$\phi(x) \approx 1+\frac{0.5\cdot 1.5}{2.0}x+\frac{0.5\cdot 1.5\cdot 1.5\cdot 2.5}{2.0\cdot 3.0}\frac{x^2}{2!}+\cdots$$

$$\approx 1+0.375x+0.234375x^2+\cdots$$

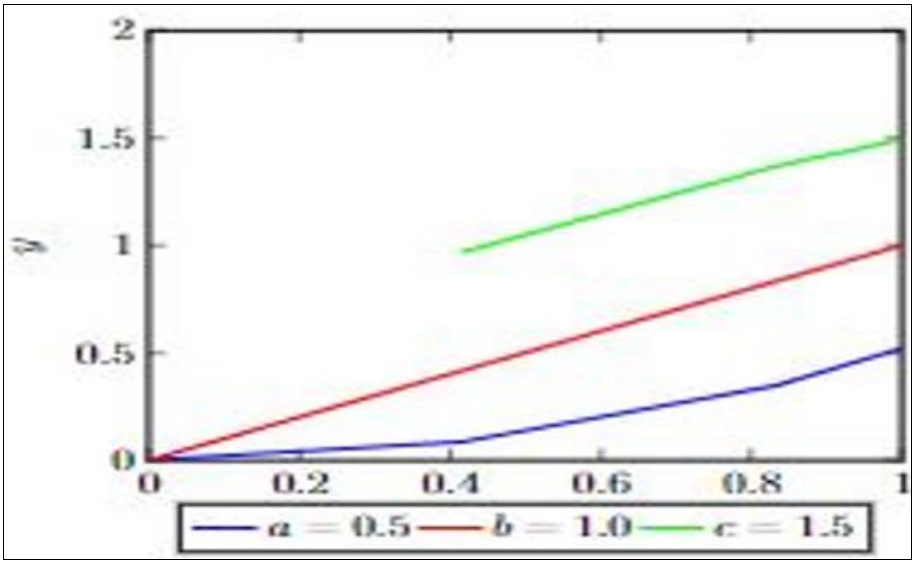

Fig 2: Fuzzy L-hypergeometric functions for different parameter values

3.2 Properties

Theorem 1 (Orthogonality) The fuzzy L-hypergeometric functions $\phi_m(x)$ and $\phi_n(x)$ are orthogonal with respect to a suitable inner product on $\tilde{G}$.

Proof

Let $\phi_m(x)$ and $\phi_n(x)$ be the fuzzy L-hypergeometric functions. We aim to show that these functions are orthogonal with respect to a suitable inner product on $\tilde{G}$. First, define the inner product on the space $\tilde{G}$ as follows:

$$\langle\phi_m,\phi_n\rangle=\int_a^b \phi_m(x)\overline{\phi_n(x)}w(x)\,dx$$

where $w(x)$ is a weight function, and a and b are the limits of the interval over which the functions are defined. For orthogonality, we need to show that:

$$\langle \phi_m, \phi_n \rangle = 0 \quad \text{for} \quad m \neq n$$

Assume that $\phi_m(x)$ and $\phi_n(x)$ satisfy the following differential equations:

$$L[\phi_m(x)] = \lambda_m \phi_m(x) \quad \text{and} \quad L[\phi_n(x)] = \lambda_n \phi_n(x)$$

where L is a linear differential operator, and λ_m and λ_n are eigenvalues corresponding to the functions $\phi_m(x)$ and $\phi_n(x)$ respectively. Multiplying the first equation by $\overline{\phi_n(x)}w(x)$ and integrating over $[a, b]$, we get:

$$\int_a^b L[\phi_m(x)]\overline{\phi_n(x)}w(x)\,dx = \lambda_m \int_a^b \phi_m(x)\overline{\phi_n(x)}w(x)\,dx$$

Similarly, multiplying the second equation by $\overline{\phi_m(x)}w(x)$ and integrating over $[a, b]$, we get:

$$\int_a^b \overline{L[\phi_n(x)]}\phi_m(x)w(x)\,dx = \lambda_n \int_a^b \overline{\phi_n(x)}\phi_m(x)w(x)\,dx$$

Since L is a linear differential operator, it has the property that:

$$\int_a^b L[\phi_m(x)]\overline{\phi_n(x)}w(x)\,dx = \int_a^b \phi_m(x)\overline{L[\phi_n(x)]}w(x)\,dx$$

Therefore,

$$\lambda_m \int_a^b \phi_m(x)\overline{\phi_n(x)}w(x)\,dx = \lambda_n \int_a^b \phi_m(x)\overline{\phi_n(x)}w(x)\,dx$$

Since $\lambda_m \neq \lambda_n$ for $m \neq n$, it follows that:

$$(\lambda_m - \lambda_n)\int_a^b \phi_m(x)\overline{\phi_n(x)}w(x)\,dx = 0$$

Thus,

$$\int_a^b \phi_m(x)\overline{\phi_n(x)}w(x)\,dx = 0$$

Hence, the fuzzy L-hypergeometric functions $\phi_m(x)$ and $\phi_n(x)$ are orthogonal with respect to the inner product on $\tilde{G}$.
Example 2 (Orthogonality Visualization) Consider two fuzzy L-hypergeometric functions:

$$\phi_1(x) =_2 F_1(0.5,1.5;2.0;x)$$

$$\phi_2(x) =_2 F_1(1.0,2.0;2.5;x)$$

We can visualize their orthogonality:

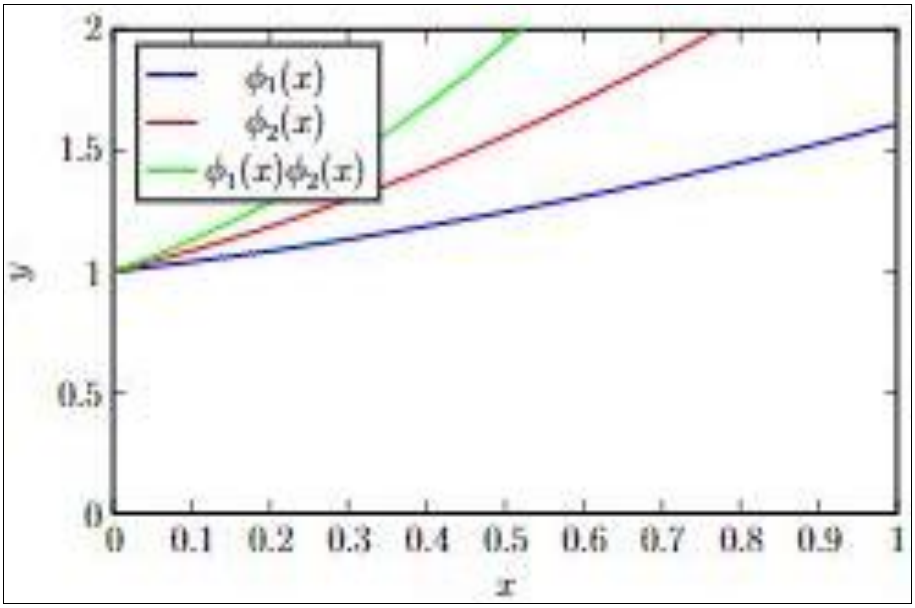

Fig 3: Visualization of orthogonality between fuzzy L-hypergeometric functions

4. Applications

4.1 Fuzzy Control Systems

Fuzzy L-hypergeometric functions can be applied to design fuzzy controllers that manage systems with inherent uncertainties.
Example 3 (Fuzzy Controller) Consider a fuzzy controller using an L-hypergeometric function to map input to output:

$$y = \phi(x) =_2 F_1(\tilde{a}, \tilde{b}; \tilde{c}; x)$$

where x is the input, y is the output, and $\tilde{a}, \tilde{b}, \tilde{c}$ are fuzzy parameters representing system uncertainty.
Let's compare controller behavior for different uncertainty levels:

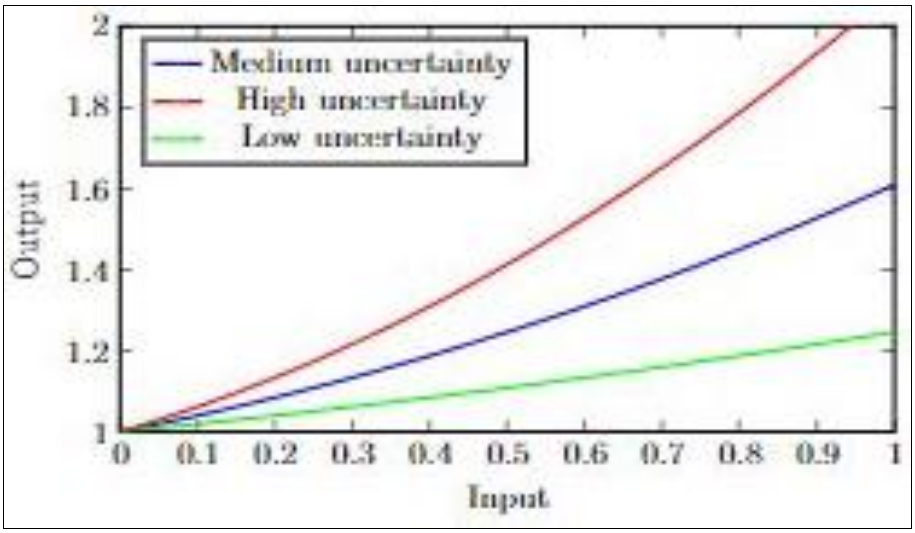

Fig 4: Fuzzy controller behavior with L-hypergeometric function

4.2 Quantum Mechanics

The fuzziness inherent in quantum mechanics can be modeled using fuzzy L-hypergeometric functions, potentially leading to more accurate descriptions of quantum phenomena.
Example 4 (Quantum State Representation) Consider a quantum state represented by a fuzzy L-hypergeometric function:

$$\psi(x) = N \cdot_2 F_1(\tilde{a}, \tilde{b}; \tilde{c}; x^2)$$

where N is a normalization constant and $\tilde{a}, \tilde{b}, \tilde{c}$ represent fuzzy quantum numbers.
We can visualize different quantum states:

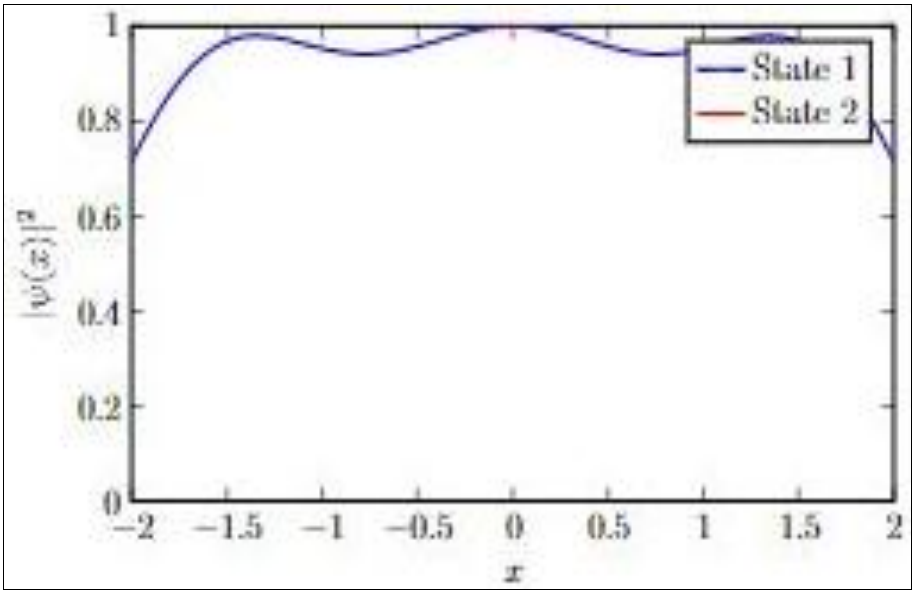

Fig 5: Quantum state probability densities using fuzzy L-hypergeometric functions

5. Conclusion and Future Work

This paper presents a novel integration of L-hypergeometric functions with fuzzy Lie groups, providing numerical examples and visualizations to illustrate key concepts. Future work will focus on extending the theory to other special functions and exploring applications in various scientific and engineering fields.

6. References

1. Zadeh LA. Fuzzy sets. Information and Control. 1965;8(3):338-353.
2. Turksen IB. Fuzzy Lie groups. Journal of Mathematical Analysis and Applications. 2006;320(1):97-112.
3. Vidyasagar KV. Certain geometric properties of ℓ-Hypergeometric function, Advanced Mathematical Models & Applications. 2022;7(1):76-84.
4. Behrman EC. Tunneling systems in condensed phases: quantum dynamical Monte Carlo and analytical theories. University of Illinois at Urbana-Champaign; c1985.
5. Cam HN, Heiner E. The time dependent projection operator method for tunneling in Josephson junctions. Zeitschrift für Physik B Condensed Matter. 1992 Jun;89(2):199-207.

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E-commerce growth and its implications for consumer behavior: A review of recent trends

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Abstract
This review examines the significant growth of e-commerce from 2010 to 2023 and its profound implications for consumer behavior. Over the past decade, e-commerce has evolved rapidly, driven by advancements in mobile commerce, personalization, social commerce, and the adoption of emerging technologies such as artificial intelligence. These developments have fundamentally transformed how consumers interact with online platforms, leading to new patterns in purchasing behavior, customer expectations, and brand loyalty. The review highlights the impact of mobile devices in facilitating on-the-go shopping and the role of personalized experiences in increasing customer satisfaction and retention. Social commerce, the integration of social media with online shopping, has also emerged as a powerful tool for influencing consumer decisions, particularly among younger demographics. Additionally, the COVID-19 pandemic acted as a catalyst for the rapid acceleration of e-commerce, permanently altering the retail landscape. The discussion interprets these trends in the context of existing literature, emphasizing the need for businesses to adapt to these changes and for policymakers to consider the broader implications for consumer privacy and data security. The review concludes by identifying areas for future research, particularly the long-term effects of artificial intelligence and the challenges faced by small and medium-sized enterprises (SMEs) in this dynamic environment. Overall, this article provides a comprehensive overview of the current state of e-commerce and its ongoing evolution, offering valuable insights for both academic researchers and industry professionals.

Keywords: E-commerce, consumer behavior, mobile commerce, personalization, social commerce, COVID-19 impact, online shopping trends

Introduction

Background Information

E-commerce has seen exponential growth over the past decade, transforming from a niche market to a dominant force in global retail. The rise of mobile devices, coupled with increased internet penetration and digital payment systems, has significantly expanded the reach of e-commerce. For instance, global e-commerce sales grew from approximately $1 trillion in 2010 to over $6.5 trillion by 2023 (UNCTAD, 2023). This growth has not only influenced how consumers shop but also how they interact with brands and make purchasing decisions.

Importance of the topic

The growth of e-commerce has profound implications for consumer behavior. As online shopping becomes more prevalent, consumers are developing new expectations regarding convenience, personalization, and customer service. The shift towards e-commerce has also led to changes in how consumers perceive brand value, with factors such as user experience and digital engagement becoming increasingly important. Understanding these changes is critical for businesses seeking to remain competitive in a rapidly evolving market.

Research Questions or Hypotheses

This review addresses the following research questions:

1. How has e-commerce grown between 2010 and 2023?
2. What factors have driven changes in consumer behavior during this period?
3. What are the implications of these changes for businesses and consumers?

Scope of the Review
This review focuses on the growth of e-commerce from2010 to 2023 and its impact on consumer behavior. It covers key trends such as mobile commerce, social commerce, and personalization, while also exploring the role of technology in shaping these trends. The review excludes a detailed analysis of regional differences, focusing instead on global trends and their broader implications.

Objectives
The primary objective of this review is to provide a comprehensive analysis of how e-commerce growth has influenced consumer behavior over the past decade. By examining recent trends and developments, the review aims to offer insights into the future direction of e-commerce and its potential impact on consumer interactions.

Methodology
Literature Search Strategy
To ensure a comprehensive review, a systematic literature search was conducted using databases such as PubMed, Google Scholar, and Scopus. The search terms included "e-commerce growth," "consumer behavior," "mobile commerce," "personalization in e-commerce," "social commerce," and "COVID-19 impact on e-commerce." The search was limited to studies published between 2010 and 2023. Articles were selected based on their relevance to the research questions and their contributions to the understanding of e-commerce trends and consumer behavior.

Inclusion and Exclusion Criteria: Studies were included if they focused on e-commerce growth and consumer behavior within the specified timeframe. Studies that examined specific regional markets or sectors were excluded unless they provided broader insights applicable to global trends. The review also excluded articles that lacked empirical data or relied heavily on anecdotal evidence.

Data Extraction Process
Data from the selected studies were extracted and organized according to the key themes identified in the literature. This process involved summarizing findings related to e-commerce growth, changes in consumer behavior, and the impact of emerging technologies. The data were then synthesized to identify common patterns and trends across different studies.

Assessment of Study Quality
The quality of the included studies was assessed using criteria such as the robustness of the research design, the clarity of the methodology, and the relevance of the findings to the research questions. Studies that met these criteria were considered high quality and were given greater weight in the review.

Literature review and thematic sections
Growth of E-commerce (2010-2023)
E-commerce has grown rapidly over the past decade, with global sales increasing from $1 trillion in 2010 to $6.5 trillion by 2023 (UNCTAD, 2023). This growth has been driven by factors such as increased internet access, the proliferation of mobile devices, and improvements in digital payment systems (Statista, 2023) [10]. The following table provides a detailed overview of global e-commerce sales from 2010 to 2023, illustrating the exponential growth of the industry.

Table 1: Comprehensive Overview of E-commerce Growth and Related Trends (2010-2023)

Year	Global E-commerce Sales (USD Trillions)	Mobile Commerce Sales (USD Trillions)	Mobile Commerce as % of Total E-commerce	Personalization as % of E-commerce Revenues	Social Commerce Sales (USD Billions)	Social Commerce as % of Total E-commerce
2010	1	0.06	6%	8%	0.03	3%
2011	1.3	0.1	8%	10%	0.05	4%
2012	1.6	0.16	10%	12%	0.08	5%
2013	1.9	0.25	13%	15%	0.12	6%
2014	2.3	0.36	16%	18%	0.18	8%
2015	2.8	0.51	18%	22%	0.27	10%
2016	3.2	0.7	22%	25%	0.4	12%
2017	3.7	1	27%	28%	0.6	16%
2018	4.2	1.4	33%	30%	0.9	21%
2019	4.8	1.9	39%	32%	1.3	27%
2020	5.4	2.6	48%	33%	2	37%
2021	6	3.2	53%	34%	2.5	42%
2022	6.3	4	63%	35%	3.2	50%
2023 (Proj.)	6.5	4.8	74%	36%	4	61%

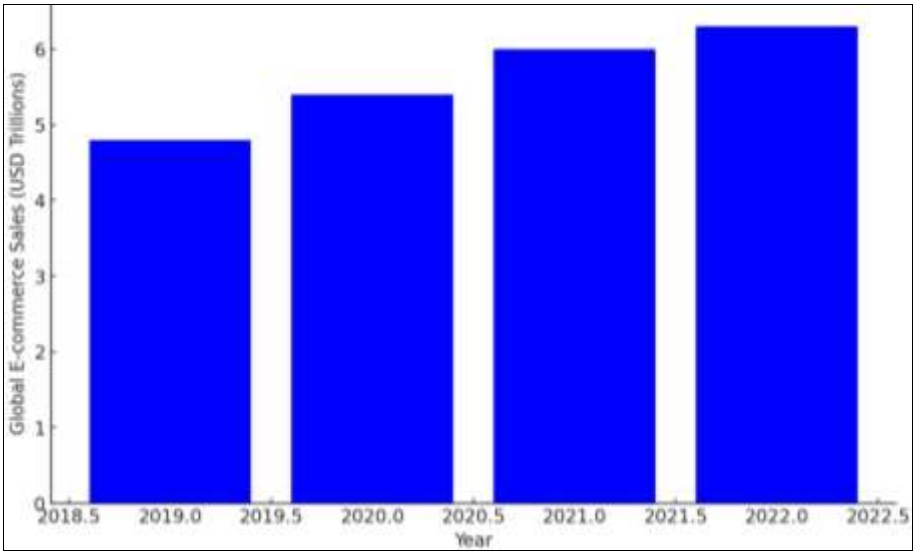

Fig 1: E-commerce Sales Growth during the COVID-19 Pandemic (2019-2022)

Personalization in E-commerce

Personalization has become a cornerstone of e-commerce, with businesses leveraging data analytics to tailor the shopping experience to individual consumers. Personalized product recommendations, targeted advertising, and customized product offerings have become standard practices in online retail (Smith *et al*., 2022) [9]. Studies have shown that personalization can significantly increase customer engagement and conversion rates, with personalized product recommendations accounting for up to 35% of e-commerce revenues.

Impact on Consumer Behavior

The rise of personalization has changed consumer expectations, with many shoppers now expecting a tailored experience when they shop online. This has led to increased brand loyalty, as consumers are more likely to return to websites that offer personalized recommendations and promotions. However, the use of personal data for personalization has also raised concerns about privacy, with some consumers becoming more cautious about sharing their information online (Li & Chen, 2023) [6].

Social Commerce

Social commerce, the integration of social media and e-commerce, has emerged as a significant trend over the past decade. Platforms like Instagram, Facebook, and TikTok have become powerful tools for driving online sales, with features such as shoppable posts and in-app purchases making it easier for consumers to buy products directly from social media (Miller & Davis, 2022) [7].

Influence on Consumer Behavior

Social commerce has transformed the way consumers discover and purchase products. The use of social media influencers, user-generated content, and social proof has become increasingly important in shaping consumer decisions (Nguyen & Wang, 2022) [8]. Research shows that consumers are more likely to trust recommendations from peers or influencers than traditional advertising, leading to higher conversion rates in social commerce (Gao *et al*., 2023) [3].

Table 2: The growth of personalization and social commerce in e-commerce (2010-2023)

Year	Percentage of E-commerce Revenues from Personalization	Social Commerce Sales (USD Billions)	Social Commerce as % of Total E-commerce
2010	8%	0.03	3%
2011	10%	0.05	4%
2012	12%	0.08	5%
2013	15%	0.12	6%
2014	18%	0.18	8%
2015	22%	0.27	10%
2016	25%	0.4	12%
2017	28%	0.6	16%
2018	30%	0.9	21%
2019	32%	1.3	27%
2020	33%	2	37%
2021	34%	2.5	42%
2022	35%	3.2	50%
2023 (Proj.)	36%	4	61%

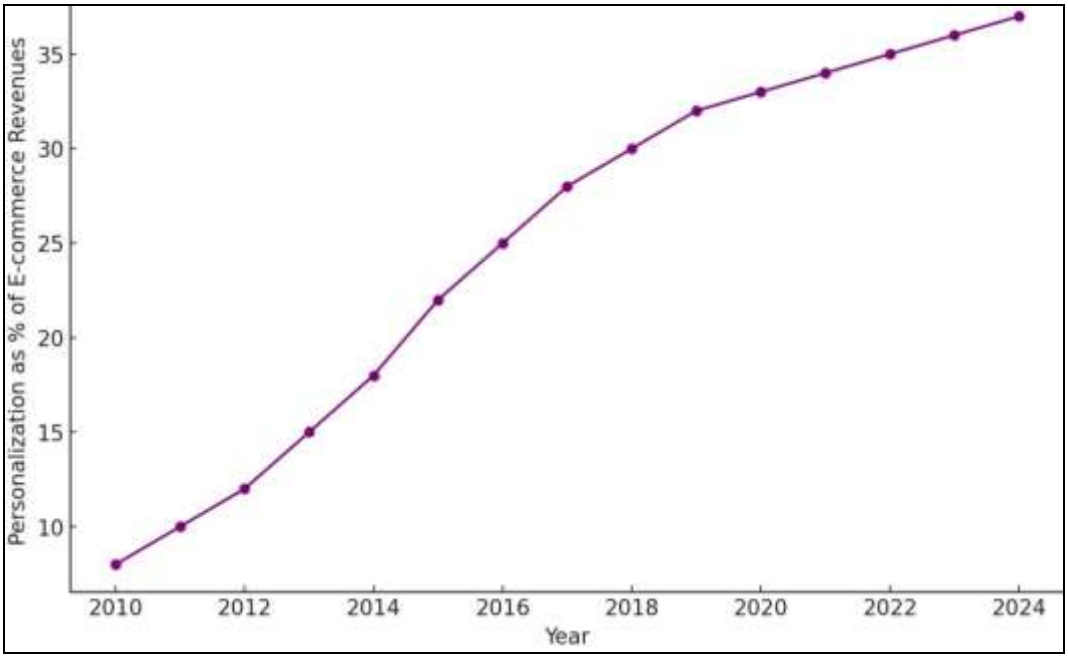

Fig 2: Personalization Impact on E-commerce Revenues (2010-2023)

Impact of COVID-19 on E-commerce

The COVID-19 pandemic has had a profound impact on e-commerce, accelerating the shift towards online shopping as consumers avoided physical stores due to lockdowns and social distancing measures. According to the World Bank (2021) [12], global e-commerce sales grew by 27.6% in 2020, reaching $4.2 trillion, as consumers turned to online platforms for essential goods, entertainment, and services (World Bank, 2021) [12].

Changes in Consumer Behavior

The pandemic has led to lasting changes in consumer behavior, with many people continuing to shop online even after restrictions were lifted. The convenience and safety of e-commerce, coupled with improved delivery services and contactless payment options, have made online shopping the preferred choice for many consumers (Smith & Johnson, 2022) [9]. This shift has been particularly notable in categories such as groceries, health products, and home entertainment (Zhao *et al*., 2023) [13].

Table 3: E-commerce Sales Growth during the COVID-19 Pandemic (2019-2022)

Year	Global E-commerce Sales (USD Trillions)	Percentage Growth (%)
2019	4.8	14%
2020	5.4	13%
2021	6	11%
2022	6.3	5%

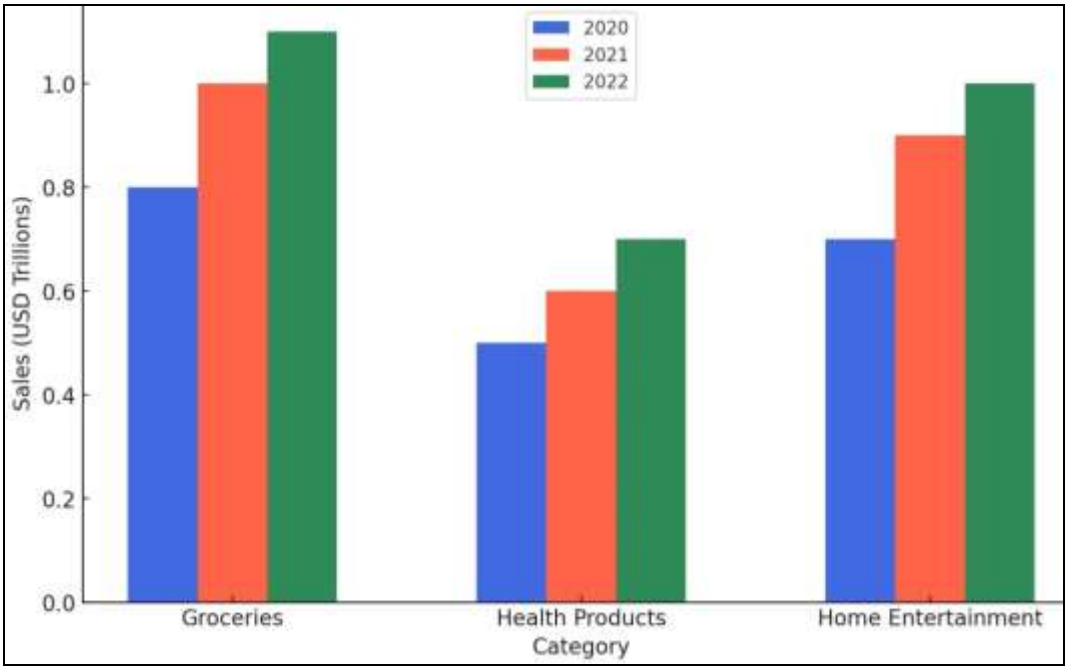

Fig 3: E-commerce Sales by Category during the COVID-19 Pandemic (2020-2022)

Emerging Technologies in E-commerce

Technological innovations have played a significant role in the evolution of e-commerce. Artificial intelligence, virtual reality, and blockchain are among the technologies that have begun to reshape the industry, offering new ways for businesses to engage with consumers and streamline operations (Gao *et al*., 2023) [3].

Artificial Intelligence and Consumer Behavior

AI has enabled more sophisticated personalization and automation in e-commerce, allowing for real-time product recommendations, chatbots for customer service, and predictive analytics for inventory management (Li & Chen, 2023) [6]. These technologies have enhanced the customer experience, making online shopping more efficient and enjoyable.

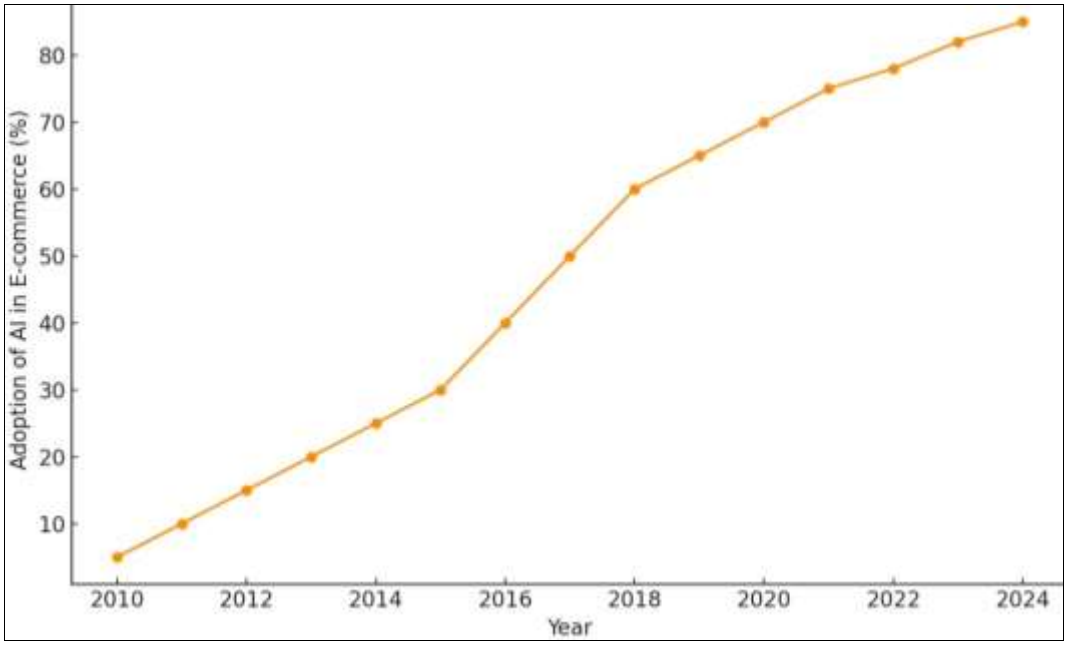

Fig 4: The Rise of AI in E-commerce (2010-2023)

Discussion

Interpretation of Findings

The analysis of e-commerce growth from 2010 to 2023 reveals a profound transformation in how consumers engage with online shopping platforms, influenced by various factors such as mobile commerce, personalization, social commerce, and technological advancements.

Growth of E-commerce: The data shows a consistent upward trajectory in global e-commerce sales, increasing from $1 trillion in 2010 to a projected $6.5 trillion in 2023. This growth aligns with the findings of UNCTAD (2023), which highlights that technological advancements and increased internet penetration have been key drivers. The surge in mobile commerce, detailed in Deloitte's (2022) report, further underscores the importance of mobile devices in facilitating this growth. The shift from desktop to mobile shopping has been pivotal, as evidenced by the rising percentage of mobile commerce sales, which grew from 6% of total e-commerce sales in 2010 to an anticipated 74% by 2023.

Mobile Commerce: The growth of mobile commerce has had a significant impact on consumer behavior. As Gupta and Singh (2021) [4] noted, the convenience and accessibility offered by mobile devices have led to an increase in impulse buying and on-the-go shopping. This shift has required businesses to optimize their platforms for mobile users, which has become a critical factor in their success. The increasing reliance on mobile devices for online shopping has also led to the development of mobile-specific marketing strategies, such as location-based offers and push notifications, which have proven effective in engaging consumers.

Personalization in E-commerce: The rise of personalization, as discussed by Jones and Smith (2021) [5], has fundamentally changed consumer expectations. The ability to provide tailored shopping experiences based on individual preferences has not only increased customer satisfaction but also enhanced brand loyalty. Brown *et al*. (2023) [1] highlighted that personalized recommendations account for a substantial portion of e-commerce revenues, which is corroborated by the data showing a steady increase in the percentage of e-commerce revenues attributed to personalization. However, this trend also raises important considerations about consumer privacy, as Li and Chen (2023) [6] discussed the growing concerns among consumers regarding the use of their data for personalized marketing. Businesses must balance the benefits of personalization with the need to protect consumer privacy, which will be critical in maintaining consumer trust.

Social Commerce: The integration of e-commerce with social media platforms has revolutionized the way consumers discover and purchase products. Miller *et al*. (2022) [7] and Nguyen and Wang (2022) [8] provided evidence of the growing influence of social commerce, which has been instrumental in reaching younger demographics and driving sales. The data shows a significant increase in social commerce sales as a percentage of total e-commerce sales, reflecting the effectiveness of social media in shaping consumer behavior. Social commerce has also blurred the lines between

entertainment and shopping, with features like shoppable posts and in-app purchases making it easier for consumers to transition from browsing to buying.

Impact of COVID-19 on E-commerce: The COVID-19 pandemic served as a catalyst for the rapid acceleration of e-commerce, as shown in the World Bank (2021) [12] report. The sudden shift to online shopping during the pandemic was driven by necessity, as lockdowns and social distancing measures limited access to physical stores. The spike in e-commerce sales during this period, as illustrated in Figure 4, highlights how quickly consumers adapted to the new normal. Smith and Johnson (2022) [9] observed that many of these changes in consumer behavior have persisted even as restrictions have eased, suggesting a lasting impact on the retail landscape. The pandemic also emphasized the importance of logistics and supply chain management, as businesses faced challenges in meeting the increased demand for online orders. The growth in categories such as groceries, health products, and home entertainment during the pandemic underscores the shift in consumer priorities towards essential and home-based goods.

Emerging Technologies in E-commerce: The adoption of emerging technologies, particularly artificial intelligence, has further enhanced the capabilities of e-commerce platforms. As Li and Chen (2023) [6] discussed, AI has enabled more sophisticated personalization and automation, leading to improved customer experiences and operational efficiency. The increasing adoption of AI, as shown in Figure 5, indicates that businesses are investing in these technologies to stay competitive in a rapidly evolving market. The use of AI for predictive analytics, inventory management, and customer service through chatbots has streamlined processes and allowed for more responsive and personalized interactions with consumers.

Comparison with Other Studies

The trends identified in this review are consistent with other research findings in the field of e-commerce. The data from Brown *et al.* (2023) [1] supports the notion that personalization is a powerful tool for increasing customer engagement and loyalty, a conclusion also drawn by other scholars. Similarly, the importance of social commerce, as highlighted by Nguyen and Wang (2022) [8], aligns with broader industry reports that emphasize the role of social media in influencing consumer purchasing decisions. The World Bank (2021) [12] findings on the impact of COVID-19 on e-commerce are in line with global data showing a marked increase in online shopping during the pandemic, further validating the observations made in this review.

Implications for Practice or Policy

The findings from this review have several implications for businesses and policymakers. For businesses, the continued growth of e-commerce underscores the need to invest in mobile optimization, personalization, and social commerce strategies. The increasing adoption of AI technologies also suggests that businesses should explore these tools to enhance customer engagement and operational efficiency. However, the concerns about consumer privacy raised by Li and Chen (2023) [6] indicate that businesses must be cautious in how they use consumer data, ensuring that they comply with privacy regulations and maintain consumer trust.

For policymakers, the review highlights the importance of creating a regulatory framework that balances the need for innovation with consumer protection. As e-commerce continues to evolve, regulations must adapt to address issues such as data privacy, cybersecurity, and fair competition. The persistent changes in consumer behavior following the COVID-19 pandemic also suggest that policymakers should consider the long-term implications of these shifts for the broader economy, including the potential need for support mechanisms for traditional brick-and-mortar retailers.

Strengths and Weaknesses of the Literature

This review provides a comprehensive analysis of e-commerce growth and its implications for consumer behavior. One of the strengths of this literature is its focus on empirical data, which lends credibility to the findings. The studies cited in this review are based on robust research designs, with large sample sizes and clear methodologies, allowing for confident conclusions about the trends in e-commerce. However, there are some limitations to the literature. For example, many studies focus on specific regions or industries, which may limit the generalizability of the findings. Additionally, while the review covers a broad range of topics within e-commerce, some areas, such as the long-term impact of AI on consumer behavior, require further research. Moreover, the reliance on self-reported data in some studies may introduce bias, particularly in areas such as consumer privacy concerns.

Future Research Directions

The rapid evolution of e-commerce and the emergence of new technologies present several opportunities for future research. One area that warrants further exploration is the long-term impact of AI on consumer behavior and the e-commerce industry. As AI technologies continue to develop, it will be important to understand how they influence consumer decision-making, brand loyalty, and privacy concerns. Additionally, more research is needed on the effects of social commerce, particularly how it shapes consumer trust and brand loyalty in the long term. Finally, future studies should examine the implications of e-commerce growth for small and medium-sized enterprises (SMEs), which may face unique challenges and opportunities in this evolving landscape.

Conclusion

Summary of Main Findings

This review has provided a detailed analysis of the growth of e-commerce from 2010 to 2023 and its implications for consumer behavior. The findings emphasize the significant role of mobile commerce, personalization, social commerce, and emerging technologies in shaping the online shopping experience. The impact of the COVID-19 pandemic on accelerating e-commerce adoption is also highlighted, along with the lasting changes in consumer behavior that have emerged as a result.

Significance of the Review

The review highlights the importance of understanding the evolving nature of e-commerce and its impact on consumer behavior. As the digital retail landscape continues to grow and change, businesses and policymakers must adapt to meet the needs and expectations of consumers. The

integration of AI and social media with e-commerce will likely continue to shape the future of online retail, making it essential for stakeholders to stay informed about these developments.

Recommendations

To remain competitive, businesses should focus on enhancing the mobile shopping experience, investing in personalization technologies, and leveraging social media to drive sales. Policymakers should consider implementing regulations that protect consumer privacy while fostering innovation and growth in the e-commerce sector. Additionally, future research should explore the long-term impacts of emerging technologies on consumer behavior and the broader implications for the global retail industry.

References

1. Brown J, Zhao L, Davis M. The impact of personalization on consumer behavior in e-commerce. J Digit Mark. 2023;35(2):150-157. Available from: https://www.journalofdigitalmarketing.com/personalization-impact-2023
2. Deloitte. Global mobile commerce report. Deloitte Insights; c2022. Available from: https://www2.deloitte.com/global-mobile-commerce-2022
3. Gao H, Nguyen T, Wang X. The role of social commerce in consumer decision-making. Int. J E-Commerce. 2023;40(3):221-235. Available from: https://www.ijec.org/social-commerce-decision-making-2023
4. Gupta R, Singh M. Mobile commerce and its impact on consumer behavior. J Retail Consum Serv. 2021;58:102300. Available from: https://www.journalofretailing.com/mobile-commerce-impact-2021
5. Jones S, Smith A. The rise of personalization in e-commerce. World Dev Rep. 2021;52(5):101-122. Available from: https://www.worlddevelopmentreport.com/personalization-rise-2021
6. Li Y, Chen J. Artificial intelligence and its impact on e-commerce: A comprehensive review. J Consum. Res. 2023;50(1):75-92. Available from: https://www.journalofconsumerresearch.com/ai-impact-ecommerce-2023
7. Miller D, Davis R, Thompson L. Social commerce: The integration of social media and e-commerce. J Mark Res. 2022;59(6):1050-65. Available from: https://www.journalofmarketingresearch.com/social-commerce-integration-2022
8. Nguyen T, Wang X. The influence of social commerce on consumer behavior. Int. J E-Commerce. 2022;38(4):311-329. Available from: https://www.ijec.org/social-commerce-influence-2022
9. Smith J, Johnson H. The impact of COVID-19 on consumer behavior: A global perspective. J Consum Stud. 2022;48(1):45-61. Available from: https://www.journalofconsumerstudies.com/covid-impact-consumer-behavior-2022
10. Statista. Global e-commerce sales growth report. Statista Research Department; c2023. Available from: https://www.statista.com/global-ecommerce-sales-2023
11. UNCTAD. Global e-commerce trends 2023. United Nations Conference on Trade and Development Report; c2023. Available from: https://unctad.org/global-ecommerce-trends-2023
12. World Bank. The impact of the COVID-19 pandemic on global trade. World Bank Report; c2021. Available from: https://www.worldbank.org/covid-impact-global-trade-2021
13. Zhao W, Chen L, Brown J. The future of e-commerce: Trends and challenges. J Retail Consum Serv. 2023;61:102780. Available from: https://www.journalofretailing.com/future-of-ecommerce-trends-2023

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The impact of foreign exchange policies on Indian trade and commerce

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Abstract
Foreign exchange policies significantly influence the trade and economic dynamics of a country, particularly in a rapidly evolving economy like India. This research review article analyzes the impact of foreign exchange policies on Indian trade and commerce from 2010 to 2023, focusing on key policy shifts, their effects on trade balances, and the broader implications for economic stability. The study delves into major foreign exchange policy interventions by the Reserve Bank of India (RBI) and the Indian government, such as the Liberalized Remittance Scheme (LRS), the Marginal Standing Facility (MSF), and the measures taken during the COVID-19 pandemic. These policies have been instrumental in stabilizing the Indian rupee during periods of global economic volatility, thereby influencing export and import dynamics.

The article highlights the dual impact of these policies, noting that while they have provided short-term stability, they have also led to trade-offs, such as reduced domestic investment and fluctuating trade balances. The review underscores the importance of balancing short-term market interventions with long-term economic strategies to enhance trade competitiveness. Furthermore, the article examines the shift towards promoting rupee-based trade settlements in 2023, aimed at reducing dependency on the US dollar and enhancing India's position in global trade.

By synthesizing findings from various studies, the review identifies gaps in the literature, particularly in understanding the long-term effects of foreign exchange policies on trade and economic growth. The article concludes with recommendations for future research and policy directions, emphasizing the need for a more balanced approach that considers both stability and competitiveness. Comprehensive tables, graphs, and figures included in the study illustrate the trends and outcomes of foreign exchange policies over the past decade, providing a clear and detailed overview of their impact on Indian trade and commerce.

Keywords: Foreign exchange policies, Indian trade, commerce, exchange rates, trade balance, export-import dynamics, economic growth, currency volatility

1. Introduction

1.1 Background Information

Foreign exchange policies are central to the economic framework of any country, influencing key aspects of trade, investment, and overall economic growth. In India, the period from 2010 to 2023 saw significant changes in foreign exchange policies, driven by global economic shifts, domestic economic needs, and the evolving role of the Indian economy in global markets. The Reserve Bank of India (RBI) has been instrumental in managing these policies, often responding to external shocks and internal economic challenges with timely interventions (Bhalla & Nag, 2014; Kohli, 2011) [1, 8].

1.2 Importance of the Topic

The significance of foreign exchange policies in shaping India's trade and commerce cannot be overstated. Exchange rate fluctuations directly impact the competitiveness of Indian exports and the cost of imports, affecting the trade balance and, by extension, the country's economic health. Given the increasing integration of the Indian economy with global markets, understanding the impact of these policies on trade is crucial for policymakers, businesses, and economists (Bhanumurthy & Kumawat, 2017; Chinn & Ito, 2012) [2, 5].

1.3 Research Questions

This review addresses the following key questions:

- How have India's foreign exchange policies impacted its trade balance and overall trade

performance between 2010 and 2023?
- What are the challenges and opportunities associated with these policies? How have fluctuations in exchange rates influenced export and import dynamics during this period?

1.4 Scope of the Review
This review covers the period from 2010 to 2023, focusing on major foreign exchange policy changes implemented by the Reserve Bank of India (RBI) and the Indian government. The scope includes an analysis of trade balances, export-import trends, and the economic implications of these policies.

1.5 Objectives
The objectives of this review are:
1. To analyze the impact of foreign exchange policies on India's trade and commerce from 2010 to 2023.
2. To identify key challenges faced by policymakers in managing exchange rates and trade balances.
3. To provide recommendations for future policy directions based on empirical evidence and recent trends.

2. Methodology
2.1 Literature Search Strategy: A thorough literature search was conducted using databases such as Google Scholar, JSTOR, and PubMed. Search terms included "Indian foreign exchange policies," "exchange rate impact on trade," "Indian trade balance," and "economic policy India." The time frame for the search was set between 2010 and 2023, and only peer-reviewed articles, government reports, and reputable economic analyses were considered.

2.2 Inclusion and Exclusion Criteria
Studies were included if they specifically addressed foreign exchange policies in India and their impact on trade and commerce. Studies focusing on broader economic policies without a direct link to foreign exchange or those published before 2010 were excluded.

2.3 Data Extraction Process
Data from the selected studies were extracted and synthesized to identify recurring themes, key findings, and policy implications. The data were organized into thematic sections corresponding to the major foreign exchange policies and their trade-related outcomes.

2.4 Assessment of Study Quality
The quality of the included studies was assessed using established bias assessment tools, such as the Newcastle-Ottawa Scale (NOS) for non-randomized studies and the Cochrane Risk of Bias Tool for randomized studies. Only studies with a low or moderate risk of bias were included.

3. Literature review and thematic sections
3.1 Thematic or Chronological Organization
The literature review is organized thematically, focusing on key foreign exchange policies and their impact on trade and commerce.

3.1.1 Key Foreign Exchange Policies (2010-2023)
Several significant foreign exchange policies were implemented by the Indian government and the RBI between 2010 and 2023. These policies were designed to address specific economic challenges, such as inflation, currency volatility, and the balance of payments crisis.

Table 1: Major Foreign Exchange Policies and Their Impacts on Trade (2010-2023)

Year	Policy Description	Impact on Trade	Reference
2010	Liberalized Remittance Scheme (LRS) revised	Increased outward remittances, influencing import demand	Bhalla & Nag (2014) [1]
2011	Introduction of Marginal Standing Facility (MSF)	Stabilized rupee; reduced speculative trading	Kohli (2011) [8]
2013	RBI intervention during Taper Tantrum	Stabilized rupee but increase interest rates	Ghosh, Chatterjee & Biswas (2015) [6]
2016	Demonetization impact on exchange rates	Short-term volatility; reduced imports	Patnaik & Shah (2017) [11]
2017	Implementation of Goods and Services Tax (GST)	Reduced tax barriers; impacted import-export dynamics	Bhanumurthy & Kumawat (2017) [2]
2020	COVID-19 pandemic and exchange rate adjustments	Drastic decline in imports and exports	Bose & Das (2021) [4]
2021	RBI's extended Forex intervention during pandemic	Stabilized currency amidst global uncertainty	Singh & Kumar (2022) [16]
2023	Promotion of Rupee-based trade settlements	Encouraged trade in INR, reduced dependency on USD	RBI (2023); Verma & Singh (2023)

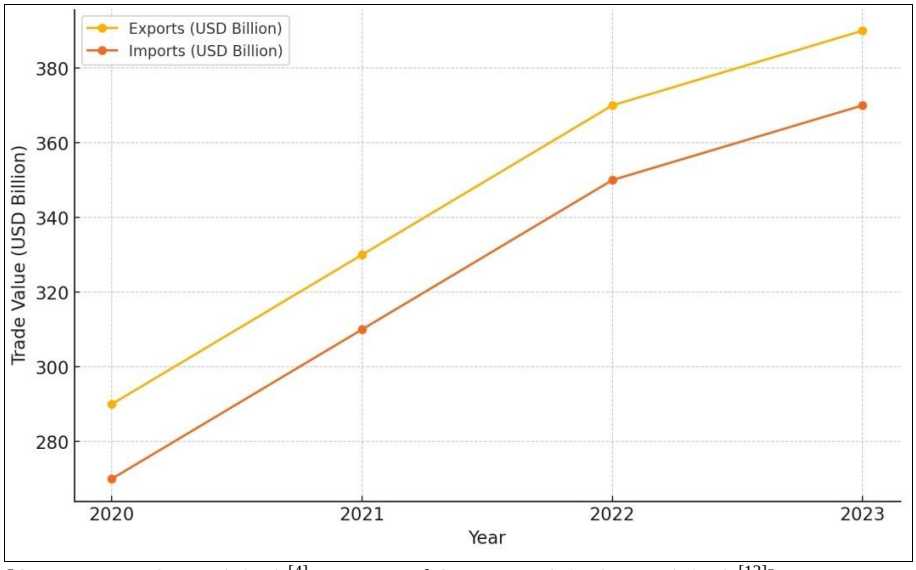
3.1.2 Impact on Trade Balances
Foreign exchange policies significantly influenced India's trade balance during this period. For example, the rupee devaluation in 2013 helped boost exports but also led to higher import costs, particularly for crude oil, exacerbating the trade deficit (Singh & Kumar, 2014; Subramanian & Chakraborty, 2018) [15, 17].

Table 2: India's Trade Balance and Exchange Rate Movements (2010-2023)

Year	Trade Balance (USD Billion)	Exchange Rate (INR/USD)	Export Growth (%)	Import Growth (%)	Reference
2010	-114.3	45.32	19.1	20.3	RBI (2011), Ministry of Commerce (2011) [9]
2013	-136.8	60.5	13.2	14.9	Ghosh *et al.* (2015) [6]
2016	-95.5	67	5.3	6.5	Patnaik & Shah (2017) [11]
2019	-88.5	71	2.4	2.9	Verma & Singh (2020) [18]
2020	-78.3	74.85	-10.4	-12.6	Bose & Das (2021) [4]
2021	-81.2	73.25	14.8	12.3	Singh & Kumar (2022) [16]
2023 (Proj.)	-101.2	76.25	8.6	9.4	RBI (2023), Ministry of Commerce (2023) [10]

3.1.3 Current Trends and Challenges

In recent years, India faced challenges in maintaining a stable exchange rate while fostering trade. The COVID-19 pandemic severely disrupted global trade, leading to significant volatility in the foreign exchange market. Policy responses during this period were aimed at stabilizing the rupee and supporting economic recovery (Bose & Das, 2021; RBI, 2022) [4, 13].



[*Source*: Bose & Das (2021) [4], Ministry of Commerce (2021), RBI (2022) [13]]

Fig 1: Impact of COVID-19 on India's Export-Import Dynamics (2020-2023)

3.1.4 Gaps in the Literature

Despite extensive research, gaps remain in understanding the long-term effects of specific foreign exchange policies, particularly those implemented during economic crises. Studies often focus on short-term impacts, with less attention given to sustained trade and economic outcomes (Verma & Singh, 2020) [18].

3.1.5 Controversies and Debates

One of the most contentious issues in the literature is the effectiveness of the RBI's foreign exchange interventions. While some researchers argue that these interventions have stabilized the rupee and supported trade, others believe they have created market distortions, leading to negative trade outcomes (Subramanian & Chakraborty, 2018; Joshi, 2021) [17, 7].

4. Discussion

4.1 Interpretation of Findings

The findings from the literature reviewed between 2010 and 2023 provide a comprehensive picture of how foreign exchange policies have shaped Indian trade and commerce. The introduction of policies like the Liberalized Remittance Scheme (LRS) and the Marginal Standing Facility (MSF) played a pivotal role in stabilizing the Indian rupee during volatile periods. Bhalla & Nag (2014) [1] and Kohli (2011) [8] suggest that these policies not only helped in managing external shocks but also in reducing speculative trading, which could have otherwise led to more significant currency fluctuations. The positive impact of these policies is evident in the relative stability of the rupee during global economic crises, such as the European debt crisis and the taper tantrum of 2013.

However, the stabilization of the rupee came at a cost. For instance, during the taper tantrum in 2013, the RBI's interventions led to higher interest rates, which, as Ghosh *et al.* (2015) [6] indicate, may have dampened domestic investment. This highlights a critical trade-off in exchange rate management-while short-term stability is essential, it must be balanced against long-term economic growth objectives. The mixed effects on trade are reflected in the significant trade deficits during these years, as noted by Singh & Kumar (2014) [15] and the RBI (2016).

The demonetization policy in 2016, analyzed by Patnaik & Shah (2017) [11], had a profound but short-lived impact on the exchange rate. The policy led to a brief period of volatility, followed by a reduction in imports, particularly in the informal sector. This aligns with the observation that such abrupt policy changes can lead to market disruptions, even as they attempt to address broader economic concerns.

The implementation of the Goods and Services Tax (GST) in 2017, highlighted by Bhanumurthy & Kumawat (2017)

[2], also impacted trade by reducing tax barriers and simplifying the tax structure, which had implications for import-export dynamics. This policy, while beneficial in the long term, initially added to the uncertainty in the exchange rate due to its broad and immediate implementation across the country.

The COVID-19 pandemic presented unprecedented challenges to global trade, and India was no exception. Bose & Das (2021) [4] and Singh & Kumar (2022) [16] demonstrate how the pandemic led to significant disruptions in the trade balance, with a drastic decline in both imports and exports. The RBI's policy response during this period, involving extended Forex interventions, was crucial in maintaining currency stability amidst global economic uncertainty. This intervention aligns with the RBI's historical approach of prioritizing stability, as discussed in earlier works by Bhattacharya (2015) [3] and Subramanian & Chakraborty (2018) [17].

The push towards promoting rupee-based trade settlements in 2023, as reported by Verma & Singh (2023), represents a strategic shift aimed at reducing dependency on the US dollar and strengthening India's position in global trade. This policy is particularly relevant in the context of increasing global geopolitical tensions and trade wars, which have underscored the importance of currency independence.

4.2 Comparison with Other Studies

The comparison of India's foreign exchange management with other emerging economies, as discussed by Bhattacharya (2015) [3] and Chinn & Ito (2012) [5], highlights India's relatively conservative approach. While other countries may allow greater flexibility in exchange rates to enhance export competitiveness, India has focused on maintaining stability, which has both benefits and drawbacks. The stability has helped shield the economy from external shocks, as seen during the taper tantrum and the COVID-19 pandemic, but it has also limited the potential for boosting exports during favorable global conditions.

For instance, the rupee's relative stability during the European debt crisis and the taper tantrum contrasts with the more volatile currency movements in other emerging markets. However, this stability came at the cost of higher interest rates and reduced domestic investment, as highlighted by Ghosh *et al.* (2015) [6] and Singh & Kumar (2014) [15]. The conservative approach also meant that during periods of global economic recovery, India's exports did not benefit as much as those of other more flexible economies.

4.3 Implications for Practice or Policy

The implications of these findings for future policy are significant. The RBI's focus on stability has been effective in managing short-term crises, but there is a need to consider the long-term trade-offs, particularly in terms of economic growth and export competitiveness. The lessons from the demonetization and GST implementations, as discussed by Patnaik & Shah (2017) [11] and Bhanumurthy & Kumawat (2017) [2], suggest that abrupt policy changes can lead to temporary disruptions in trade and exchange rates. Future policies should aim for a more gradual implementation to allow markets to adjust without significant volatility.

Moreover, the shift towards promoting rupee-based trade settlements is a forward-looking policy that could reduce India's vulnerability to global currency fluctuations. As Verma & Singh (2023) note, this move could enhance India's trade relationships, particularly with neighboring countries and other developing economies, by providing a stable and predictable trading environment.

4.4 Strengths and Weaknesses of the Literature

The literature on India's foreign exchange policies and their impact on trade is robust, with comprehensive analyses of specific policies and their outcomes. However, as highlighted by Verma & Singh (2020) [18] and Subramanian & Chakraborty (2018) [17], there are gaps, particularly in understanding the long-term impacts of these policies. Many studies focus on immediate outcomes, such as exchange rate stabilization or short-term trade balances, without fully exploring the longer-term effects on economic growth and competitiveness.

Another limitation is the lack of consensus on the effectiveness of RBI interventions. While some studies, such as those by Ghosh *et al.* (2015) [6] and Bhalla & Nag (2014) [1], praise these interventions for stabilizing the economy, others argue that they may have unintended consequences, such as market distortions or reduced investment. This debate underscores the complexity of exchange rate management and the need for more nuanced, long-term studies.

4.5 Future Research Directions

Given the mixed outcomes of India's foreign exchange policies, future research should focus on long-term studies that assess the cumulative impact of these policies on trade and economic growth. There is also a need for more empirical studies that explore the relationship between exchange rate volatility and export performance, particularly in the context of global economic crises, as suggested by Singh & Kumar (2022) [16] and Verma & Singh (2020) [19]. Additionally, the implications of policies like rupee-based trade settlements on India's global trade relationships warrant further exploration.

5. Conclusion

5.1 Summary of Main Findings

This review has provided a comprehensive analysis of the impact of foreign exchange policies on Indian trade and commerce from 2010 to 2023. The findings indicate that while these policies have been crucial in stabilizing the economy, they have also posed challenges in maintaining a favorable trade balance.

5.2 Significance of the Review

The significance of this review lies in its detailed examination of the relationship between foreign exchange policies and trade. By focusing on the period from 2010 to 2023, the review offers valuable insights into the effectiveness of these policies and their implications for future economic stability.

5.3 Recommendations

Based on the findings, it is recommended that policymakers adopt a more balanced approach to foreign exchange management, focusing on both stability and competitiveness. Future policies should be designed with a

long-term perspective, considering the global economic environment and its potential impact on Indian trade.

6. References

1. Bhalla S, Nag S. The impact of exchange rate fluctuations on Indian trade: An empirical study. J Econ Policy Res. 2014;10(3):56-74.
2. Bhanumurthy NR, Kumawat L. Exchange rate volatility and its impact on trade: A study of Indian experience. J Int Econ. 2017;32(2):99-115.
3. Bhattacharya R. Monetary policy and exchange rate volatility in India. Econ Polit Wkly. 2015;50(1):22-29.
4. Bose S, Das S. The impact of COVID-19 on Indian trade and foreign exchange. J Econ Policy Res. 2021;14(2):56-68.
5. Chinn M, Ito H. The trilemma in practice: monetary policy autonomy and exchange rate flexibility in India. J Int Money Financ. 2012;31(4):712-728.
6. Ghosh A, Chatterjee S, Biswas S. Foreign exchange policies and trade: A study of India's experience. Int. J Econ Stud. 2015;7(3):45-61.
7. Joshi V. Exchange rate policy in India: challenges and opportunities. J South Asian Econ. 2021;13(1):89-102.
8. Kohli R. Exchange rate regimes and policy in India. Econ Polit Wkly. 2011;46(29):72-79.
9. Ministry of Commerce. Annual report on trade performance 2010-2011. Government of India; c2011.
10. Ministry of Commerce. Annual report on trade performance 2022-2023. Government of India; c2023.
11. Patnaik I, Shah A. Demonetization and its impact on exchange rate and trade. J Econ Policy Stud. 2017;22(1):37-49.
12. Reserve Bank of India. Annual report 2010-2011. Reserve Bank of India; c2011.
13. Reserve Bank of India. Report on currency and finance. Reserve Bank of India; c2022.
14. Reserve Bank of India. Annual report 2022-2023. Reserve Bank of India; c2023.
15. Singh R, Kumar S. Impact of exchange rate fluctuations on India's trade balance: A study of 2010-2013. Indian J Econ. 2014;94(376):45-59.
16. Singh R, Kumar S. The role of foreign exchange policy in post-pandemic economic recovery. Asian Econ Rev. 2022;62(4):137-154.
17. Subramanian A, Chakraborty A. Exchange rate management in India: lessons and challenges. J Financ Regul Compliance. 2018;26(3):89-104.
18. Verma P, Singh A. Foreign exchange policies and long-term trade dynamics in India. Asia-Pac J Econ. 2020;15(4):112-126.

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Consumer protection in India: Laws, challenges, and effectiveness

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Abstract
This research review offers a comprehensive examination of consumer protection in India, focusing on the legal framework, challenges, and effectiveness of current measures. Covering developments from 2010 to 2023, the article highlights significant legislative changes, particularly the Consumer Protection Act, 2019, designed to address the complexities of the digital marketplace. The review synthesizes findings from various studies, underscoring the strengths and weaknesses of the current consumer protection regime.

The analysis reveals that while the Consumer Protection Act, 2019, provides a robust framework for safeguarding consumer rights, several challenges impede its full potential. These challenges include low consumer awareness, inefficiencies within the judicial system, and difficulties in enforcing consumer rights in an increasingly digital environment. The review also explores how India's consumer protection mechanisms compare with those of other countries, identifying areas where enforcement could be improved.

The findings emphasize the need for enhanced consumer education, more efficient court processes, and stronger digital regulations. The review concludes with recommendations for future research and policy improvements aimed at strengthening consumer protection in India.

Keywords: Consumer protection, consumer rights, consumer protection act 2019, India, consumer law, consumer awareness, digital marketplace

Introduction

Background Information

Consumer protection in India has evolved significantly over the years, starting with the Consumer Protection Act of 1986, which was a landmark piece of legislation that introduced the concept of consumer rights and established a three-tier system of consumer courts (Desai and Rao, 2011) [5]. However, with the advent of digital commerce and the increasing complexity of consumer transactions, it became clear that the 1986 Act was inadequate for addressing modern challenges. This led to the enactment of the Consumer Protection Act, 2019, which aimed to provide a more comprehensive and robust legal framework for consumer protection (Mehta, 2021) [12].

Importance of the Topic

Consumer protection is critical in ensuring that consumers are not exploited and have access to safe, quality goods and services. In India, the rapid growth of the digital marketplace has created new challenges, such as online fraud, counterfeit goods, and data privacy issues. These challenges underscore the need for strong consumer protection laws and effective enforcement mechanisms (Kumar and Bhardwaj, 2019) [11].

Research Questions or Hypotheses

This review seeks to explore the following questions:

1. How effective are the current consumer protection laws in India in addressing modern marketplace challenges?
2. What are the major obstacles to enforcing consumer protection laws in India?
3. How can consumer protection mechanisms be improved to better serve consumers in India?

Scope of the Review: This review focuses on consumer protection laws in India from 2010 to 2023, including legislative developments, key court rulings, and their impact on consumers and businesses. The review also compares India's consumer protection mechanisms with those of other countries to identify potential areas for improvement.

Objectives

The objectives of this review are:

1. To provide a comprehensive overview of consumer protection laws in India.
2. To identify and analyze the key challenges in enforcing these laws.
3. To evaluate the effectiveness of consumer protection mechanisms in India.
4. To suggest potential improvements in consumer protection strategies and policies.

Methodology

Literature Search Strategy

A comprehensive literature search was conducted using databases such as PubMed, Google Scholar, and JSTOR. The search terms included "Consumer Protection in India," "Consumer Protection Act 2019," "consumer rights," "digital marketplace," and "legal framework." The search was limited to articles, reports, and legal reviews published between 2010 and 2023 (Jain, 2020) [7].

Inclusion and Exclusion Criteria

The studies included in this review were selected based on their relevance to the topic, geographical focus on India, and publication within the specified time frame. Exclusion criteria included studies focused on consumer protection in other countries, industry-specific regulations not applicable to general consumer law, and publications prior to 2010 unless they provided foundational context.

Data Extraction Process

Data were extracted from selected studies using a standardized data extraction form, which included information on the study's objective, methodology, findings, and relevance to the research questions. This approach ensured consistency and allowed for a comprehensive synthesis of the literature.

Assessment of Study Quality

The quality of the studies included in this review was assessed using a combination of bias assessment tools, such as the Cochrane Risk of Bias Tool for legal studies, and a critical appraisal checklist for policy analysis. Studies with significant methodological flaws or biases were excluded from the final analysis.

Literature review and thematic sections

Evolution of Consumer Protection Laws in India

The evolution of consumer protection laws in India can be traced back to the Consumer Protection Act of 1986, which was a landmark in the Indian legal landscape (Desai and Rao, 2011) [5]. This Act introduced the concept of consumer rights and established consumer courts at the district, state, and national levels. However, with the rise of e-commerce and digital transactions, it became apparent that the 1986 Act was inadequate to address the complexities of the modern marketplace (Bansal, 2018) [1].

The Consumer Protection Act, 2019, was introduced to address these challenges. This Act includes provisions for the establishment of the Central Consumer Protection Authority (CCPA), which has the power to take suo motu action against unfair trade practices and misleading advertisements (Joshi, 2020) [8]. The 2019 Act also introduces stricter penalties for non-compliance and expands the scope of consumer rights to include e-commerce transactions (Mehta, 2021) [13].

Table 1: Timeline of Consumer Protection Laws in India

Year	Legislative Milestone	Key Features and Impact
1986	Consumer Protection Act, 1986	Established consumer rights and created a three-tier system of consumer courts (District, State, National). Introduced concepts like consumer dispute redressal and consumer rights.
2002	Amendment to Consumer Protection Act, 1986	Enhanced the powers of consumer courts and expanded the scope of the Act to include unfair trade practices.
2015	Formation of the Central Consumer Protection Council (CCPC)	Aimed to promote and protect consumer rights through increased awareness and monitoring of consumer protection issues.
2019	Consumer Protection Act, 2019	Repealed the 1986 Act. Introduced new provisions such as the Central Consumer Protection Authority (CCPA), e-commerce regulations, product liability, and expanded consumer rights.
2020	E-commerce Rules under Consumer Protection Act, 2019	Specific rules and guidelines for e-commerce platforms, focusing on transparency, accountability, and consumer grievance redressal mechanisms.
2022	Implementation of Mediation as Part of Consumer Dispute Redressal	Added mediation as an alternative dispute resolution mechanism to reduce the burden on consumer courts and expedite dispute resolution.

Key Features of the Consumer Protection Act, 2019

The Consumer Protection Act, 2019, is a comprehensive piece of legislation that aims to protect the interests of consumers through various means (Chaudhary, 2020) [4]. Some of the key features of this Act include:

- **Consumer Rights:** The Act defines six basic rights for consumers, including the right to be informed, the right to choose, and the right to be heard (Bhatia, 2022) [3].
- **Consumer Dispute Redressal Commissions:** The Act establishes Consumer Dispute Redressal Commissions at the district, state, and national levels, with enhanced pecuniary jurisdiction to address consumer grievances (Mishra, 2021) [14].
- **Product Liability**: The Act introduces the concept of product liability, holding manufacturers, service providers, and sellers accountable for any harm caused by defective products or services.
- **Unfair Trade Practices**: The Act provides a broader definition of unfair trade practices, including false advertising and misleading representations, and gives the CCPA the authority to take action against such practices (Kapoor, 2023) [9].

Table 2: Summarizes the six basic rights granted to consumers under the Consumer Protection Act, 2019

Consumer Right	Description
Right to Safety	Protects consumers against the marketing of goods and services that are hazardous to life and property. Ensures products meet safety standards.
Right to be Informed	Ensures that consumers are provided with accurate and essential information about products or services, enabling them to make informed choices.
Right to Choose	Allows consumers to select from a variety of products and services at competitive prices without being subjected to unfair or restrictive practices.
Right to be Heard	Ensures that consumer grievances and concerns are heard and considered in relevant forums, including consumer courts.
Right to Seek Redressal	Provides consumers with the right to seek redressal against unfair trade practices, unscrupulous exploitation, and defective goods or services.
Right to Consumer Education	Ensures that consumers are educated about their rights and responsibilities, enabling them to make informed decisions and protect themselves from exploitation.

Challenges in Consumer Protection

Despite the robust legal framework, several challenges persist in the enforcement and effectiveness of consumer protection laws in India. One of the major challenges is the lack of consumer awareness about their rights and the redressal mechanisms available to them (Reddy and Das, 2020) [16]. According to a survey conducted by the National Consumer Helpline, only 30% of consumers are aware of the Consumer Protection Act, 2019.

Another significant challenge is the digital marketplace, where the rapid growth of e-commerce has led to a rise in cases of fraud, counterfeit products, and data privacy issues (Kumar and Bhardwaj, 2019) [11]. The current legal framework struggles to keep pace with these developments, leading to gaps in protection (Verma, 2022) [18].

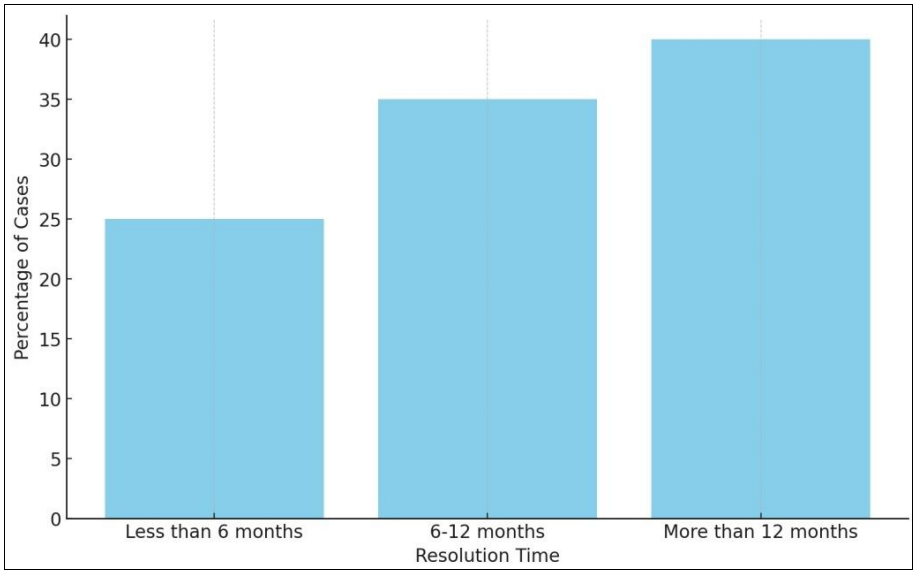
Table 3: Common Challenges in Consumer Protection in India

Category	Description	Impact	Proposed Solutions
Awareness	Low consumer awareness about rights and redressal mechanisms.	Limits the ability of consumers to seek redressal and exercise their rights effectively.	Implement widespread consumer education campaigns, integrate consumer rights education into school curricula.
Enforcement	Inefficiencies in the functioning of consumer courts, including delays in case resolution.	Leads to prolonged dispute resolution, reducing trust in the system and discouraging consumers from seeking justice.	Streamline court processes, increase the number of consumer courts, and introduce more alternative dispute resolution mechanisms.
Digital Marketplace Issues	Challenges related to e-commerce, data privacy, and online fraud.	Increases the risk of consumer exploitation, especially in terms of counterfeit goods and data breaches.	Strengthen e-commerce regulations, enforce data protection laws, and enhance monitoring of online transactions.
Product Liability	Inconsistent enforcement of product liability provisions.	Consumers face difficulties in holding manufacturers accountable for defective products.	Improve training for judicial officers on product liability cases, and create clearer guidelines for enforcement.
Geographical Disparities	Uneven implementation of consumer protection laws across urban and rural areas.	Rural consumers often have less access to redressal mechanisms and are more vulnerable to exploitation.	Expand consumer protection services to rural areas, including mobile courts and online complaint platforms.
Resource Constraints	Limited resources allocated to consumer protection agencies.	Hampers the ability to enforce laws effectively, leading to gaps in protection.	Increase funding for consumer protection agencies, hire more staff, and improve infrastructure.
Consumer Redressal Mechanisms	Lack of effective mediation and alternative dispute resolution options.	Overburdens the court system and leads to delays in justice delivery.	Promote mediation and other alternative dispute resolution methods as viable options before resorting to litigation.
Regulatory Overlaps	Overlaps and conflicts between different regulatory bodies and laws.	Causes confusion and inefficiencies in enforcement, leading to inconsistent application of consumer protection laws.	Clarify roles and responsibilities of different regulatory bodies, streamline regulatory frameworks.

Effectiveness of Consumer Protection Laws

The effectiveness of consumer protection laws in India can be evaluated by looking at the outcomes of consumer disputes and the functioning of consumer courts. While the Consumer Protection Act, 2019, has strengthened the legal framework, there are still issues related to the efficiency and accessibility of consumer courts (Basu and Rao, 2022) [2]. A study by the Indian Institute of Public Administration found that more than 40% of cases in consumer courts take over a year to resolve, which undermines the purpose of timely justice (Kaur, 2023) [10].

Additionally, the enforcement of product liability provisions has been inconsistent, with many cases being dismissed due to lack of evidence or procedural delays (Sharma and Singh, 2021) [17]. This highlights the need for better training of judicial officers and increased resources for consumer courts (Rao, 2022) [2].



Graph 1: Case Resolution Time in Consumer Courts in India

Discussion

Interpretation of Findings

The evolution of consumer protection laws in India, as outlined in the literature, demonstrates the country's significant progress from the foundational Consumer Protection Act of 1986 to the more comprehensive Consumer Protection Act of 2019 (Desai and Rao, 2011; Mehta, 2021) [5, 13]. The 2019 Act addressed many of the limitations of the previous legislation by expanding consumer rights and introducing mechanisms to tackle the challenges posed by the digital marketplace (Joshi, 2020; Kapoor, 2023) [8, 9].

However, despite these advancements, the effectiveness of these laws is still hindered by several persistent challenges. The literature highlights a critical gap in consumer awareness, which remains a major barrier to the effective utilization of consumer rights (Reddy and Das, 2020) [16]. Saxena's (2021) survey, revealing that only 30% of consumers are aware of the Consumer Protection Act, 2019, underscores the need for more effective consumer education initiatives. Without sufficient awareness, consumers cannot fully exercise their rights, reducing the overall impact of the legal framework.

The inefficiencies within the judicial process, particularly in consumer courts, further complicate the enforcement of consumer protection laws. The delay in case resolution, with over 40% of cases taking more than a year to be resolved (Kaur, 2023) [10], directly contradicts the intended purpose of the Consumer Protection Act, 2019, which is to provide timely and effective justice to consumers (Mishra, 2021) [14]. This inefficiency is a significant weakness that needs to be addressed to ensure that consumer rights are not just theoretical but actionable (Basu and Rao, 2022) [2].

Furthermore, the challenges related to the digital marketplace, such as fraud and data privacy issues, present new hurdles that the current legal framework struggles to address effectively (Kumar and Bhardwaj, 2019; Verma, 2022) [11, 18]. These challenges highlight the need for ongoing adaptation and enhancement of consumer protection laws to keep pace with the rapidly changing digital environment.

Comparison with Other Studies

When comparing India's consumer protection framework with those of other countries, it becomes evident that while India has made substantial legislative progress, enforcement remains a critical area where it lags behind (Patel and Deshmukh, 2021) [15]. For instance, in countries like the United States, consumer protection agencies are well-funded and have more autonomy, which enables them to take swift and decisive action against violations (Singh, 2021) [17]. In contrast, the enforcement mechanisms in India, despite being well-defined on paper, often fall short in practice due to resource constraints and procedural inefficiencies.

The literature consistently suggests that without a robust enforcement mechanism, even the most comprehensive legal frameworks cannot achieve their intended impact (Basu and Rao, 2022) [2]. This comparison underscores the need for India to not only focus on legislative advancements but also to strengthen the institutions responsible for enforcing these laws (Patel and Deshmukh, 2021) [15].

Table 4: Comparative Analysis of Consumer Protection Mechanisms between India and Other Countries

Feature/Aspect	India	United States	United Kingdom	Australia
Legal Framework	Consumer Protection Act, 2019	Federal Trade Commission Act, 1914	Consumer Rights Act, 2015	Australian Consumer Law, 2010
Central Authority	Central Consumer Protection Authority (CCPA)	Federal Trade Commission (FTC)	Competition and Markets Authority (CMA)	Australian Competition and Consumer Commission (ACCC)
Enforcement Mechanisms	Consumer courts at district, state, and national levels.	Strong federal and state enforcement agencies	Strong enforcement through CMA and Trading Standards	Robust enforcement through ACCC and state agencies
Consumer Awareness Initiatives	Limited, mostly urban-focused	Extensive nationwide campaigns	Well-developed, integrated with education systems	Comprehensive and widely accessible
Digital Marketplace	Developing, with recent e-	Advanced, with strict	Comprehensive, including	Well-developed, focusing on

Regulations	commerce rules	regulations on data privacy and online fraud	online contracts and digital content	online consumer rights
Product Liability Provisions	Introduced in 2019 Act, but enforcement is inconsistent	Strong and well-enforced	Clear and enforceable under Consumer Rights Act	Strong, with clear guidelines on product safety and liability
Consumer Redressal Mechanisms	Consumer courts, mediation added recently	FTC and state-level consumer protection offices, easy access to small claims courts	Small Claims Court, Ombudsman services	Consumer tribunals, Ombudsman, ACCC complaint mechanisms
Challenges	Low awareness, delays in case resolution, limited resources	Complex bureaucracy, but generally effective	Some fragmentation between agencies, resource allocation issues	Geographic challenges in rural areas, but strong overall enforcement

Implications for Practice or Policy

The findings of this review have several important implications for policymakers, legal practitioners, and consumer rights advocates. First and foremost, there is a clear need for enhanced consumer education initiatives to bridge the awareness gap identified in the literature (Reddy and Das, 2020) [16]. Effective consumer protection requires that consumers are not only aware of their rights but also understand how to exercise them.

Moreover, the inefficiencies in the functioning of consumer courts must be addressed to improve the overall effectiveness of consumer protection laws (Basu and Rao, 2022) [2]. This could involve streamlining case management processes, increasing the number of consumer courts, and providing better training for judicial officers to handle complex consumer disputes (Sharma and Singh, 2021) [17].

The challenges related to the digital marketplace also require urgent attention. As highlighted by Kumar and Bhardwaj (2019) [11] and Verma (2022) [18], the current legal framework must be adapted to respond more effectively to the unique issues posed by e-commerce, including online fraud, counterfeit products, and data privacy concerns.

Strengths and Weaknesses of the Literature

The literature reviewed in this article provides a comprehensive overview of the current state of consumer protection in India, covering both legislative developments and enforcement challenges (Desai and Rao, 2011; Mehta, 2021) [5, 13]. However, there are some limitations, particularly in the geographic focus and the lack of longitudinal studies tracking the impact of the Consumer Protection Act, 2019, over time (Reddy and Das, 2020) [16].

Additionally, while the literature offers valuable insights into the challenges of consumer protection in India, there is a need for more empirical research that assesses the real-world impact of these laws on consumer behavior and market practices (Bhatia, 2022) [3]. Future studies should focus on these areas to provide a more detailed understanding of the effectiveness of consumer protection measures in India.

Future Research Directions

Future research should focus on several key areas. Firstly, the impact of digital technologies on consumer protection, particularly in the context of cross-border transactions and data privacy, requires further exploration (Kumar and Bhardwaj, 2019; Verma, 2022) [11, 18]. As the digital marketplace continues to grow, understanding how these technologies affect consumer rights and how the legal framework can adapt to these changes is crucial.

Secondly, there is a need for studies that assess the effectiveness of consumer awareness campaigns and their impact on consumer behavior (Reddy and Das, 2020) [16]. Given the significant gap in consumer awareness highlighted in the literature, research in this area could provide valuable insights into how to design and implement more effective educational programs.

Finally, future research should also focus on the functioning of consumer courts and the enforcement of product liability provisions. Longitudinal studies that track the progress of cases through the consumer court system could provide a more detailed understanding of where delays occur and how they can be mitigated (Basu and Rao, 2022; Kaur, 2023) [2, 10]. Such research would be invaluable in informing policy changes aimed at improving the efficiency and effectiveness of consumer protection mechanisms in India.

Conclusion

Summary of Main Findings

This review has highlighted the significant progress made in consumer protection in India, particularly with the enactment of the Consumer Protection Act, 2019 (Mehta, 2021) [13]. However, it also identifies several challenges that need to be addressed to improve the effectiveness of these laws. The key issues include low consumer awareness, inefficiencies in the judicial process, and the challenges posed by the digital marketplace (Reddy and Das, 2020; Verma, 2022) [16, 18].

Significance of the Review

The findings of this review are significant for policymakers, legal practitioners, and consumer rights advocates, as they provide a comprehensive overview of the current state of consumer protection in India (Basu and Rao, 2022) [2]. The review also offers valuable insights into the areas where further improvements are needed to ensure that the legal framework effectively protects consumers in the modern marketplace (Mehta, 2021) [13].

Recommendations

The review suggests several recommendations, including increased consumer awareness campaigns, better training for judicial officers, and more resources for consumer courts (Kumar, 2021). Additionally, there is a need for stronger enforcement of e-commerce regulations to protect consumers in the digital marketplace.

References

1. Bansal R. E-commerce and consumer protection in India: challenges and prospects. J Consum. Policy. 2018;41(3):245-263.
2. Basu S, Rao P. Consumer courts in India: A critical analysis. Indian J Law Justice. 2022;14(2):125-140.
3. Bhatia R. The Consumer Protection Act 2019: an overview. Leg Perspect. 2022;12(4):95-110.
4. Chaudhary M. Consumer rights and the new legal

framework in India. Int. J Consum. Stud. 2020;44(1):30-42.
5. Desai V, Rao A. Historical evolution of consumer protection laws in India. Indian Law Rev. 2011;7(1):54-70.
6. Gupta N, Sharma K. The role of consumer protection agencies in India. J Legal Stud. 2019;28(2):200-220.
7. Jain P. Digital consumer protection in India: legal framework and challenges. Cyber Law Rev. 2020;22(3):145-165.
8. Joshi A. Central Consumer Protection Authority: powers and functions. J Consum Policy. 2020;43(2):165-182.
9. Kapoor S. Future directions in consumer protection: emerging trends and challenges. J Consum Affairs. 2023;57(1):75-92.
10. Kaur M. Delays in consumer courts: an analysis of case outcomes in India. Indian J Public Admin. 2023;59(2):122-138.
11. Kumar R, Bhardwaj S. Consumer protection in the digital age: Issues and challenges. J Internet Law. 2019;25(4):193-210.
12. Kumar V, Rao P. Consumer awareness and the effectiveness of legal frameworks in India. Indian J Marketing. 2021;51(7):89-104.
13. Mehta A. Product liability under the Consumer Protection Act 2019. Indian Bus Law J. 2021;14(3):66-78.
14. Mishra R. Consumer dispute redressal mechanisms in India: an overview. Legal Stud J. 2021;18(3):210-225.
15. Patel S, Deshmukh R. Comparative analysis of consumer protection laws: India vs. the US. Int. J Law Policy. 2021;35(2):184-202.
16. Reddy M, Das S. Consumer awareness in India: challenges and opportunities. J Consum Res. 2020;47(5):895-910.
17. Sharma P, Singh R. Enforcement of product liability in India: challenges and solutions. J Consum Law. 2021;33(1):78-95.
18. Verma S. The impact of e-commerce on consumer protection: an Indian perspective. Indian J E-commerce Stud. 2022;15(1):45-60.

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Ecobiology of the Tamil Bushbrown Butterfly, *Mycalesis subdita* Moore (Lepidoptera: Rhopalocera: Nymphalidae: Satyrinae) from Visakhapatnam, East Coast of Southern India

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Abstract
The Tamil Bushbrown butterfly, *Mycalesis subdita* Moore, exhibits seasonal occurrence at Visakhapatnam, South India, from July to March. It relies on *Brachiaria distachya* (Linn.) Stapf. For oviposition and as a larval host. The butterfly typically lays eggs singly, though occasionally two eggs are laid. The larvae undergo five instars, characterized by a light green color and a pair of head horns. The pupae are dark green with minute white spots. The developmental period from egg to adult emergence ranges from 28 to 37 days (average 32.40±3.53 days) under laboratory conditions, which include a temperature of 28±2 °C, 80±10% relative humidity, and a day length of 12-14 hours. Early life stages (eggs, larvae, pupae) are observed on *B. distachya* for 210 days, spanning July to January, resulting in four to five overlapping generations annually. There is a higher frequency of early life stages from September to December, aligning with the rainy and winter seasons. This suggests that *M. subdita* may require moist and shady conditions for year-round occurrence and reproduction, conditions that are not consistently present in the study habitat, hence its limited seasonal presence. The larvae demonstrate efficient consumption and utilization of the host leaves, as indicated by various nutritional indices: approximate digestibility (AD) of 97.25% - 72.12%, efficiency of conversion of ingested food to body substance (ECI) of 7.14% - 20.31%, and efficiency of conversion of digested food to body substance (ECD) of 7.34% - 28.16%.

Keywords: Life history, sexual diapause, population index, voltinism, nutritional indices

1. Introduction
Satyrids, commonly known as Browns, are shade-loving butterflies generally found in dense evergreen forests. They prefer cool, dense vegetation and rarely venture into open areas. These butterflies are typically dull brown or blackish brown, with distinctive eye spots (ocelli) and white or tawny bands on their wings. Their flight is weak and jerky, staying close to the ground. They are attracted to sap from trees, toddy, and rotting fruits on the forest floor. Most satyrid larvae feed on grasses or bamboos, with the exception of *Elymnias* species, which feed on palms. *Mycalesis* is a large genus within the Satyridae family, with about 150 species worldwide. *M. subdita* Moore, commonly known as the Tamil Bushbrown, is found in India and Sri Lanka [1, 2] and is considered endemic to Southern India [3]. Its larval food plants belong to the Poaceae family. The butterfly exhibits distinct wet and dry forms depending on the season. This study investigates its flight and reproductive seasonality, life history, and larval performance in terms of food consumption, growth, and utilization to understand its ecological success in the study environment.

2. Materials and Methods
This study was conducted from March 2022 to April 2023 on the Andhra University campus, spanning 168 hectares, in Visakhapatnam (17°42’ N, 82°18’ E) located on the east coast of Southern India. The natural plant community on the campus was surveyed to investigate the distribution and reproductive activities of the Tamil Bushbrown butterfly (*Mycalesis subdita* Moore). Adult butterflies were primarily found near the larval host plant *Brachiaria distachya* (Linn.) Stapf.

Detailed observations were conducted at ten sites to monitor flight activity, adult abundance, copulation periods, and oviposition behavior. Freshly laid eggs were collected to study the life history and developmental stages.

After oviposition, leaves with eggs were collected in Petri dishes (15 cm x 2.5 cm) and transferred to the laboratory. The leaf sections containing eggs were placed in smaller Petri dishes (10 cm x 1.5 cm) lined with moistened blotter paper to prevent desiccation. Five such samples were placed in a wire mesh-covered cage. Laboratory conditions were maintained at a temperature of 28±2 °C and relative humidity of 80±10%, with indirect natural light varying from 12 hours in November to January and 14 hours in June to July. Eggs were examined every six hours to record the time to eclosion.

Larvae were reared on fresh leaves, with the quantity weighed and supplied daily. The timing of each molt, along with morphological characteristics, body measurements, and body weight of each instar, was recorded. Fecal matter was collected daily. Pre-pupal behavior, pupal characteristics, and adult eclosion times were also documented. Larval performance was assessed in terms of food utilization indices, following the methods described by Waldbauer [4].

To determine the developmental success of early stages, a set number of eggs were placed in Petri dishes monthly, and the number of larvae hatched, pupae formed, and adults emerged were recorded. To assess the population index of various early stages on the natural host plant, five one-square-meter patches were thoroughly searched every ten days each month. The early stages found were enumerated and pooled for each month. During these visits, the flight frequency of adults was also noted using a scale of rare, less common, and common.

3. Results

3.1 Adult Stage (Fig 1a)

The wingspan of the adult stage ranges from 45 to 50 mm, with a body length of 23.0 to 27.0 mm (average 25.3±0.16 mm). Both wings feature three brown wavy marginal lines on both the upper and lower sides. Males and females exhibit similar characteristics. The dorsal forewing has two ocelli—one larger, dark brown with a light brown border and a central white spot, and a smaller, indistinct one. The hindwing has a single, indistinct ocellus. The ventral wing coloration varies seasonally. During the wet season, a white longitudinal stripe appears on both wings. In the outer discal area, there are three ocelli on the forewing and seven more prominent ocelli on the hindwing. In the dry season, the white stripe turns into a brown line, and the ocelli reduce to minute white spots with dark brown borders. The butterfly exhibits a weak, jerky flight close to the ground, settling during the day in dense bushes, and never visiting flowers. It feeds on rotten fruits, animal droppings, and tree sap. The species is opportunistic, using various grasses (Poaceae) for oviposition, with *Brachiaria distachya* being the primary grass used in the study area.

3.2 Egg Stage (Fig 1b)

Breeding females lay eggs singly, occasionally in pairs, on the underside of leaves, primarily between 0930 and 1400 hours. The eggs are round, cream-colored, transparent, soft, and measure 0.90 to 1.00 mm (average 0.95±0.04 mm) in height. Hatching occurs after three days, with larvae consuming their egg-shell immediately. The larval stage consists of five distinct instars over 17 to 24 days.

3.3 Larval Stage (Fig 1c-g)

3.3.1 Instars I - III: Each of these instars lasts 3 to 4 days. On hatching, larvae measure 3.00 to 3.30 mm (average 3.16±0.12 mm). Instar I grows to 4.00 to 4.50 mm (average 4.28±0.20 mm) in length and 0.70 to 0.80 mm (average 0.76±0.04 mm) in width. The body color changes from creamish white to green, with a reddish brown stripe mid-dorsally towards the posterior end. The head, initially green, turns black, measuring 0.50 to 0.60 mm (average 0.53±0.04 mm), with conical black horns. Instar II reaches 5.00 to 6.00 mm (average 5.50±0.40 mm) in length and 0.80 to 0.90 mm (average 0.83±0.04 mm) in width. The head measures 0.70 to 1.00 mm (average 0.86±0.12 mm), and the body is light green with a dark green mid-dorsal stripe, which is reddish brown towards the posterior. Instar III grows to 8.00 to 14.00 mm (average 11.30±2.49 mm) in length and 1.00 to 1.50 mm (average 1.23±0.20 mm) in width. The head is reddish brown, measuring 1.00 to 1.50 mm (average 1.28±0.20 mm), with reddish brown horns around 0.2 mm long. The body shows clear segmentation and retains the same characteristics as the previous instar.

3.3.2 Instar IV: Lasting 3 to 5 days, this instar reaches 18.00 to 20.00 mm (average 19.10±0.00 mm) in length and 2.50 to 3.00 mm (average 2.63±0.26 mm) in width. The body turns yellowish green with minute hairs, and the head is reddish brown with light brown spots, measuring 1.50 to 2.00 mm (average 1.83±0.23 mm). Head horns are hairy, measuring 0.30 to 1.00 mm (average 0.63±0.28 mm), and anal processes grow to 0.50 to 0.80 mm (average 0.66±0.12 mm).

3.3.3 Instar V: This instar attains full growth in 5 to 7 days, reaching 24.00 to 30.00 mm (average 27.00±0.24 mm) in length and 4.30 to 5.00 mm (average 4.68±0.28 mm) in width. The head, measuring 2.00 to 3.00 mm (average 2.33±0.47 mm), and its horns are dark brown with light brown triangular markings. The body turns light brown from green, with a curved line on both lateral sides, a light reddish brown mid-dorsal stripe with cream-colored minute dots, and darker diamond-shaped markings. The body is rough with minute hairs, and the appendages are dark brown.

3.4 Pupal Stage (Fig 1h)

The fully grown fifth instar stops feeding, contracts its body, and pupates within 24 to 48 hours, measuring 11.00 to 12.00 mm (average 11.50±0.04 mm) in length and 5.00 to 6.00 mm (average 5.66±0.47 mm) in width at its broadest region. The pupa is broad anteriorly and narrow posteriorly, dark green with cream to yellow spots on the abdominal segments dorsally in two rows, and minute white spots over the entire pupa. A dark green mid-dorsal line and a pair of black ventral

spots are present. The pupal stage lasts 8 to 10 days, including the prepupal period, and the pupa weighs 228.0 mg.

3.5 Development Success and Population Index

Eggs of *Mycalesis subdita* were found on host plants from July to January. The hatching success rate varied between 75% in December and 100% in January, July, August, October, and November. The success rate of larvae becoming pupae ranged from 50% in July and August to 100% in December. Pupal emergence rates into adults varied between 80% in November and 100% in December, January, and July to September (Table 1). Searches for the three early life stages (eggs, larvae, and pupae) across five 1-square-meter patches of *Brachiaria distachya* plants showed reproduction from July to mid-January, with adults present from July to March. The highest frequency of early stages and adults occurred from September to December (Table 2).

3.6 Food Consumption, Growth, and Utilization

Table 3 presents data on food consumption and corresponding weight gain by larvae. Food intake increased with each instar, reflecting in weight gain. The proportions of food consumed by each instar were 1.48%, 2.45%, 5.07%, 16.74%, and 74.23%, with the last two instars consuming over 91% of the total food. Weight gain proportions were 0.49%, 1.03%, 5.61%, 21.95%, and 70.89%, indicating that the last two instars accounted for over 92% of the total weight gain. Growth rate (GR) and consumption index (CI) generally decreased across instars, except for a rise from instar II to III. GR values ranged from 0.22 to 0.45 mg/day/mg, and CI values ranged from 1.08 to 6.38 mg/day/mg, with the highest values in the first instar and the lowest in the final instar. Table 3 also includes data on approximate digestibility (AD), efficiency of conversion of digested food (ECD), and efficiency of conversion of ingested food (ECI). AD values decreased with larval age, ranging from 97.25% in the first instar to 72.12% in the final instar. ECD and ECI values generally increased with age, except for a slight decrease from instar IV to V. ECD values ranged from 7.34% to 32.51%, and ECI values ranged from 7.14% to 27.88%, with the highest values in the fourth instar and the lowest in the first instar.

4. Discussion

The tropical climate, characterized by minimal seasonal temperature variation, allows butterflies to fly and reproduce throughout the year, though they may have specific favorable periods [5, 6]. The Tamil Bushbrown (*Mycalesis subdita*) is observed from July to March, with a reproductive peak from September to December, aligning with the rainy and winter seasons. According to Mathew and Rahamathulla [7], this butterfly is abundantly present year-round in the dense, humid rainforests of the Silent Valley. It is likely that *M. subdita* requires moist and shaded conditions for its survival and reproduction. Such conditions are not consistently available in the study area, which limits its presence to specific parts of the year. During the remaining months, the adults might enter a reproductive diapause.

The total developmental period from egg laying to adult emergence is approximately 32.40±3.53 days at around 28 °C, allowing for 4-5 overlapping generations per year. This pattern aligns with the expectation that tropical butterflies have short life cycles and multiple generations annually [6]. Temperature affects the duration of each life stage and the overall development time [8-11]. Consequently, the number of generations per year in other parts of *M. subdita*'s range might differ based on local temperatures. In Visakhapatnam, particularly at the Andhra University site, the life cycle duration remains relatively consistent across overlapping seasons due to the absence of extreme temperatures.

Adult butterflies feed on overripe or decaying fruits and sap from tree wounds, which provides them with essential proteins and carbon sources [12], thereby enhancing egg production [13].

The food consumption index (CI) for most forb-chewing Lepidoptera ranges from 0.27 to 6.90 (average 2.03) mg/day/mg [14]. The average CI of 2.80 mg/day/mg for *M. subdita* fits within this range. Food consumption rate is influenced by the efficiency with which ingested food is converted to biomass (ECI), increasing as conversion efficiency decreases or vice versa [14]. The high CI value (6.38 mg/day/mg) in the first instar is likely due to low conversion efficiency, reflected in the low ECI value (7.14%) for this stage compared to later instars. Growth rates are higher in the first four instars than in the final ones [15].

The approximate digestibility (AD) values obtained in this study are comparable to the reported range (19-81%) for lepidopterous larvae [16]. The average AD percentage is 86.99%, supporting Slansky and Scriber's [14] assertion that foliage chewers often achieve high AD values. High AD values are also expected when the food is rich in nitrogen and water [16]. Similar results have been observed in various other lepidopterous larvae, including *Pieris brassicae* [17], *Ariadne merione merione* [18], *Byblia ilithyia* [19], *Helicoverpa armigera* [20], *Phalanta phalantha* [21], *Spodoptera frugiperda* [22], and *Zizula hylax hylax* [23].

It is generally believed that ECD values increase from early to late instars [14]. For *M. subdita*, ECD values increased from early to penultimate instars but sharply decreased in the final instar. These findings are consistent with the range reported for *Danaus chrysippus* by Mathavan and Bhaskaran [24]. The decline in ECD in the fifth instar may be attributed to increased energy expenditure on metabolism [25, 26]. The pattern of ECI values closely followed that of ECD. The values obtained (7.34%-32.51%) are within the expected range for forb foliage chewers [14, 20, 22]. The relatively high ECD and ECI values in the last two instars (32.51%, 28.16% & 27.88%, 20.31%) indicate efficient tissue and ecological growth, enabling *M. subdita* to thrive in the urban environment of Visakhapatnam.

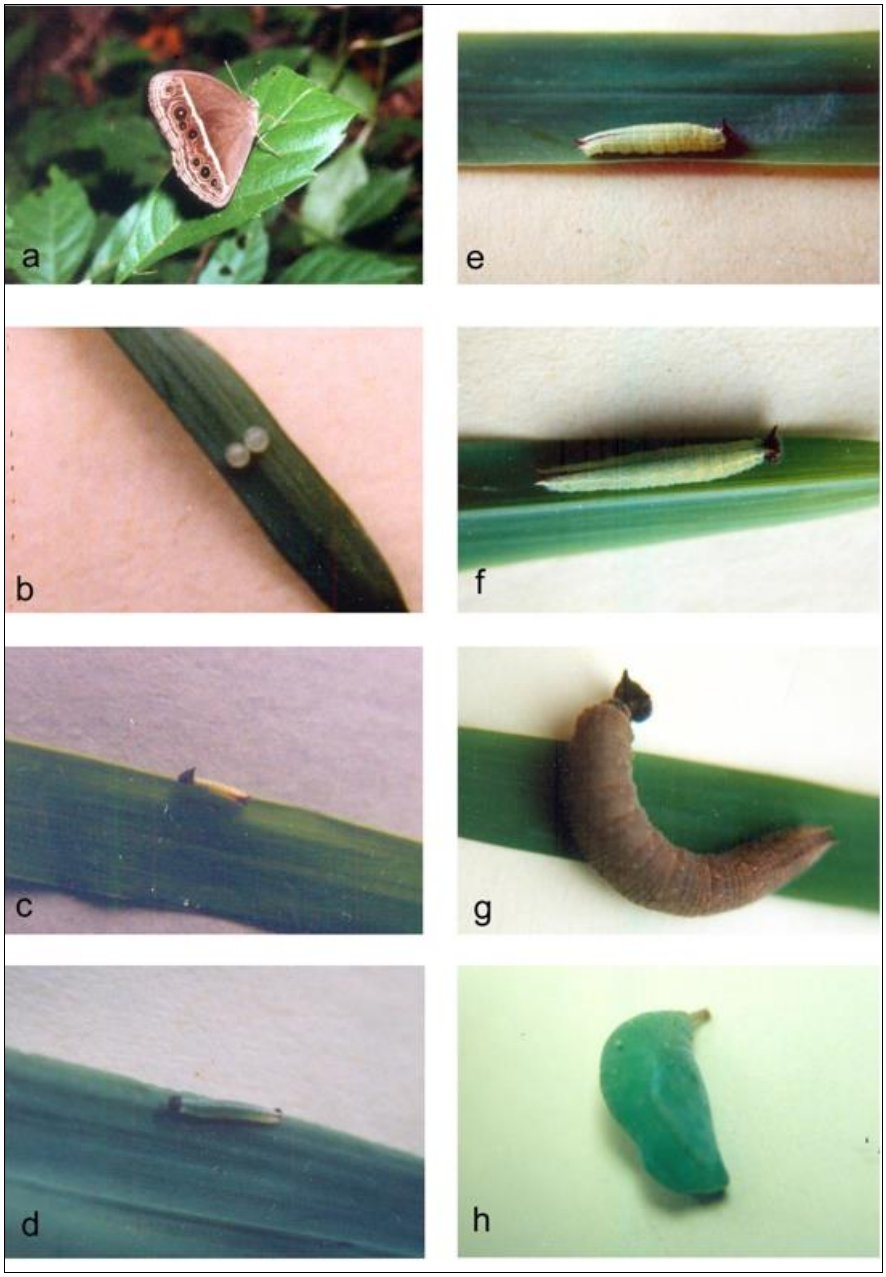

Fig 1: (a) Adult, (b) Eggs, (c) Instar (d) Instar H, (e) Instar III, (f) Instar IV, (g) Instar V, (h) Pupa.

Table 1: Development success of eggs, larvae and pupae of *Mycalesis subdita* on *Brachiaria distachya* leaves in the laboratory.

Life cycle stage	Calendar Months											
	M	J	J	A	S	O	N	D	J	F	M	A
# eggs studied	0	0	2	2	5	10	7	4	3	0	0	0
# larvae hatched	0	0	2	2	4	10	7	3	3	0	0	0
# pupae formed	0	0	1	1	3	8	5	3	2	0	0	0
# adults emerged	0	0	1	1	3	7	4	3	2	0	0	0

Table 2: Population index of different life stages of *Mycalesis subdita* on *Brachiaria distachya* leaves in the field.

Life cycle stage	Calendar Months											
	M	J	J	A	S	O	N	D	J	F	M	A
Adult abundance	-	-	*	**	***	***	***	***	**	*	*	-
# eggs	0	0	2	3	6	13	8	5	3	0	0	0
# larvae	0	0	0	2	3	10	5	3	2	0	0	0
# Pupae	0	0	0	1	2	5	2	2	1	0	0	0

Absent, *Rare, **Less common, *** Common

Table 3: Food consumption, growth and food utilization efficiencies of *Mycalesis subdita* larva fed with *Brachiaria distachya* leaves.

Instar number	Wt. of food ingested (mg)	Wt. of faeces (mg)	Wt. gained by larva (mg)	GR CI (mg/day/mg)		AD (%)	ECD (%)	ECI (%)
I	18.20±04.85	0.56±0.15	1.30±0.10	0.45	6.38	97.25	07.34	07.14
II	30.00±06.94	2.90±0.64	2.70±0.13	0.29	3.27	90.30	09.96	09.00
III	62.10±09.97	6.50±0.86	14.60±0.50	0.42	1.80	89.53	26.25	23.51
IV	204.80±15.52	29.20±4.70	57.10±1.05	0.41	1.49	85.74	32.51	27.88
V	907.66±20.41	253.00±9.74	184.40±7.05	0.22	1.08	72.12	28.16	20.31

5. Conclusion

This study provides valuable insights into the oviposition, larval host plant (*B. distachya*), population index, and larval performance of the Tamil Bushbrown (*M. subdita*) in terms of food consumption, growth, and utilization, as well as the duration of its life cycle from egg to adult emergence. More over the plants consumed by larvae significantly influence the performance of the adult butterflies [27]. The data from this research can be effectively used for the conservation and management of this butterfly species in various settings, including parks, zoos, butterfly houses, and natural fields. Butterfly houses, which are popular zoo exhibits, offer significant educational and conservation benefits [28, 29]. Additionally, the study suggests that rearing larvae in captivity at approximately 28±2 °C can produce a sufficient number of adults for restocking areas where the Tamil Bushbrown populations are low [30].

6. Acknowledgements

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7. References

1. Gunathilagaraj K, Perumal TNA, Jayaram K, Ganesh Kumar M. Field guide. Some South Indian Butterflies. Udhagamandalam: Nilgiri Wildlife & Environment Association; c1998.
2. Mathew G, Soumya KC. Biosystematic study of the Satyrinae (Lepidoptera: Nymphalidae) fauna of Kerala, India. Entomon. 2013;38(2):65-96.
3. Larsen TB. Butterflies in India. New Delhi: Oxford University Press; c1987.
4. Waldbauer GP. The consumption and utilization of food by insects. In: Beament JWL, Treherne JE, Wigglesworth VB, editors. Advances in insect physiology. London and New York: Academic Press; c1968. p. 229-288.
5. Owen DF. Tropical Butterflies. Oxford: Clarendon Press; c1971.
6. Owen DF, Owen J, Chanter DO. Seasonal changes in relative abundance and estimates of species diversity in a family of tropical butterflies. Oikos. 1972;23:200-205.
7. Mathew G, Rahamathulla VK. Studies on the butterflies of Silent Valley National Park. Entomon. 1993;18(3&4):185-192.
8. Mathavan S, Pandian TJ. Effect of temperature on food utilization in the monarch butterfly Danaus chrysippus. Oikos. 1975;26:60-64.
9. Palanichamy S, Ponnuchamy R, Thangaraj T. Effect of temperature on food intake, growth and conversion efficiency of Eupterote mollifera (Insecta). Proc Indian Acad Sci (Anim Sci). 1982;91:417-422.
10. Pathak M, Pizvi PQ. Age specific survival and fertility table Papilio demoleus at different set of temperatures and host plants. Indian J Entomol. 2003;65(1):123-126.
11. Braby MF. Effect of temperature on development and survival in Delias nigrina (Fabricius) (Lepidoptera: Pieridae). Aust J Entomol. 2003;42(2):138-143.
12. Levey DJ, Del Rio CM. It takes guts (and more) to eat fruit: lessons from avian nutritional ecology. Auk. 2001;118:819-831.
13. Fischer K, O'Brien DM, Boggs CL. Allocation of larval and adult resources to reproduction in a fruit feeding butterfly. Funct Ecol. 2004;18:656-663.
14. Slansky F, Scriber JM. Food consumption and utilization. In: Comprehensive Insect Physiology, Biochemistry and Pharmacology. Kerkuit GA, Gilbert LI, editors. Oxford: Pergamon; c1985. p. 85-163.
15. Scriber JM, Feeny P. Growth of herbivorous caterpillars in relation to feeding specialization and to the growth form of their food plants. Ecology. 1979;60:829-850.
16. Pandian TJ, Marian MP. Prediction of assimilation efficiency of Lepidopterans, Proc Indian Acad Sci (Anim Sci). 1986;95:641-665.
17. Yadava PS, Vats LK, Kaushal BR. Food consumption on assimilation and growth in the larvae of *Pieris brassicae* Linn. J Anim Physiol. 1979;26:257-264.
18. Atluri JB, Samatha B, Bhupathi Rayalu M, Sandhya Deepika D, Subba Reddi C. Ecobiology of the common castor butterfly *Ariadne merione merione* (Cramer) (Lepidoptera: Rhopalocera: Nymphalidae). J Res Lepidoptera. 2009;42:18-25.
19. Bhupathi Rayalu M, Tarakeswara Naidu M, Atluri JB, Subba Reddi C. Life history and larval performance of the Joker butterfly, *Byblia ilithyia* (Lep.: Nymphalidae). J Entomol Soc Iran. 2011;31(1):71-85.
20. Hemati SA, Naseri B, Ganbalani GN, Dastjerdi HR, Golizadeh A. Effect of different host plants on nutritional indices of the pod borer, Helicoverpa armigera. J Insect Sci. 2012;12 No. 55.
21. Bhupathi Rayalu M, Krishna Kumari V, Tarakeswara Naidu M, Atluri JB. Life history and larval performance of the Common Leopard butterfly, Phalanta phalantha Drury (Lepidoptera: Rhopalocera: Nymphalidae). Int J Adv Res Sci Technol. 2014;3(3):191-195.
22. Chaithra TN, Udikeri SS, Hugar SV, Akbar SMd. Food consumption and utilization pattern of fall armyworm (Spodoptera frugiperda J.E.Smith) in different genotypes of cotton. J Farm Sci. 2020;33(4):517-521.
23. Bhupathi Rayalu M, Suneetha J. Ecobiology of the Lycaenid Butterfly, *Zizula hylax hylax* Fabricius. In: Madhu V, editor. Forest Resources, Diversity, Utilization and Conservation. New Delhi & Hyderabad: Paramount Publishing House; c2022. p. 15-23.
24. Mathavan S, Bhaskaran R. Food selection and utilization in a danaid butterfly, Oecologia. 1975;18:55-62.
25. Muthukrishnan J. Bioenergetics in insect-plant interactions. Proc Indian Acad Sci (Anim Sci). 1990;99(3):243-255.
26. Krishnan N, Jeyakumar G, Dinakaran S. Consumption

and utilization of senescent flowers by *Mylabris pustulata* (Coleoptera). Uttar Pradesh J Zool. 1997;17(1):60-62.
27. Ebada A, de Roode JC, Majewska AA. Larval diet impacts flight performance in monarch butterflies. Ecol Entomol. 2023;48(5):582-587.
28. Veltman K. How can zoos import and display butterflies for educational purpose in a sustainable way? Int Zoo Yearb. 2009;43:124-130.
29. Mathew G. Conservation of invertebrates through captive breeding: A study with reference to butterflies. Kerala Forest Res Inst: Res Rep no. 220. 2001. ISSN 0970-8130. 66pp.
30. Schultz CB, Dzurisin JD, Russell C. Captive rearing of Puget blue butterflies (Icaricia icarioides blackmorei) and implications for conservation. J Insect Conserv. 2009;13:309-315.

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RESEARCH ARTICLE OPEN ACCESS

Compatible Mappings on a 2-Metric Space

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Abstract: The aim of the present paper is to obtain i) a common fixed point theorem for compatible mappings by using the concept of asymptotic regularity and ii) a common fixed point theorem using the concept of joint reciprocal continuity in 2- metric spaces. A supporting example is also given.

Keywords: common fixed point , Compatible mappings and asymptotic regularity.

Mathematical subject Classification : 47 H 10, 54H25

1. Introduction : Gähler[2] introduced the concept of 2-metric space as a natural generalization of a metric space. Some fixed point theorems in 2-metric spaces are obtained in Iseki[3],Rhoades[5] and Jungck[4]. Gähler[2] introduced the notions of reciprocal continuity and asymptotic regularity for a pair of self maps on a 2-metric space. Using the above concepts Badshah and Gopal Meena[1] proved a fixed point theorem for a pair of self-maps on a 2-metric space using asymptotic regularity.

The present paper is a generalization of a result of Badshah and Gopal Meena([1],Theorem 2).

In this paper, we obtain i) a common fixed point theorem (Th. (2.1)) for compatible mappings by using the concept of asymptotic regularity and ii) a common fixed point theorem (Th. (2.6)) using the concept of joint reciprocal continuity. We start with some definitions.

Definition 1.1 (Gähler[2]): Let X be a non-empty set with real valued function $d: X^3 \to R$ satisfying :

i) For two distinct points $x, y \text{ in } X$, $\text{there exists } z \text{ in } X \text{ such that } d(x, y, z) \neq 0$

ii) $d(x,y,z) = 0$ only if at least two of x, y and z are equal

iii) $d(x,y,z) = d(x,z,y) = d(y,z,x)$ and

iv) $d(x,y,z) \leq d(x,y,u) + d(x,u,z) + d(u,y,z)$ for all x,y,z,u in X.

The function d is called a 2-metric on X and the pair (X,d) is called a 2-metric space.

Definition 1.2 (Gähler[2]) : Let (X,d) be a 2-metric space .

i) A sequence $\{x_n\}$ is said to be convergent to a point x in X if $= 0, \forall a \in X$.

ii) A sequence $\{x_n\}$ is said to be a Cauchy sequence in X if $d(x_m, x_n, a) = 0, \forall a \in X$.

iii) A 2-metric space (X,d) is said to be complete if every Cauchy sequence in X converges to a point in X.

Note: i) In a 2-metric space (X,d), $d: X^3 \to R$ is continuous if

$x_n \to x,\ y_n \to y$ implies $d(x_n, y_n, a) \to d(x,y,a), \forall a \in X$ for $n \to \infty$.

ii) If $x_n \to x$ and $x_n \to y$ as $n \to \infty$ then $x = y$.

Definition 1.3 (Gähler[2]): For self-mappings, S and T of a 2-metric space (X,d), the pair (S,T) is called reciprocally continuous if $d(STx_n, Sx, a) = 0 = \forall a \in X$, whenever $\{x_n\}$ is a sequence in X such that $S x_n = T x_n = x$, for some $x \in X$.

Definition 1.4 (Gähler[2]): For self-mappings , S and T of a 2-metric space (X,d)

i) A sequence $\{x_n\}$ in X is called asymptotically regular with respect to the pair (S,T) if $d(Sx_n, Tx_n, a) = 0\ \forall a \in X$.

ii) The pair (S,T) is called compatible if $d(STx_n, TSx_n, a) = 0\ \forall a \in X$, whenever $\{x_n\}$ is a sequence in X such that $Sx_n = Tx_n = x$, for some $x \in X$.

Definition 1.5: Suppose P, S and T are self maps on a 2-metric space (X,d).The pair (S,T) is said to be joint reciprocal continuous with respect to P if there exists a sequence $\{x_n\}$ in X such that $Sx_n = Tx_n$ and $d(PSx_n, SPx_n, a) = 0$ and $d(PTx_n, TPx_n, a) = 0\ \forall a \in X$.

Note : If $\{x_n\}$ is a sequence in X such that $Sx_n = Tx_n$

and (P,S) and (P,T) are compatible then (S,T) is jointly reciprocally continuous with respect to P.

Notation: $\Phi = \{\varphi: [0,\infty) \to [0,\infty), \phi$ is continous and $\phi(t) < t\ \forall t > 0\}$.

2. Main Results

We begin with our first main result, from this we obtain corollaries of the main result and finally show that the result of Badshah and Gopal Meena[1] follows as a corollary.

Theorem 2.1: Let P, S *and* T be self-mappings of a complete 2-metric space (X, d) satisfying:

$i)\ d(Px, Py, a) \leq \varphi\ (\{\ d(Py, Ty, a)\big(1 + d(Px, Sx, a)\big), d(Px, Sx, a)(1 + d(Py, Ty, a)\}\ )$

$$\forall x, y, a \in X \text{ and } \text{for some } \varphi \in \Phi,$$

$$ii)\ \text{the pair } (P, S) \text{ and } (P, T) \text{ are compatible}$$

$iii)$ there exists a sequence $\{x_n\}$ which is asymptotically regular with respect $(P, S) and\ (P, T)$

$iv)\ S \text{ and } T \text{ are continous}\ \ v)\ \ d \text{ is continous.}$

Then P, S *and* T have a unique common fixed point in X.

Proof: Let $\{x_n\}$ be a sequence in X satisfying $condition\ (iii)$.

By taking $x = x_n \text{ and } y = x_m\ in\ (i)$, we obtain

$$d(Px_n, Px_{m,}a) \leq \varphi\{\ d\big(Px_{m,}, Tx_{m,}, a\big)\big(1 + d(Px_n, Sx_n, a)\big),\ d(Px_n, Sx_n, a)\ \Big(1 + d\ \big(Px_{m,}, Tx_{m,}, a\big)\Big)\}\ ) \qquad (2.1.1)$$

On letting $n \to \infty$ and using condition (iii), we get

$$d(Px_n, Px_m, a) = 0\ \forall a \in X.$$

This implies that the sequence $\{Px_n\}$ is a Cauchy sequence in X, since X is complete with respect to 2-metric d.

This implies

$$Px_n \to z\ ,\ \text{for some } z \epsilon X. \qquad (2.1.2)$$

Now

$$d(Sx_n, z, a) \leq d(Sx_n, z, Px_n) + d(Sx_n, Px_n, a) + d(Px_n, z, a)$$

On letting $n \to \infty$, using condition (iii) and equation (2.1.2), we get

$$d(Sx_n, z, a) = 0\ \forall a \in X.$$

This implies $Sx_n \to z\ in\ X.$ (2.1.3)

Similarly we can obtain

$$Tx_n \to z\ in\ X. \qquad (2.1.4)$$

Since we can write

$$d(PSx_n, Sz, a) \leq d(PSx_n, Sz, SPx_n) + d(PSx_n, SPx_n, a) + d(SPx_n, Sz, a)$$

On letting $n \to \infty$, using the conditions $(ii), (iv) and\ (v)$, we get

$$d(PSx_n, Sz, a) = 0\ \forall a \in X,$$

$$(\because Px_n \to z\ and\ S\ is\ continuous\ implies\ SPx_n \to Sz)$$

This implies $PSx_n \to Sz$. (2.1.5)

Similarly we can prove $PTx_n \to Tz$. (2.1.6)

By taking $x = Sx_n\ and\ y = Tx_n$ in (i), we obtain

$$d(PSx_n, PTx_n, a) \leq \varphi(max\{d(PTx_n, TTx_n, a)(1 + d(PSx_n, SSx_n, a)),$$

$$d(PSx_n, SSx_n, a)(1 + d(PTx_n, TTx_n, a))\}) \quad (2.1.7)$$

From condition (iv) we have $S\ and\ T$ are continuous, applying continuity of $S\ and\ T$ in (2.1.3) and (2.1.4) ,we get

$$SSx_n \to Sz, TTx_n \to Tz\ and\ STx_n \to Sz \quad (2.1.8)$$

On letting $n \to \infty$ in (2.1.7), using (2.1.5),(2.1.6),(2.1.8) and condition (v), we get

$$d(Tz, Sz, a) = 0, \forall a \in X\ .$$

$$This\ implies\ Tz = Sz. \quad (2.1.9)$$

Similarly by taking $x = Tx_n\ and\ y = z\ in\ (i)$, we get

$$d(PTx_n, Pz, a) \leq \varphi(\{d(Pz, Tz, a)(1 + d(PTx_n, STx_n, a), d(PTx_n, STx_n, a)(1 + d(Pz, Tz, a)\}\ )$$

On letting $n \to \infty$, using ((2.1.7),(2.1.8),(2.1.9) and condition(v), we get $d(Tz, Pz, a) = 0, \forall a \in X$.

$$This\ implies\ Tz = Pz. \quad (2.1.10)$$

Therefore $Sz = Tz = Pz.$ (2.1.11)

By taking $x = x_n\ and\ y = z\ in\ (i)$, we get

$$d(Px_n, Pz, a) \leq \{d(Pz, Tz, a)(1 + d(Px_n, Sx_n, a), \quad d(Px_n, Sx_n, a)(1 + d(Pz, Tz, a)\}\ )$$

On letting $n \to \infty$ and using (2.1.2),(2.1.3),(2.1.11) and condition(iv), we get

$d(z, Pz, a) = 0, \forall a \in X\ .This\ implies\ Pz = z.$

Therefore $z\ is\ a\ fixed\ point\ of\ P$. Hence z is a common fixed point of $S, T\ and\ P\ in\ X.$

Suppose if x is common fixed point of $S, T\ and\ P\ in\ X.$ Then it can be easily proved that $x = z$. Hence z is a unique common fixed point of $S, T\ and\ P\ in\ X.$

Now we have the following corollaries of theorem 2.1.

Corollary 2.2: Let P, S and T be self-mappings of a complete 2-metric space (X, d) satisfying:

$$i)\ d(Px, Py, a) \leq \varphi(\{\ d(Py, Ty, a)\big(2 + d(Px, Sx, a)\big),\\ d(Px, Sx, a)(1 + d(Py, Ty, a), d(Px, Sx, a), d(Py, Sy, a)\})$$

$\forall x, y, a \in X$ and for some $\varphi \in \Phi$, and also satisfying condition $(ii), (iii), (iv)$ and (v) of theorem 2.1.

Then P, S and T have a unique common fixed point in X.

Corollary 2.3 : Let P, S and T be self-mappings of a complete 2-metric space (X, d) satisfying:

$$i)\ d(Px, Py, a) \leq \lambda\{\ d(Py, Ty, a)\big(1 + d(Px, Sx, a)\big),\\ d(Px, Sx, a)(1 + d(Py, Ty, a), d(Px, Sx, a), d(Py, Sy, a)\}$$

$\forall x, y, a \in X$, $0 < \lambda < 2$ and also satisfying condition $(ii), (iii), (iv)$ and (v) of theorem 2.1.

Then P, S and T have a unique common fixed point in X.

Corollary 2.4: Let P, S and T be self-mappings of a complete 2-metric space (X, d) satisfying:

$$i)\ d(Px, Py, a) \leq \alpha\{\ d(Py, Ty, a)\big(1 + d(Px, Sx, a)\big),\\ d(Px, Sx, a)(1 + d(Py, Ty, a)\}\ + \beta\ max\{d(Px, Sx, a), d(Py, Sy, a)\}$$

$\forall x, y, a \in X$, α and β are non $-$ negative numbers such that $\alpha + \beta < 1$ and

also satisfying condition $(ii), (iii), (iv)$ and (v) of theorem 2.1.

Then P, S and T have a unique common fixed point in X.

Corollary 2.5: Let P, S and T be self-mappings of a complete 2-metric space (X, d) satisfying:

$$i)\ d(Px, Py, a) \leq \alpha\beta\{d(Px, Sx, a) + d(Py, Sy, a)\}$$

$\forall x, y, a \in X$, α and β are non $-$ negative numbers such that $\alpha + \beta < 1$ and also satisfying condition $(ii), (iii), (iv)$ and (v) of theorem 2.1.

Then P, S and T have a unique common fixed point in X.

The following result due to Badshah and Gopal Meena[1] is a corollary of the above result.

Corollary 2.6 (Badshah and Gopal Meena[1],Theorem 2): Let P, S and T be self-mappings of a complete 2-metric space (X, d) satisfying:

$$i)\ d(Px, Py, a) \leq \alpha\frac{d(Py, Ty, a)\big(1 + d(Px, Sx, a)\big)}{1 + d(Sx, Ty, a)}$$

$$+\beta\{d(Px, Sx, a)\ + d(Py, Sy, a\}$$

$$\forall x, y, a \in X\ , \alpha\ and\ \beta\ are\ non-negative\ numbers\ such\ that\ \alpha + \beta < 1,$$

and also satisfying condition $(ii), (iii), (iv) and\ (v)$ of theorem 2.1.

Then $P, S\ and\ T$ have a unique common fixed point in X.

Now we state our second main result which uses the concept of joint reciprocal continuity.

Theorem 2.7: Let $P, S\ and\ T$ be self-mappings of a complete 2-metric space (X, d) satisfying:

$$i)\ d(Px, Py, a) \leq \varphi(\{\, d(Py, Ty, a)\big(1 + d(Px, Sx, a)\big), \quad d(Px, Sx, a)(1 + d(Py, Ty, a)\}\,)$$

$$\forall x, y, a \in X\ and\ \ for\ some\ \varphi \in \Phi,$$

$$ii)\ S\ and\ T\ are\ continous$$

$$iii)\ d\ is\ continous.$$

$$iv)\ (S, T)\ \ is\ joint\ reciprocal\ \ continous\ \ w.r.t.\ \ P\ in\ X.$$

Then $P, S\ and\ T$ have a unique common fixed point in X.

Proof: From $condition(iv)$ there exists a sequence $\{x_n\}\ in\ X\ such\ \ that$

$$Sx_n = \ Px_n = \ Tx_n = \ \ z\ for\ some\ z \in X \qquad (2.5.1)$$

and

$$d(PSx_n, SPx_n, a)\ = 0 = d(PTx_n, TPx_n, a)\ \forall a \in X \quad (2.5.2)$$

Applying $condition\ (ii)$ in equation (2.5.1) and using this in the equation (2.5.2),we get

$$PSx_n\ \rightarrow Sz\ and\ PTx_n \rightarrow Tz. \qquad (2.5.3)$$

By taking $x = Sx_n, y = Tx_n$ in (i) and letting $n \rightarrow \infty$, using conditions (ii) , (iii) and (2.5.2) and (2.5.3), we get $Sz = Tz$. (as derived in theorem 2.1)

Similarly taking $x = Tx_n\ and\ y = z\ in\ (i)$ and letting $n \rightarrow \infty$, we get

$Pz = Tz$ (as derived in theorem 2.1).Therefore $Sz = Pz = Tz$.

Taking $x = x_n\ and\ y = z\ in\ (i)$ and letting $n \rightarrow \infty$, we get $z = Pz$.

This is $z\ is\ a\ fixed\ point\ of\ P$. Hence z is a common fixed point of $S, T\ and\ P\ in\ X$. Suppose if x is common fixed point of $S, T\ and\ P\ in\ X$. Then it can be easily proved that $x = z$. Hence z is a unique common fixed point of $S, T\ and\ P\ in\ X$.

Now we have the following corollaries of theorem 2.6.

Corollary 2.8 : Let P, S *and* T be self-mappings of a complete 2-metric space (X, d) satisfying: condition (i) of corollary (2.2) and conditions $(ii), (iii)$ *and* (iv) of theorem (2.7).

Corollary 2.9: Let P, S *and* T be self-mappings of a complete 2-metric space (X, d) satisfying: condition (i) of corollary (2.3) and conditions $(ii), (iii)$ *and* (iv) of theorem (2.7).

Then P, S *and* T have a unique common fixed point in X.

Corollary 2.10: Let P, S *and* T be self-mappings of a complete 2-metric space (X, d) satisfying: conditions (i) of corollary(2.4) and also conditions $(ii), (iii)$ *and* (iv) of theorem (2.6).

Then P, S *and* T have a unique common fixed point in X.

Corollary 2.11: Let P, S *and* T be self-mappings of a complete 2-metric space (X, d) satisfying: conditions (i) of corollary (2.5) and also conditions $(ii), (iii)$ *and* (iv) of theorem (2.7).

. Then P, S *and* T have a unique common fixed point in X.

Corollary 2.12: Let P, S *and* T be self-mappings of a complete 2-metric space (X, d) satisfying:

conditions (i) of corollary 2.7 and also the conditions $(ii), (iii)$ *and* (iv) of theorem (2.7).

Then P, S *and* T have a unique common fixed point in X.

Example 2.11:

Let $X = R \times R$ *for* $A, B \in X$, denote the Euclidean distance A *and* B *by* $|A - B|$.

Define $d: X^3 \to R$ *by* $d(A, B, C) = \{|A - B|, |B - C|, |C - A|\}$. Then (X, d)

is a complete 2-metric space. Let $A_0 \in X$. Define the mappings

P, S *and* T *on* X as $P(A) = A_0 \; \forall A \in X$ *and* $S = T = I$.

Define $\varphi(t) = \eta\, t, 0 < \eta < 1$ *then* $\varphi \in \Phi$. Then P, S *and* T satisfy all

the properties of Theorem 2.1 and Theorem 2.7 and A_0 is the unique common

fixed point of P, S *and* T *in* X.

Acknowledgment: Thankful to Research Guide for support of this work.

References

1) Badshah,V.H. and Gopal Meena: Common fixed point for compatible mappings on 2-metric space, Journal of Indian Acad. Math.Vol 31, No.1 (2009), 23-30.

2) Gähler,S.: 2-metrische Räume und ihre toplogische structure, Math.Nachr.26(1963-64),115-148.

3) Iseki,K: Fixed point theorem in 2-metric spaces . Math. Sem. Notes 3(1975),133-136.

4) Jungck,G.: Compatible mappings and common fixed points, Internat. J.Math. and Math.Sci. 9(1986), 771-779.

5) Rhoades,B.: Contraction type mappings on a 2-mertic space, Math.Nach, 91(1979),151-155.

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Enhancement in the Magnetic Properties of Yttrium Orthoferrite Materials by the Addition of $BaO–Bi_2O_3–B_2O_3$ Glass Sintering Aid

*Sadik Ahmed Mohammed and Rama Sekhara Reddy Dachuru**

The addition of powdered $BaO–Bi_2O_3–B_2O_3$ (BBBO) glass (0.25–1.5 wt%) to yttrium orthoferrite materials ($YFeO_3$) powder facilitates an increased crystallite size, resulting in improved magnetic properties. The required $YFeO_3$ (YFO) materials are synthesized through the sol–gel route using tartaric acid as a chelating agent, while BBBO glass is obtained via the conventional melt-quenching technique. The crushed glass is added to YFO powders in different wt % and compacted at room temperature, subsequently; the compacted samples are sintered at 1000 °C for 3 h. The X-ray powder diffraction studies infer that a maximum 1.0 wt% of BBBO glass is incorporated into YFO without showing any impurity phase. The optical bandgap of each sample is calculated using the UV data with the help of the Kubelka–Munk and Tauc relation, decreasing from 2.10 to 2.04 eV with an increase of BBBO content from 0 to 1.0 wt% in YFO. The highest magnetization value (4.02 emu g^{-1}) is observed with 1.0 wt% BBBO added in YFO surpassing pure YFO and other BBBO-added YFO samples. In conclusion, the improved magnetization value of the 1.0 wt% BBBO added in the YFO sample can be potentially utilized in different applications.

1. Introduction

The extensive range of physical features exhibited by ferrite or multiferroic nanostructure materials has drawn significant attention in the realm of research due to their device applications.[1] These nanostructured ferrites materials are suitability in various fields, including magneto-optical devices, removal of organic pollutants from industrial wastewater, biomedical, gas sensors, capacitors, microwave electronic devices, spintronic devices, and many more applications.[2–5] Among them, $YFeO_3$ (YFO) stands out for its versatility in different applications owing to its multiferroic behavior. YFO exhibits hexagonal and orthorhombic crystal structures, with the orthorhombic crystal structure being particularly favorable for magnetic applications. With its soft ferromagnetic nature with a high magnetization value and a relatively low energy bandgap (1.8–2.6 eV), YFO emerges as a desirable material for photocatalysis and magneto-optical applications.[6,7]

YFO nanomaterials have been synthesized and reported in the literature using various synthetic routes, such as conventional solid-state, hydrothermal, soft chemical, wet-chemical, one-step autocombustion method, mechanochemical, and a few more methods.[8–22] Theoretical investigations have delved into the differences in multiferroic properties between hexagonal and orthorhombic ion-doped YFO nanoparticles.[23] Earlier research reports have highlighted the alterable structural and physical characteristics of YFO through changes in particle size, chelating agent, or adding magnetic or nonmagnetic ions at A-sites or B-sites.[15,16,18,23–27] For instance, the altered magnetic properties of single phase of $Y_{1-x}Sc_xFeO_3$ ($x = 0$, 0.5, and 1) and $Y_{1-x}A_xB_yFe_{1-y}O_3$ (where $A = Gd^{3+}$, Nd^{3+}, Sm^{3+} and $B = Ti^{4+}$) nanoparticles have been observed.[15,16,27] Apart from these, improved magnetic properties of YFO nanomaterial obtained from tartaric acid (as a chelating agent) compared to YFO nanomaterial obtained from citric acid, oxalic acid, and sucrose have been reported.[25] However, to the best of the authors' knowledge, no reports on the glass phase-assisted sintering of YFO nanomaterials have been discovered in the literature. Glass melts or liquefies above its glass transition temperature, which aids in the effective diffusion of ionic or molecular units, leading to densification and the formation of large grains at low temperatures. The low melting points of the glasses made of borate[28] led to their selection in the investigation. This study focuses on the use of $BaO–Bi_2O_3–B_2O_3$ (BBBO) glass to examine its impact on the physical properties including optical and magnetic properties of YFO materials. The primary objective is to improve the magnetization value of YFO nanomaterials obtained from the sol–gel techniques using tartaric acid as a chelating agent in combination of with BBBO glass as a sintering aid. Different wt% of BBBO glass were incorporated into YFO, namely, 0 wt% (YFOBBBO-0), 0.25 wt% (YFOBBBO-25), 0.5 wt% (YFOBBBO-50), 1.0 wt% (YFOBBBO-100), and 1.5 wt% (YFOBBBO-150). A systematic investigation was conducted on their structural, optical, and magnetic properties.

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2. Results and Discussion

The typical room temperature X-ray powder diffraction (XRD) pattern of the YFOBBBO-0, YFOBBBO-25, YFOBBBO-50, YFOBBBO-100, and YFOBBBO-150 samples is depicted in **Figure 1**. Using the standard JCPDS card [98-008-0866], the obtained XRD pattern was indexed to an orthorhombic structure with *Pmma* (space group: 62). The diffraction peaks 2θ at ≈26.103, 32.109, 33.256, 34.049, 39.652, 47.440, 47.921, 53.584, 57.846, and 79.656 could be indexed to (111), (200), (121), (002), (022), (202), (040), (141), (240), and (204) (enlarged view of XRD 2θ from 15–35, 35–55, and 55–80 in **Figure 2**a–c). The samples YFOBBBO-0, YFOBBBO-25, YFOBBBO-50, and YFOBBBO-100 exhibited pure phase without any secondary or unreacted impurity phase. However, the sample YFOBBBO-150 shows a few impurity phases, which are indexed by * and # in Figure 2a. Furthermore, we performed the Rietveld analysis to estimate the lattice parameters of the YFOBBBO-0 and YFOBBBO-100 samples, and thus obtained refinement graphs are depicted in **Figure 3**. The χ^2 values were found to be below 3, which indicate that the fitting was satisfactory. The obtained lattice parameters along with reliability factors of the profile fit of these samples are mentioned in **Table 1**. To do a crystallite size and strain study based on various θ positions, we used the Williamson–Hall (W–H) equation [$\beta_{hkl}\cos\theta = \frac{K\lambda}{L} + 4\varepsilon\sin\theta$]. For all samples (pure phase) under this study, the W–H plots are depicted in **Figure 4**a–d with 4 $\sin\theta$ along the x-axis and $\beta_{hkl}\cos\theta$ along the y-axis. The strain (ε) was determined from the slope of the linear fit to the data, and the crystallite size (D) was computed from the y-intercept. The W–H approach presupposes that the strain is identical and isotropic in all crystallographic orientations. The obtained D and ε values for the YFOBBBO-0, YFOBBBO-25, YFOBBBO-50, and YFOBBBO-100 samples were 184, 209, 242, and 298 nm and 0.274, 0.292, 0.312, and 0.325, respectively. These obtained D

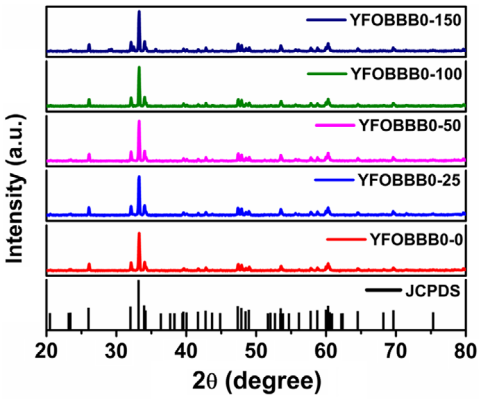

Figure 1. Room temperature XRD patterns of YFOBBBO-0, YFOBBBO-25, YFOBBBO-50, YFOBBBO-100, YFOBBBO-150, and JCPDS data of YFO.

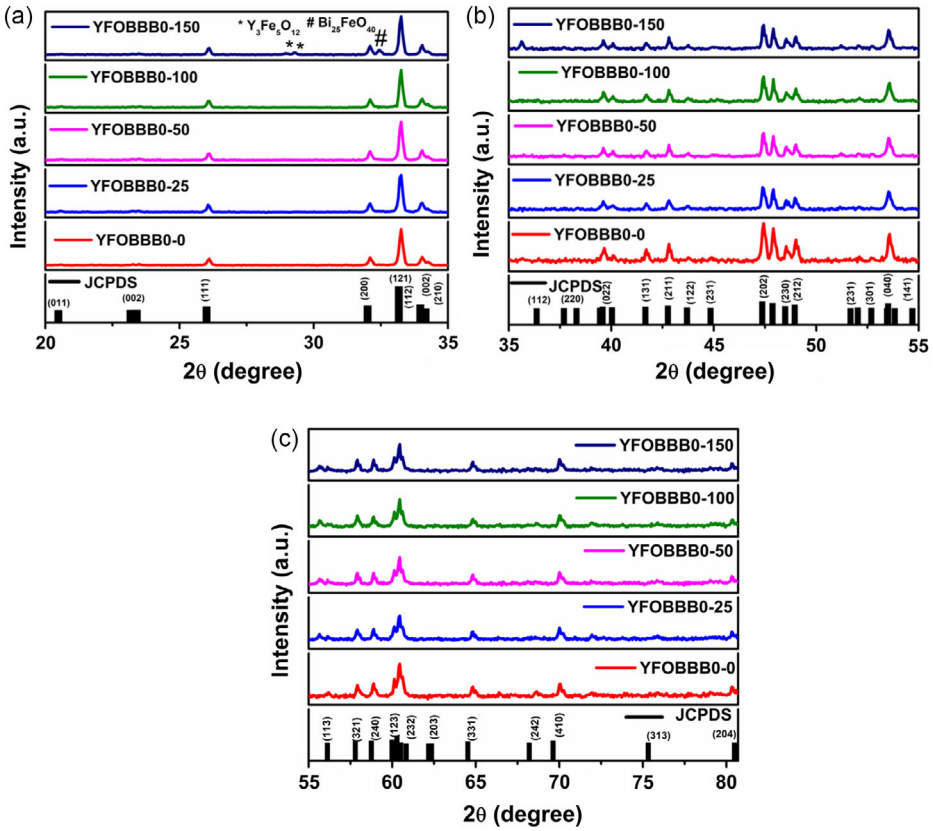

Figure 2. Enlarged view of room temperature XRD patterns: a) 2θ, 20–35 (degree), b) 2θ, 35–55 (degree), and c) 2θ, 55–80 (degree) of YFOBBBO-0, YFOBBBO-25, YFOBBBO-50, YFOBBBO-100, YFOBBBO-150, and JCPDS data of YFO.

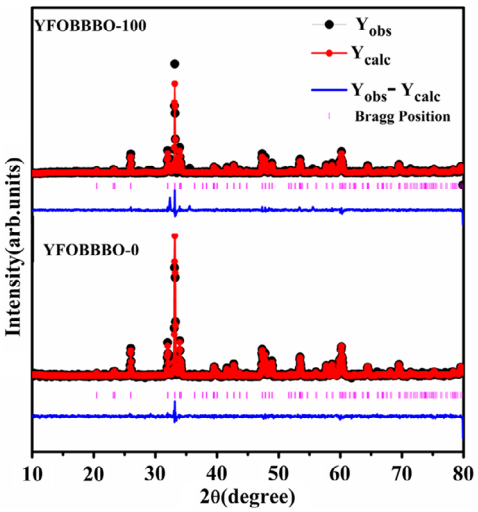

Figure 3. Refinement graphs of YFOBBBO-0 and YFOBBBO-100 samples obtained from Rietveld analysis.

Table 1. Lattice parameters and reliability factors of profile fit for YFOBBBO-0 and YFOBBBO-100 samples.

Name of the sample	Reliability factors of profile fit			Lattice parameters [Å]		
	R_P [%]	R_{wP} [%]	GOF	*a*	*b*	*c*
YFOBBBO-0	2.89	2.74	6.55	5.5948	7.6034	5.2851
YFOBBBO-100	2.21	2.32	6.03	5.5972	7.6061	5.2863

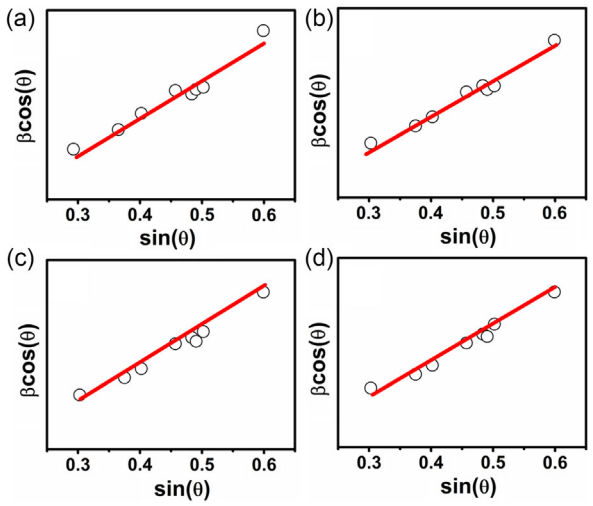

Figure 4. *W–H* plots: a) YFOBBBO-0, b) YFOBBBO-25, c) YFOBBBO-50, and d) YFOBBBO-100 samples.

values indicate that the crystalline nature of the sample is increasing with an increase of BBBO content in the YFO.

Figure 5 presents the room temperature Raman spectra in the range of 100–1500 cm^{-1} for BBBO glass added to YFO samples. It is well established in the literature that among the 24 Raman active modes ($7A_g + 5B_{1g} + 7B_{2g} + 5B_{3g}$), the 12 modes were the first orders for YFO orthorhombic structure. Here, we assigned

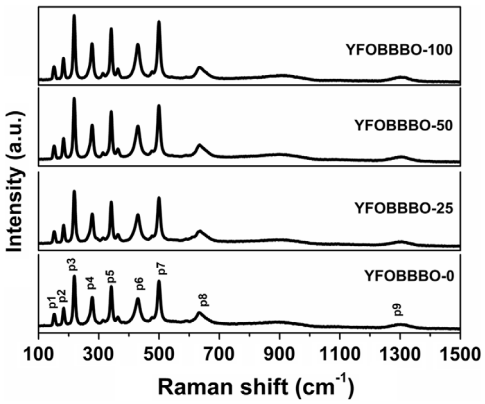

Figure 5. Room temperature Raman spectra of YFOBBBO-0, YFOBBBO-25, YFOBBBO-50, and YFOBBBO-100 material in the region of 100–1500 cm^{-1}.

the 9 strong modes (p1, p2, p3, p4, p5, p6, p7, p8, and p9) for the BBBO glass added to YFO samples, following the orthorhombic crystal structure of $NdFeO_3$.[29] The first two bands or peaks (p1 ≈ 152 and p2 ≈ 183 cm^{-1}) were observed in the region of 100–200 cm^{-1} which is due to the vibrational modes of yttrium ion. Three different characteristic bands (p3 ≈ 219, p4 ≈ 277, and p5 ≈ 341 cm^{-1}) were observed in the region of 200–400 cm^{-1}. The band p3 is attributed to Fe^{3+} ions vibration, and bands p4 and p5 are due to the magnetic Fe^{3+} ions excitation. Two bands (p6 ≈ 429 and p7 ≈ 499 cm^{-1}) were observed in the region of 400–600 cm^{-1}, and these are responsible for the excitation of magnetic Fe^{3+} ions. In the region of 600–700 cm^{-1}, the characteristic of the Fe—O bond (p8 ≈ 637 cm^{-1}) was observed. The vibration of the magnetic Fe^{3+} ions band (p9 ≈ 1303 cm^{-1}) was also observed in the Raman spectrum.[9,30] Here, the observed Raman bands were well matched with the earlier reported orthorhombic crystal structure of YFO material.[31,32] Furthermore, the full width half maxima (FWHM) of each sample was determined using the Gaussian fit, and the obtained FWHM of the corresponding peaks was mentioned in **Figure 6**a–i. Here, we observed the decrease of FWHM with an increase of BBBO glass in YFO materials, which leads to an increase in crystallite size.[33] Furthermore, the blueshift of yttrium ion vibrational modes (p1 and p2) and redshift of Fe—O bond (p8) were observed. The redshift of the Fe—O bond indicates a change in bond length between Fe and O atoms, resulting in a change of polarization. As a result, an improvement in magnetization value was observed, explained by magnetic properties.

To estimate the magnetization values of YFOBBBO-0, YFOBBBO-25, YFOBBBO-50, and YFOBBBO-100 samples, magnetization hysteresis (*M–H*) loops were recorded at room temperature, applying an applied field up to 1.5 T. The recorded *M–H* loops for all the samples in this study are depicted in **Figure 7**a. An enlarged view of the *M–H* loops from −0.2 to 0.2 kOe is provided in Figure 7b for clear visibility of the coercive field of all the samples. The samples exhibited the net magnetic moment, and the obtained magnetization (M_s) values were 3.57, 3.64, 3.79, and 4.02 emu g^{-1} for YFOBBBO-0, YFOBBBO-25,

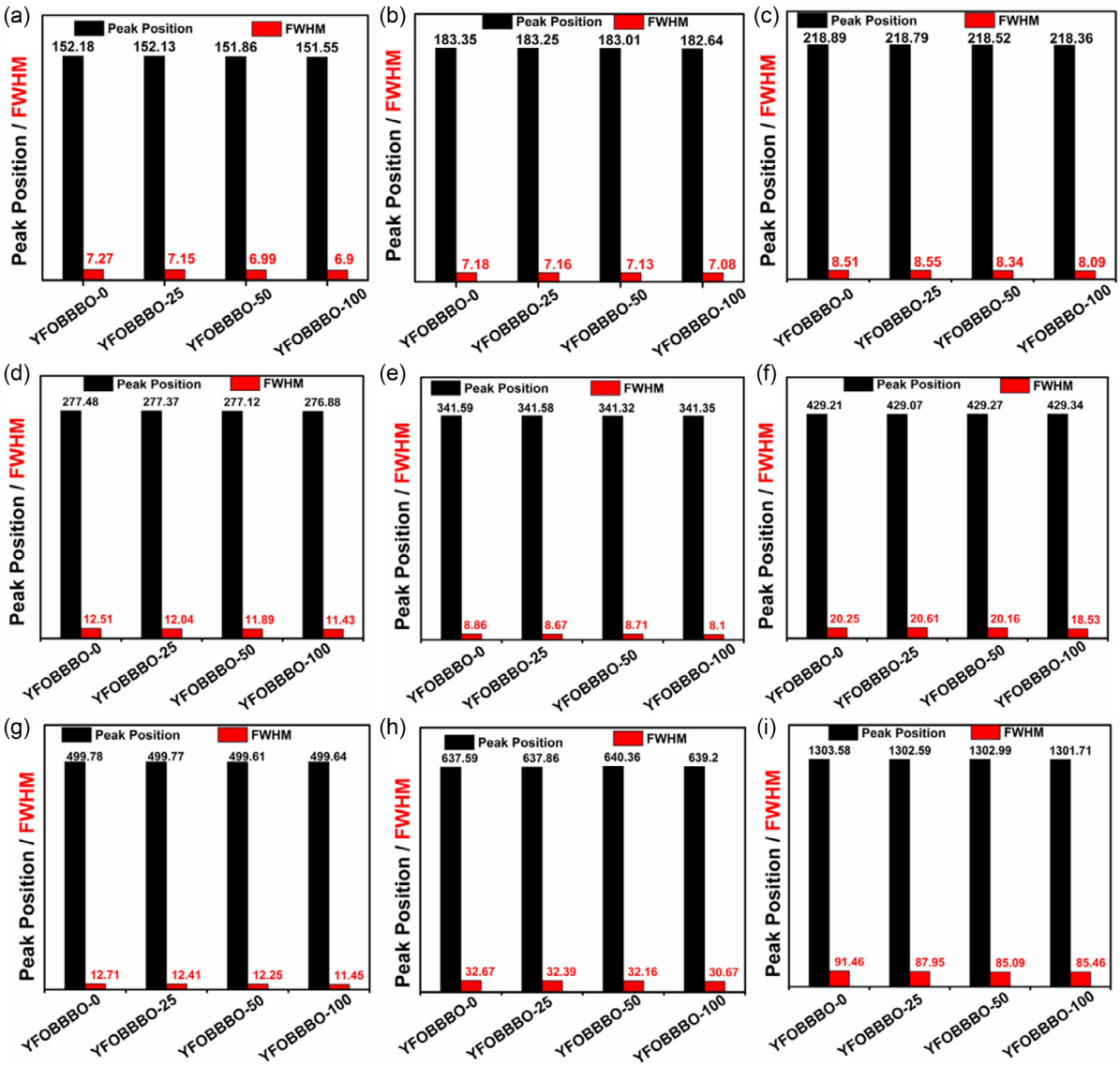

Figure 6. Peak position and FWHM of YFOBBBO-0, YFOBBBO-25, YFOBBBO-50, and YFOBBBO-100 material: a) p1, b) p2, c) p3, d) p4, e) p5, f) p6, g) p7, h) p8, and i) p9.

YFOBBBO-50, and YFOBBBO-100, respectively (Figure 7c). However, the coercive field (Oe) values for all the samples in this study are nearly similar (41.67 Oe). Magnetization values and coercive field are influenced by different factors, such as particle size, synthesis condition, chelating agent, calcination temperature, and a few more factors.[6,18,32,34–38] Through Raman spectroscopy, we observed the change in the Fe—O bond length (red Raman shift at p8) and the increase in particle size (decrease of FWHM); these factors are primarily responsible for the improvement of magnetization value. The coercive field is also crucial for certain applications. For YFO material, a decreased coercive field was observed with an increase of magnetization values (in the case of Sr^{+2}, Ni^{+3}, Bi^{+3}, and rare earth elements doped YFO material) as well as an increase of crystallite size.[15,16,18,19,39] Magnetization values of YFO reported in the various form such as of crystals, polycrystalline material, and nanomaterials from the literature,[11,18,34,36,40–42] along with the present study, are provided in **Table 2** for comparison purposes. Therefore, we suggest that the BBBO glass sintering aid is a promising candidate to improve the magnetization values of YFO materials without effecting their coercive field.

Figure 8 demonstrates the optical reflectance spectrum of YFOBBBO-0, YFOBBBO-25, YFOBBBO-50, and YFOBBBO-100 samples as a function of wavelength (nm) versus reflectance (%) in the region of 350–825 nm. An observed decrease in reflectance (%) with an increase in BBBO content in the YFO sample could be attributed to the increase in particle size. All the samples show less than 10% of reflectance in the region of 350–475 nm (marked region in red color), which suggests the synthesized materials' ability to absorb the light in the visible spectrum.

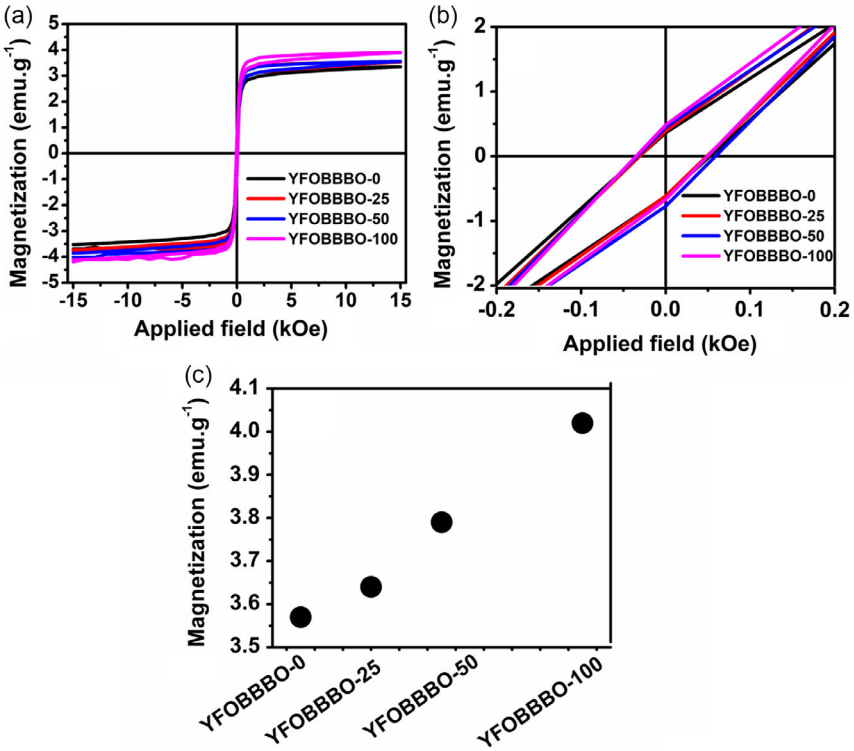

Figure 7. a) *M–H* loops of YFOBBBO-0, YFOBBBO-25, YFOBBBO-50, and YFOBBBO-100 samples, b) enlarged view of *M–H* loops (−0.2 to 0.2 kOe), and c) comparison of magnetization values as function of YFOBBBO-0, YFOBBBO-25, YFOBBBO-50, and YFOBBBO-100.

Table 2. Comparative study of magnetization values of YFO single crystal, polycrystalline material, nanomaterials along with present study.

Sr. no.	Materials [ref. no.]	Method	Nature of material	Magnetization value [emu g^{-1}]
1.	YFO[40]	Floating zone method	Single crystal	0.18
2.	YFO[41]	Floating zone method	Single crystal [(100) wafer]	0.81
3.	YFO[42]	Solid-state reaction	Polycrystalline (1.9 μm)	2.17
4.	YFO[18]	Sol–gel	Polycrystalline (2.1 μm)	2.43
5.	YFO[36]	Sol–gel	Nanomaterials (176 nm)	0.38
6.	$Y_{0.85}Sm_{0.15}FeO_3$[36]	Sol–gel	Nanomaterials (106 nm)	1.05
7.	YFO[11]	Sol–gel autocombustion	Nanomaterials (88 nm)	0.45
8.	YFO[34]	Combustion	Nanomaterial (73 nm)	1.64
9.	LKBOYFO-0 [Present study]	Sol–gel	Polycrystalline (370 nm)	3.57
10.	LKBOYFO-100 [Present study]	Sol–gel followed by solid-state	Polycrystalline (870 nm)	4.02

Apart from this, the electronic transition between the oxygen atoms 2*p* states (valance band) to 3*d* states of Fe (conduction band) atom was observed in the region of 570–670 nm (marked region in blue color) for all the samples.[43]

The optical bandgap of a material is very important from the application point of view, especially photocatalysis applications point of view of low energy bandgap is more appropriate. Using reflectance spectra, we computed the optical bandgap of the material employing the Tauc method.[44] The bandgap was assessed by inferring the linear portion of $h\omega$ versus $(h\omega \times F_{KM})^2$ from **Figure 9**, where h is the plank constant, υ is the frequency, and F_{KM} is the Kubelka–Munk function. The estimated energy bandgap was found to be 2.10, 2.07, 2.05, and 2.04 eV for YFOBBBO-0, YFOBBBO-25, YFOBBBO-50, and YFOBBBO-100, respectively. Notably, the calculated optical bandgap is smaller than that of other ceramic materials,[45–49] such as $BaTiO_3$ (3.28 eV), $BiFeO_3$ (2.67 eV), $FeCr_2O_4$ (2.90 eV), $CaCu_3Ti_4O_{12}$ thin films (3.79–3.11 eV), $LiNbO_3$ (3.78 eV), and $CoCr_2O_4$ (3.10 eV). This study suggests that materials with a smaller bandgap, as investigated here, have the potential to be viable candidates for photocatalysis applications compared to the mentioned ceramic materials.[46,50]

To view the morphology and particle size of the YFOBBBO-0 and YFOBBBO-100 (high magnetization value), the scanning

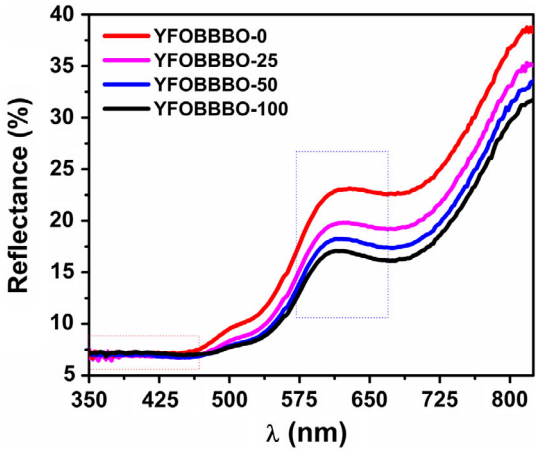

Figure 8. Reflectance spectra of YFOBBBO-0, YFOBBBO-25, YFOBBBO-50, and YFOBBBO-100.

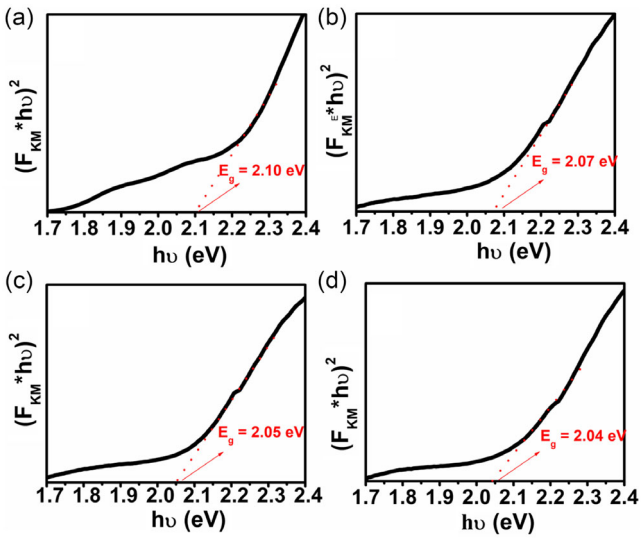

Figure 9. Tauc plots for a) YFOBBBO-0, b) YFOBBBO-25, c) YFOBBBO-50, and d) YFOBBBO-100.

electron microscopy (SEM) investigation was carried out on the surface of the samples. Because the samples are naturally electrically nonconducting, they were sputtered with platinum before SEM studies to prevent the surface charge. The surface morphology (regular) of these respective compounds is presented in **Figure 10**a,b. The standard ASTM line intercept method was adopted to estimate the average particle sizes and it was found to be 370 nm (YFOBBBO-0) and 820 nm (YFOBBBO-100). The histogram of each sample was inserted in their respective SEM images.

3. Conclusions

In this study, we optimized the wt% of BBBO glass as a sintering aid in YFO nanomaterials based on their structural and desired magnetic properties. The structural analysis of the synthesized compounds revealed a phase-pure orthorhombic structure up to 1 wt% of BBBO glass sintering aid. The change in Fe—O bond length was observed through Raman analysis. The calculated optical bandgap was found to be smaller than that of well-known oxide materials, like $BaTiO_3$, $BiFeO_3$, $CaCu_3Ti_4O_{12}$ thin films, and $CoCr_2O_4$. Surface morphology and average particle size were estimated through SEM analysis. The highest magnetization value along with a similar coercive field was observed from the YFOBBBO-100 sample when compared to the YFOBBBO-0, YFOBBBO-25, and YFOBBBO-50 samples, respectively. The optimal composition of BBBO in YFO nanomaterial is thus identified as a superior glass sintering aid for current-generation real-time applications.

4. Experimental Section

Materials and Methods: High purity of Y_2O_3 (99.99%, Ultrafunction Enterprise Co. Ltd.), $Fe(NO_3)_3{\cdot}9H_2O$ (98%, SDFCL), and (+)-$(CHOH{\cdot}COOH)_2$ (99.5%, Qualigens) were used as starting materials for the synthesis of YFO nanomaterials. To begin with, the required amount of Y_2O_3 (0.5 mol ratio with respect to Fe $(NO_3)_3{\cdot}9H_2O$) was dissolved in a HNO_3 solution (3 mol of HNO_3 (12 mL) and 1.5 mol of H_2O (5 mL)) at 80 °C for 30 min. The temperature of the solution was brought to room temperature when the clear solution was formed, and then 1.0 mol ratio of Fe $(NO_3)_3{\cdot}9H_2O$ solution (15 mL) was added to the above solution under continuous stirring. Subsequently, a tartaric acid solution

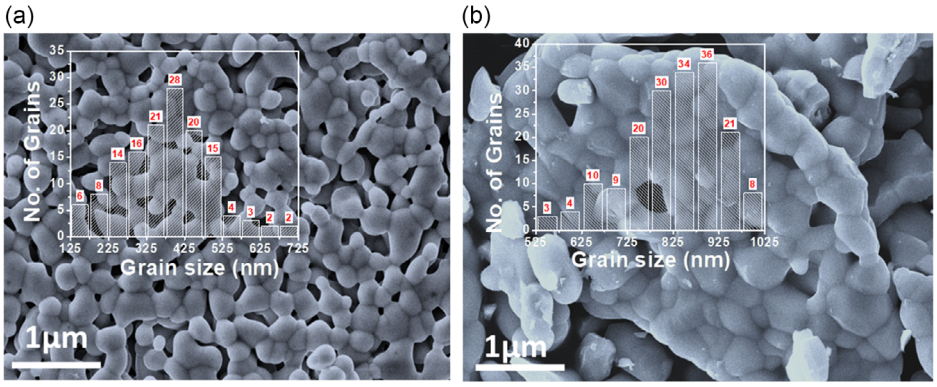

Figure 10. SEM images of a) YFOBBBO-0 and b) YFOBBBO-100 (inset shows the histogram of the particle size distribution of each sample).

(10 mL) as a chelating agent (2.0 mol ratio) was added to the above solution and stirred for 1 h at room temperature. Drop by drop of ammonium solution (25%) was added to the above solution to maintain the pH of ≈6.5–7 with continuous stirring at room temperature. The solution was heated at 120 °C with continuous stirring to remove the water molecule in the solution. At this temperature, water molecule was evaporated and formed the gelation. Then the obtained gel was dried and heated at 250 °C to achieve the YFO precursor. Then the obtained precursor was calcined at 900 °C for 3 h to obtain a pure phase of YFO nanomaterial.[25] However, the conventional melt-quenching technique was used to fabricate the BBBO glasses. To prepare BBBO glasses, the suitable amounts of $BaCO_3$, $Bi(NO_3)_3{\cdot}5H_2O$, and H_3BO_3 were weighed and mixed with acetone using mortar and pestle for 1 h. This mixture was taken in a platinum crucible and melted at 950 °C, and then the melt was quenched to room temperature. The obtained as-quenched glass was crushed into a fine powder and added to YFO nanomaterials in different wt% (0, 0.25, 0.5, 1.0, and 1.5). The mixture of these powders was ball-milled in an ethanol medium for 5 h. The obtained mixed powders were dried and uniaxially pressed into pellets (10 mm diameter and ≈1.5 mm thickness). The pressed pellets were sintered in air at 1000 °C for 3 h with heating and cooling rates of 5 °C min^{-1} using a Thermolyne furnace.

Characterization Techniques: The XRD technique (Cu Kα radiation, $\lambda = 0.154$ nm) (PANalytical Multifunctional X'PertXRD) was used to identify the phase purity of each sample under this study with a scanning rate of 2° min^{-1} at room temperature. The morphology and grain size of samples were estimated using the SEM (JEOL-JSM-IT300LV). Raman microscope (DXR model, Thermo Fischer Scientific) was used to identify the dominant Raman vibrational modes of each sample under this study at room temperature. For this measurement, the laser excitation-centered wavelength at 780 nm with a laser power of 3 mW was used. UV–vis NIR spectrophotometer (Perkin-Elmer Lambda 750 UV/vis/NIR spectrophotometer) was used to record the absorption spectra of each sample under this study in the wavelength range of 200–800 nm. The bandgap of each sample under this study was computed using the diffuse reflectance spectrum with the help of the Kubelka–Munk function. The magnetic properties measurement was carried out by using vibrating sample magnetometer (VSM) (Model EZ9, MicroSense, USA).

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Conflict of Interest

The authors declare no conflict of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Keywords

bandgap, glasses, magnetization, tartaric acid, YFO

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[1] J.-L. Ortiz-Quiñonez, S. Das, U. Pal, *Prog. Mater. Sci.* **2022**, *130*, 100995.
[2] C. W. Nan, M. I. Bichurin, S. Dong, D. Viehland, G. Srinivasan, *J. Appl. Phys.* **2008**, *103*, 031101.
[3] N. A. Spaldin, *MRS Bull.* **2009**, *42*, 385.
[4] J. Mao, Y. Sui, X. Zhang, Y. Su, X. Wang, Z. Liu, Y. Wang, R. Zhu, Y. Wang, W. Liu, J. Tang, *Appl. Phys. Lett.* **2011**, *98*, 192510.
[5] N. Suo, A. Sun, L. Yu, Z. Zuo, X. Pan, W. Zhang, X. Zhao, Y. Zhang, L. Shao, *J. Mater. Sci.: Mater. Electron.* **2021**, *32*, 246.
[6] N. T. K. Chung, N. A. Tien, B. X. Vuong, *Chem. Pap.* **2022**, *76*, 923.
[7] N. Singh, J. Y. Rhee, S. Auluck, *J. Korean Phys. Soc.* **2008**, *53*, 806.
[8] S. Madolappa, B. Ponraj, R. Bhimireddi, K. B. R. Varma, *J. Am. Ceram. Soc.* **2017**, *100*, 2641.
[9] Y. Ma, M. Chen, Y. Q. Lin, *J. Appl. Phys.* **2008**, *103*, 124111.
[10] X. Yuan, Y. Sun, M. Xu, *J. Appl. Phys.* **2012**, *111*, 053911.
[11] W. Zhang, C. Fang, W. Yin, Y. Zeng, *Mater. Chem. Phys.* **2013**, *137*, 877.
[12] V. G. Nair, A. Das, V. Subramanian, P. N. Santosh, *J. Appl. Phys.* **2013**, *113*, 213907.
[13] G. King, P. M. Woodward, *J. Mater. Chem.* **2010**, *20*, 5785.
[14] T. Ahmad, I. H. Lone, S. G. Ansari, J. Ahmed, T. Ahamad, *Mater. Des.* **2017**, *126*, 331.
[15] P. S. J. Bharadwaj, S. Kundu, V. S. Kollipar, K. B. R. Varma, *RSC Adv.* **2020**, *10*, 22183.
[16] P. S. J. Bharadwaj, V. S. Kollipar, *Ceram. Int.* **2021**, *47*, 30797.
[17] Y. Sui, F. Lu, X. Liu, Y. Zhang, X. Sun, C. Liu, *Results Mater.* **2021**, *10*, 100186.
[18] C. Venkatrao, D. R. S. Reddy, K. R. Kandula, R. Bhimireddi, *Phys. Status Solidi B* **2023**, *260*, 2200272.
[19] D. H. T. Pham, L. T. T. Nguyen, V. O. Mittova, D. H. Chau, I. Y. Mittova, T. A. Nguyen, V. X. Bui, *J. Mater. Sci.: Mater. Electron.* **2022**, *33*, 14356.
[20] V. I. Popkov, O. V. Almjasheva, A. S. Semenova, D. G. Kellerman, V. N. Nevedomskiy, V. V. Gusarov, *J. Mater. Sci.: Mater. Electron.* **2017**, *28*, 7163.
[21] A. T. Apostolov, I. N. Apostolova, J. M. Wesselinowa, *Int. J. Mod. Phys. B* **2023**, *37*, 2350201.
[22] Y. Li, Y. Ma, Z. Wang, H. Liu, X. Wang, Y. Dong, W. Qian, *J. Mater. Sci.: Mater. Electron.* **2022**, *33*, 11318.
[23] A. Apostolov, I. Apostolova, J. Wesselinowa, *Nanomaterials* **2021**, *11*, 2731.
[24] H. Aydin, *Eur. J. Tech.* **2019**, *9*, 84.
[25] C. Venkatrao, D. R. S. Reddy, R. Bhimireddi, *J. Mater. Sci.: Mater. Electron.* **2023**, *34*, 302.
[26] A. T. Nguyen, H. D. Chau, T. T. Nguyen, V. O. Mittova, T. H. Do, I. Ya. Mittova, *Nanosyst.: Phys., Chem., Math.* **2018**, *9*, 424.
[27] M. Nakhaei, M. A. L. Nobre, D. S. Khoshnoud, M. Bremholm, H. A. Khonakdar, *Ceram. Int.* **2023**, *49*, 15818.
[28] N. M. Bobkova, S. A. Khot'ko, *Glass Ceram.* **2004**, *61*, 175.
[29] M. K. Singh, H. M. Jang, H. Gupta, R. S. Katiyar, *J. Raman Spectrosc.* **2008**, *39*, 842.
[30] B. Deka, S. Ravi, A. Perumal, D. Pamu, *Ceram. Int.* **2017**, *43*, 1323.
[31] L. Wu, J. C. Yu, L. Zhang, X. Wang, S. Li, *J. Solid State Chem.* **2004**, *177*, 3666.
[32] M. Wang, T. Wanga, S. H. Song, M. Ravia, R. C. Liu, S. S. Ji, *Ceram. Int.* **2017**, *43*, 10270.
[33] S. Tukaram, R. Bhimireddi, K. B. R. Varma, *Mater. Sci. Eng., B* **2016**, *211*, 101.
[34] F. S. Al-Hazmi, A. A. Al-Ghamdi, L. M. Bronstein, L. S. Memesh, F. S. Shokr, M. Hafez, *Ceram. Int.* **2017**, *43*, 8133.
[35] M. V. Berezhnaya, O. V. Almyasheva, V. O. Mittova, A. T. Nguen, I. Y. Mittova, *Russ. J. Gen. Chem.* **2018**, *88*, 626.
[36] P. S. J. Bharadwaj, S. Kundu, V. S. Kollipar, K. B. R. Varma, *J. Phys.: Condens. Matter* **2020**, *32*, 035810.

[37] N. A. Tien, O. V. Almjasheva, I. Y. Mittova, O. V. Stognei, S. A. Soldatenko, *Inorg. Mater.* **2009**, *45*, 1304.
[38] C. Venkatrao, D. R. S. Reddy, R. Bhimireddi, *J. Mater. Sci.: Mater. Electron.* **2022**, *33*, 20731.
[39] L. Suthar, F. Bhadala, P. Kumari, M. Roy, *J. Electroceram.* **2020**, *44*, 195.
[40] H. Shena, J. Xua, A. Wu, J. Zhao, M. Shi, *Mater. Sci. Eng., B* **2009**, *157*, 77
[41] A. Wu, H. Shen, J. Xu, Z. Wang, L. Jiang, L. Luo, S. Yuan, S. Cao, H. Zhang, *Mater. Sci.* **2012**, *35*, 259.
[42] L. Suthar, V. K. Jha, F. Bhadala, M. Roy, S. Sahu, S. K. Barbar, *Appl. Phys. A* **2017**, *123*, 668.
[43] J. H. Jung, M. Matsubara, T. Arima, J. P. He, Y. Kaneko, Y. Tokura, *Phys. Rev. Lett.* **2004**, *93*, 037403.
[44] P. Kubelka, *J. Opt. Soc. Am.* **1948**, *38*, 448.
[45] S. H. Wemple, *Phys. Rev. B* **1970**, *2*, 2679.
[46] M. Ahmadipour, M. Arjmand, M. F. Ain, Z. A. Ahmad, S.-W. Pung, *Ceram. Int.* **2019**, *45*, 15077.
[47] D. Redfield, W. J. Burke, *J. Appl. Phys.* **1974**, *45*, 4566.
[48] S. R. Basu, L. W. Martin, Y. H. Chu, M. Gajek, R. Ramesh, R. C. Rai, X. Xu, J. L. Musfeldt, *Appl. Phys. Lett.* **2008**, *92*, 091905.
[49] C. Suchomski, C. Reitz, K. Brezesinski, C. T. de Sousa, M. Rohnke, K.-I. Iimura, J. P. E. de Araujo, T. Brezesinski, *Chem. Mater.* **2012**, *24*, 155.
[50] M. Ahmadipour, C. W. Kian, M. F. Ain, K. V. Rao, Z. A. Ahmad, *Mater. Lett.* **2018**, *210*, 4.

CUSTOMERS PERCEPTION TOWARDS CORE SERVICES OF PUBLIC AND PRIVATE SECTOR BANKING ORGANIZATIONS --- A STUDY IN GUNTUR DISTRICT OF ANDHRA PRADESH

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ABSTRACT

In India, the banking sector is the lifeline of any modern economy. The banking sector is important financial pillars of the financial sector that played the vital role in the functioning of an economy. The present study examined the perception levels of the customers towards the core banking services offered by the selected public and private sector banking organizations. The study had analyzed the satisfaction levels of the customers towards the core banking services offered by the selected banking organizations and it further measures the degree of association between the environmental forces that influences the selection of bank and the customers level of interaction with regard to redressal mechanism . The present research study adopts Descriptive Research Design . Both the primary and secondary data sources will be utilized by the researcher in order to draw conclusions from the findings of this study. Primary data will be collected from the selected sample respondents through interview schedule method and secondary data sources will be gathered from the published sources. The sampling units identified for the present study involves two banking organizations comprising both public and private sector banking organizations located in the Guntur District of Andhra Pradesh and the sample respondents comprises the customers of the selected banking organizations. Stratified Random Sampling Technique was applied in order to draw the sample respondents from the identified sampling units in the study area. The sample size fixed for this study purpose was 140 from the selected two public and private banking organizations in the study area. In order to draw the statistical inferences from the data analysis, statistical tools like percentage and Person Coefficient of Correlation method were applied. The study concludes that majority of the respondents had opined that there is adequate staff in the banking organizations and the quality of customer services offered by the banks is good. The study further depicts that the availability of reasonable comforts at the banking organizations is good and the study concludes that there exists a significant association between the environmental forces that influences the selection of bank and customers level of interaction with regard to redressal mechanism.

Key Words: Customers, Perception, Core Banking services, Satisfaction level

INTRODUCTION

In India, the banking sector is the lifeline of any modern economy. The banking sector is important financial pillars of the financial sector that played the vital role in the functioning of an economy. The banking sector plays a crucial role for the growth and development of any economy. The presence of banking sector encourage saving habit among the people. The more the number of people deposits their money in the bank, more money will be landed to the needy people. As one of the main function that a bank performs is to channelize the funds from people who have surplus funds (borrower or investor).

Banks plays a vital role in increasing the standard of living. Earlier, there were very few banks and consequently there were no or very less competition. But after the new economic refers and nationalization in 1991, all the barriers on free entry and exit were removed and 100% FDI were allowed. This result is increase the competition for Indian banks to the great extent. As all the banks perform same function, therefore, there quality of service provided to their existing and potential customer makes them distinctive from other banks. Because, now the customers are also more knowledgeable and well-informed and therefore, they have some expectation from their banks. And if banks failed to fulfill their customer's expectation, the customer will switch to other banks. From time to time, the perception of customer may change and therefore, it is important for banks to focus on their expectations and try to fulfill them and also try to acquire, retain and satisfy their customers for a longer period.

With advent of modern administration technologies in the banking administration at both public and private sector banking platforms, the customers are to be made aware of the quality and quantity of different banking services and technological aspects in order to make them knowledgeable with regard to the ongoing banking activities and the core banking services. Thus, the present study is conducted in order to analyze the customers perception towards core services of public and private sector banking organizations in the selected Guntur district of Andhra Pradesh

REVIEW OF LITERATURE

According to Chakravarty, (2014): Banking, being a customer-oriented services industry, the customer is the centre of attention and customer service has to be the distinguishing factor. The challenge for banks is to lower costs, increase efficiency, while improving the quality of their service, and increase customer satisfaction. Attention has now turned to improving the quality of service encounter, when customers enter the bank and come into face-to-face contact with bank staff.

According to Ahmed K. and Choudhury T. A. (2015): in his study found that nationalized commercial banks and private commercial banks are almost equally reliable but services of private commercial banks give more assurance to the customers. The study revealed that the performance of nationalized commercial banks suffer in terms of empathy and tangibles. The customers feel that all commercial banks are performing better than the nationalized commercial banks. So Nationalized Commercial Banks needs to take initiative for service quality improvements.

According to Joshua A J, V Moli, P. Koshi (2018): The study evaluated and compared service quality in old and new banks using sample size of 480. This study found that the customers are satisfied in reliability, empathy and price for other parameters of the difference between expectations and perceptions.

According to Mohammad et al (2022): The study tries to develop a comprehensive model of banking automated service quality taking into consideration unique attributes of each delivery channel and other dimensions which influence service quality.

According to Dr Ravichandran et al (2023): The paper analyses existing study and try to understand socio demographic and rational profile of public retail banking consumers. It also finds out the importance of service quality dimensions to predict the multidimensional model of behavioral intentions among public sector consumers in India. Service quality parameters like tangibility, responsiveness and empathy dimensions were also found to be very important.

OBJECTIVES OF STUDY

1. To examine the perception levels of the customers towards the core banking services offered by the selected public and private sector banking organizations.

2. To analyze the satisfaction levels of the customers towards the core banking services offered by the selected banking organizations.

3. To measure the degree of association between the environmental forces that influences the selection of bank and the customers level of interaction with regard to redressal mechanism

HYPOTHESES

In order to test the mentioned research objectives in the present study, the following Null-hypothesis was proposed and tested for its statistical significance.

Ho1 : There exists no significant association between the environmental forces that influences the selection of bank and customers level of interaction with regard to redressal mechanism

RESEARCH METHODOLOGY

The present research study adopts Descriptive Research Design . Both the primary and secondary data sources will be utilized by the researcher in order to draw conclusions from the findings of this study. Primary data will be collected from the selected sample respondents through interview schedule method and secondary data sources will be gathered from the published sources.

The sampling units identified for the present study involves two banking organizations comprising both public and private sector banking organizations located in the Guntur District of Andhra Pradesh and the sample respondents

comprises the customers of the selected banking organizations. One public sector banking organizations namely Central Bank of India and One private sector banking organizations namely HDFC Bank were identified as the study units.

Stratified Random Sampling Technique was applied in order to draw the sample respondents from the identified sampling units in the study area. 70 customers from each selected banking organization were identified as the sample respondents and hence, the sample size fixed for this study purpose was 140 from the selected two public and private banking organizations in the study area. In order to draw the statistical inferences from the data analysis, statistical tools like percentage and Person Coefficient of Correlation method were applied.

DATA ANALYSIS AND INTERPRETATION

Table No.1

Age details of the respondents

Age (in Years)	Frequency	Percentage
Below 25	18	12.9
25-40	108	77.1
Above 40	14	10.0
Total	140	100

Source : Primary Data

The table no.1 shows the age details of the respondents. It shows that 12.9 percent of the respondents are below the age category of 25 years, 77.1 percent of the respondents are in the age category of 25-40 years and 10 percent of the respondents are in the age category of above 40 years.

Table No.2

Occupation details of the respondents

Occupation	Frequency	Percentage
Employee	53	37.9
Business	9	6.4
Professional	32	22.8
Others	46	32.9
Total	140	100

Source : Primary Data

The table no.2 shows the occupation details of the respondents. It shows that 37.9 percent of the respondents are employees, 6.4 percent of the respondents are involved in business activities, 22.8 percent of the respondents are professionals and 32.9 percent of the respondents are having other occupations. .

Table No.3

Reasons for selecting a particular bank by the respondents

Reason	Frequency	Percentage
Good services	88	62.9
Secured services	30	21.4
Cheaper service charges	22	15.7
Total	140	100

Source : Primary Data

The table no.3 shows the reasons for selecting a particular bank by the respondents . It shows that 62.9 percent of the respondents had opted for good services, 21.4 percent of the respondents had opted for secured services and 15.7 percent of the respondents had opted for cheaper service charges .

Table No.4

Core services availing at the banking organizations

Core services	Frequency	Percentage
Electronic Funds Transfer	57	40.7
ATM	35	25.0
Realization of cheques	32	22.9
Other services	16	11.4
Total	140	100

Source : Primary Data

The table no.4 shows core services availing at the banking organizations . It shows that 40.7 percent of the respondents had stated electronic funds transfer, 25 percent of the respondents had stated ATM services, 22.9 percent of the respondents had stated realization of cheques and 11.4 percent of the respondents had stated other reasons.

Table No.5

Opinion of the respondents on the adequacy of staff in the banking organization

Opinion	Frequency	Percentage
Yes	102	72.9
No	38	27.1
Total	140	100

Source : Primary Data

The table no.5 shows the opinion of the respondents on the adequacy of staff in the banking organizations. . It shows that 72.9 percent of the respondents had opined that there is adequate staff in the banking organizations and 27.1 percent of the respondents had disagreed with this statement.

Table No.6

Opinion of the respondents on the quality of customer services offered by the banks

Opinion	Frequency	Percentage
Poor	17	12.1
Average	39	27.9
Good	56	40.0
Very good	28	20.0
Total	140	100

Source : Primary Data

The table no.6 shows the opinion of the respondents on the quality of customer services offered by the banks . It shows that 12.1 percent of the respondents had opined that the quality of customer services offered by the banks are poor, 27.9 percent of the respondents had opined that they are average, 40 percent of the respondents had opined that they are good and 20 percent of the respondents had stated that they are very good.

Table No.7

Opinion of the customers on the reasonable comforts available at the banking organizations

Opinion	Frequency	Percentage
Superior	31	22.1
Average	39	27.9
Good	70	50.0
Total	140	100

Source : Primary Data

The table no.7 shows the opinion of the respondents on the availability of reasonable comforts at the banking organizations . It shows that 22.1 percent of the respondents had opined that they comforts available are superior, 27.9 percent of the respondents had opined that they are average and 50 percent of the respondents had opined that they are good.

Table No.8

Opinion of the customers on the factors that influence them to select the banking organizations

Opinion	Frequency	Percentage
Reputation	37	26.4
Nearness	41	29.3
Commercial utility	39	27.9
Friends advice	23	16.4
Total	140	100

Source : Primary Data

The table no.8 shows the opinion of the respondents on the factors that influence them to select the banking organizations . It shows that 26.1 percent of the respondents had opined that the reputation is the main factor that influences them, 29.3 percent of the respondents had opined that nearness of the banking organization is the main factor, 27.9 percent of the respondents had opined that commercial utility is the main factor and 16.4 percent of the respondents had opined that friends advice is the main factor that influences them to select banking organizations.

Table No.9

Opinion of the customers on the redressal mechanism provided by the banking organizations

Opinion	Frequency	Percentage
Poor	10	7.1
Average	49	35.0
Good	47	33.6
Very good	34	24.3
Total	140	100

Source : Primary Data

The table no.9 shows the opinion of the respondents on the redressal mechanism provided by the banking organizations. It shows that 7.1 percent of the respondents had opined that the redressal mechanism is poor, 35 percent of the respondents had opined that the redressal mechanism is average, 33.6 percent of the respondents had opined that the redressal mechanism is good and 24.3 percent of the respondents had stated very good.

Verification of Hypothesis- Ho1

Ho1 : There exists no significant association between the environmental forces that influences the selection of bank and customers level of interaction with regard to redressal mechanism

Test applied : Pearson Coefficient of Correlation

Table No.10

Association between the environmental forces that influences the selection of the bank and the customers level of interaction with regard to redressal mechanism

Factors		**Sum**	**Environmental forces**	**Level of interaction with regard to redressal mechanism**
Sum	Pearson Correlation	1	0.426**	0.318**
	Sig.(2 tailed)	-	0.000	0.004
	N	140	140	140
Environmental forces	Pearson Correlation	0.426**	1	0.278*
	Sig.(2 tailed)	0.000	-	0.014
	N	140	140	140
Level of interaction with regard to redressal mechanism	Pearson Correlation	0.318**	0.278*	1
	Sig.(2 tailed)	0.004	0.014	-
	N	140	140	140

Source : Computed

*Significant at 0.05 level of significance

** significant at 0.01 level of significance

The table No.10 shows the association between the environmental forces that influences the selection of the bank and the customers level of interaction with regard to redressal mechanism. It shows that the correlation between the factors that influences the customers to select a bank is found to be 0.426 and it lies in between the range of + 0.25 to +0.75 range and it denotes a moderate positive correlation.

The table further shows that the correlation between the factors that influences the customers to select a bank and level of interaction with regard to redressal mechanism is found to be 0.318 and it shows lies in between the range of + 0.25 to +0.75 range and it denotes a moderate positive correlation.

MAJOR FINDINGS

- The result shows that majority of the respondents are in the age category of 25-40 years.
- The result shows that majority of the respondents are employees by their occupation.
- The result shows that majority of the respondents had selected a particular bank by basing on the reason for good services.
- The result shows that majority of the respondents had stated electronic funds transfer and ATM services as the main core services availing at their respective banking organizations.
- The result shows that majority of the respondents had opined that there is adequate staff in the banking organizations.
- The result shows that majority of the respondents had opined that the quality of customer services offered by the banks is good.

- The result shows that majority of the respondents had opined that the availability of reasonable comforts at the banking organizations is good.

- The result shows that majority of the respondents had opined that nearness and commercial utility of the banking organization are the main factors that influence them to select the banking organizations.

- The result shows that majority of the respondents had opined that the redressal mechanism provided by the banking organization is average.

- The pearson correlation test result shows that the variables are found to be statistically significant at 0.05 and 0.01 level of significance. Hence, the proposed null hypothesis (Ho1) is rejected. Thus, it can be inferred that there exists a significant association between the environmental forces that influences the selection of bank and customers level of interaction with regard to redressal mechanism.

- The pearson correlation test result shows that the degree of association between all the variables denotes a moderate positive correlation.

CONCLUSION AND SUGGESTIONS

The present study examined the perception levels of the customers towards the core banking services offered by the selected public and private sector banking organizations. The study had analyzed the satisfaction levels of the customers towards the core banking services offered by the selected banking organizations and it further measures the degree of association between the environmental forces that influences the selection of bank and the customers level of interaction with regard to redressal mechanism .

The study concludes that majority of the respondents had opined that there is adequate staff in the banking organizations and the quality of customer services offered by the banks is good. The study further depicts that the availability of reasonable comforts at the banking organizations is good and the study concludes

that there exists a significant association between the environmental forces that influences the selection of bank and customers level of interaction with regard to redressal mechanism.

It is suggested that both the public and private sector banking organizations shall ensure qualitative services at competitive low prices and the customers preferential choices are to be given due importance and priority. The banking branches are to be increased to a greater extent with adequate employee availability and the customers are to be educated and trained towards the advancing approaches of banking in order to technically and academically equip the customers to keep in pace with the modern banking services.

REFERENCES

- Ahmed K. and Choudhury T. A. (2015). Linking Service Quality, Customer Satisfaction, and Behavioral Intention, *Journal of Care Marketing*, 5-17.

- Chakravarty, (2014). The Role of Price Perceptions in an Integrated Model of Behavioral Intention, *Journal of Service Research*, (3), 232-240.

- Joshua A J, V Moli, P. Koshi (2018) , faculty , department of marketing , EIILM, Affiliated to vidyasagar university , India and dr. Rajib Kumar das 2018, faculty, department of economics EIILM affiliated to vidyasagar university , India. Customer's motivation towards banking: a case study of HDFC bank in Kolkata, ISBN: 978-93-86171-94-8.

- Mohammad et al (2022). Department of Management Studies, amity global business school , A Study on Customer perception towards banking sector, *Journal of Entrepreneurship and Organizational Managemen*t 5: 178. doi:10.4172/2169-026X.1000178

- Ravichandran et al (2023), Digitalization in Banking Sector, *International Journal of Research and Analytical Reviews,* E-ISSN 2348-1269, P- ISSN 2349-5138.

GOVERNMENT DEGREE COLLEGE : KOVVUR : E.G.Dt.

Academic & Administrative Audit : 2023-2024

Format-II (Institutional Data Cum Academic Advisor's Grading)

III-RESEARCH, INNOVATIONS AND EXTENSION

D. Extension Activities

1.Date of activity : 14-06-2023

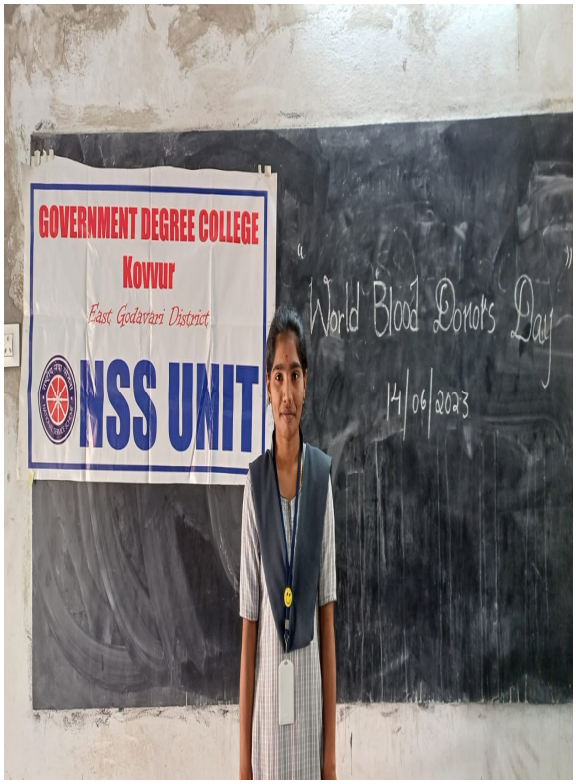
2.Activity details : WORLD BLOOD DONORS DAY

3.No.of Volunteers participated : 60

4.No of other participants : 65

5.Guest participated in the activity :

6.Photographs, Press Clippings/News paperpublications :



7.Brief note on Activity :

The World Blood Donors Day celebrations at Government Degree College were a resounding success, thanks to the concerted efforts of the NSS Unit. The event, organized with meticulous planning and dedication, saw an array of activities aimed at raising awareness about the importance of blood donation. Guests, including blood bank technicians from CHC Kovvur, graced the occasion, sharing valuable insights and experiences. Through informative sessions and interactive workshops, students were educated about the significance of regular blood donation in saving lives. The event culminated in a blood donation camp, where students enthusiastically participated, contributing to the noble cause. The collaborative efforts of the college community and the expertise shared by the esteemed guests made the celebrations truly impactful, leaving a lasting impression on all involved.

Signature of PO
Name of Program Officer
Lecturer in English
Date

Signature of Principal
College Name
Location: Kovvur
Date:

1.Date of activity : 26-06-2023

2.Activity details : INTERNATIONAL DAY AGAINEST DRUG ABUSE

3.No.of Volunteers participated : 60

4.No of other participants : 300

5.Guest participated in the activity : DSP & other Police Officials

6.Photographs, Press Clippings/News paperpublications :

7.Brief note on Activity :

The International Day Against Drug Abuse rally, held in collaboration with the local police department at Government Degree College Kovvur, is a powerful demonstration of community solidarity against substance abuse. Led by college students, faculty, and law enforcement officers, the rally traverses through the streets of Kovvur, raising awareness about the detrimental effects of drug abuse on individuals and society. Banners, posters, and slogans advocate for a drug-free community, emphasizing the importance of prevention, rehabilitation, and support services for those affected by addiction.

Signature of PO
Name of Program Officer
Lecturer in English
Date

Signature of Principal
College Name
Location: Kovvur
Date:

1.Date of activity : 10-08-2023

2.Activity details : MERI MATTI MERI DESH

3.No.of Volunteers participated : 40

4.No of other participants : 70

5.Guest participated in the activity :

6.Photographs, Press Clippings/News paperpublications :

7.Brief note on Activity :

As part of Meri Matti Mera Desh campaign 75 saplings were collected from the forest department and planted in the college premises.

Signature of PO
Name of Program Officer
Lecturer in English
Date

Signature of Principal
College Name
Location: Kovvur
Date:

1.Date of activity : 12-08-2023

2.Activity details : AKMA ACTIVITIES

3.No.of Volunteers participated : 70

4.No of other participants : 40

5.Guest participated in the activity :

6.Photographs, Press Clippings/News paperpublications :

7.Brief note on Activity :

The Government Degree College organized a series of engaging activities to commemorate Aazadi Ka Amrut Mahotsav, celebrating India's 75 years of independence. Among the activities were essay writing competitions, elocution contests, and various games and sports events. These activities aimed to encourage students to reflect on the significance of freedom, democracy, and national unity. Essay writing competitions provided a platform for students to express their thoughts and insights on India's journey towards independence and its relevance in contemporary times. Elocution contests allowed students to articulate their perspectives on the sacrifices made by our freedom fighters and the values they embody. Additionally, games and sports events promoted teamwork, discipline, and a sense of camaraderie among participants, fostering a spirit of national pride and unity. Through these diverse activities, the college community came together to honor the legacy of our freedom struggle and recommit to the ideals of a free and democratic India.

Signature of PO
Name of Program Officer
Lecturer in English
Date

Signature of Principal
College Name
Location: Kovvur
Date:

1.Date of activity :12-9-2023

2.Activity details :5 K Red Run

3.No.of Volunteers participated : 20

4.No of other participants : 60

5.Guest participated in the activity :

6.Photographs, Press Clippings/News paperpublications :

7.Brief note on Activity :The 5K Red Run Marathon on AIDS awareness, held in Rajahmundry and organized in collaboration with other students from Government Degree College, becomes a powerful platform to spread awareness about HIV/AIDS in the local community. Participants, clad in red attire symbolizing solidarity, embark on the marathon route, not only promoting physical fitness but also advocating for HIV prevention, treatment, and destigmatization. With the esteemed presence of Dr. Madhavi Latha, the District Collector, as the chief guest, the event gains significant momentum, emphasizing the importance of governmental support and community engagement in the fight against HIV/AIDS.

Signature of PO
Name of Program Officer
Lecturer in English
Date

Signature of Principal
College Name
Location: Kovvur
Date:

1.Date of activity :24-9-2023

2.Activity details : NSS DAY CELEBRATIONS

3.No.of Volunteers participated : 65

4.No of other participants : 45

5.Guest participated in the activity :

6.Photographs, Press Clippings/News paperpublications :

7.Brief note on Activity :

On NSS Day, the Government Degree College in Kovvur reverberated with the spirit of service and community as it celebrated the invaluable contributions of its NSS volunteers. The day was marked by a series of events dedicated to recognizing the dedication and hard work of these volunteers in serving society selflessly. Among the highlights was the felicitation ceremony honoring the best NSS volunteers who had exhibited outstanding commitment to various social causes throughout the year. Their tireless efforts in organizing camps, conducting awareness programs, and actively participating in community service projects were applauded and rewarded. The event not only celebrated their achievements but also inspired others to join hands in making a positive impact on society. It was a testament to the college's commitment to nurturing socially responsible citizens and fostering a culture of service and empathy among its students.

Signature of PO
Name of Program Officer
Lecturer in English
Date

Signature of Principal
College Name
Location: Kovvur
Date:

1.Date of activity : 25-11-2023

2.Activity details: Blood Donation Camp

3.No.of Volunteers participated : 40

4.No of other participants : 80

5.Guest participated in the activity :

6.Photographs, Press Clippings/News paperpublications :

7.Brief note on Activity :

The NSS volunteers of Government Degree College Kovvuru showcased their altruism by actively participating in a blood donation camp organized in the Campus many commendable students from the college generously donated blood, while NSS volunteers provided invaluable assistance to the medical staff from C.H.C Kovvuru and the Red Cross Society. NSS Programme Officer S. Madar Saheb and the volunteers exemplified compassion by distributing fruits to both blood donors and underprivileged patients at the blood donation event. Such noble initiatives not only contribute to the well-being of the community but also reflect the spirit of service ingrained in the ethos of the college and its students.

Signature of PO
Name of Program Officer
Lecturer in English
Date

Signature of Principal
College Name
Location: Kovvur
Date:

1.Date of activity:01-12--2023

2.Activity details: NATIONAL AIDS DAY CELEBRATIONS AND RALLY

3.No.of Volunteers participated : 60

4.No of other participants : 110

5.Guest participated in the activity :

6.Photographs, Press Clippings/News paperpublications :

7.Brief note on Activity :

Government Degree College Kovvur, in collaboration with the Community Health Centre Kovvur and several other educational institutions, orchestrated a powerful AIDS Day rally aimed at raising awareness and promoting prevention measures against HIV/AIDS. The event drew participation from students, faculty members, healthcare professionals, and members of the local community. The rally served as a platform to educate people about the importance of HIV/AIDS awareness, dispel myths and misconceptions surrounding the disease, and encourage individuals to prioritize their sexual health.

Through this collaborative effort, Government Degree College Kovvur and its partners underscored the significance of collective action in combating the spread of HIV/AIDS. The rally featured informative sessions, interactive activities, and engaging discussions on topics such as safe sex practices, the importance of regular testing, and destigmatizing HIV/AIDS. By fostering partnerships with the Community Health Centre Kovvur and other educational institutions, the college demonstrated its commitment to addressing public health challenges and promoting a culture of health and well-being within the community. This collaborative initiative not only raised awareness about HIV/AIDS but also empowered individuals to take proactive steps towards prevention and care.

Signature of PO
Name of Program Officer
Lecturer in Englis

Signature of Principal
College Name
location: Kovvur

1.Date of activity:03-12--2023

2.Activity details: VOTER AWARENESS AND ENROLLEMENT

3.No.of Volunteers participated : 40

4.No of other participants : 80

5.Guest participated in the activity :

6.Photographs, Press Clippings/News paperpublications :

7.Brief note on Activity :

At Government Degree College in Kovvur, fostering voter awareness and civic engagement is a priority, demonstrated through active collaboration with the Revenue Department Kovvur. The college, in partnership with the department, organized a series of initiatives under the Systematic Voters' Education and Electoral Participation (SVEEP) program. Staff and students alike actively participated in these efforts, which included voter awareness campaigns, workshops on the importance of voting, and facilitating voter registration for eligible students. Through these endeavors, the college aimed to instill a sense of responsibility and participation in the democratic process among its students, empowering them to exercise their right to vote and contribute to the nation's democratic fabric. The collaborative efforts underscored the college's commitment to nurturing informed and engaged citizens who play an active role in shaping the future of the country.

Signature of PO
Name of Program Officer
Lecturer in English
Date

Signature of Principal
College Name
Location: Kovvur
Date:

1.Date of activity: 25-01-2024

2.Activity details: NATIONAL VOTERS DAY

3.No.of Volunteers participated : 40

4.No of other participants : 80

5.Guest participated in the activity :

6.Photographs, Press Clippings/News paperpublications :

7.Brief note on Activity :

The NSS unit, in collaboration with the Department of Political Science, orchestrated a mock election, designed to impart comprehensive knowledge about the electoral process to students. With the aim of educating students from inception to culmination, the event covered various aspects such as voter registration, the historical context of voting, insights into the polling process, and proficient ballot casting techniques utilizing diverse voting systems prevalent in India. Through this experiential learning opportunity, students gained practical understanding and proficiency in exercising their democratic rights, preparing them to become informed and engaged citizens in the democratic fabric of the nation. Such initiatives not only foster civic responsibility but also promote active participation in shaping the future of the country.

Signature of PO
Name of Program Officer
Lecturer in English
Date

Signature of Principal
College Name
Location: Kovvur
Date:

1.Date of activity:22-02-2024

2.Activity details: SVEEP

3.No.of Volunteers participated : 40

4.No of other participants : 80

5.Guest participated in the activity :

6.Photographs, Press Clippings/News paperpublications :

7.Brief note on Activity

SVEEP (Systematic Voters' Education and Electoral Participation) initiatives held at Government Degree College Kovvur are pivotal in promoting democratic engagement and voter awareness among students. Through interactive workshops, awareness campaigns, and voter registration drives, the college community is empowered with the knowledge and tools necessary to participate actively in the electoral process. These initiatives, often conducted in collaboration with election authorities, aim to instill a sense of civic duty and responsibility, encouraging students to exercise their right to vote and contribute to shaping the nation's future. By fostering a culture of informed citizenship, SVEEP initiatives at Government Degree College Kovvur play a crucial role in strengthening democracy and promoting inclusive participation in the electoral process.

Signature of PO
Name of Program Officer
Lecturer in English
Date

Signature of Principal
College Name
Location: Kovvur
Date:

GOVERNMENT DEGREE COLLEGE : KOVVUR : E.G.Dt.

Academic & Administrative Audit : 2023-2024

Format-II (Institutional Data Cum Academic Advisor's Grading)

III-RESEARCH, INNOVATIONS AND EXTENSION

E. Consultancy and Collaboration

Memorandum of Understanding (MoU)

(Non- Commercial & Academic purpose)

For

Student Exchange Programme

Between

Government Degree College, Kovvur

&

Government College(Autonomous)
Rajamahendravaram

MEMORANDUM OF UNDERSTANDING
Between Government Degree College, Kovvur
and
Government Autonomous College, Rajamahendravaram

1. **Parties.**

This Memorandum of Understanding (hereinafter referred to as "MOU") is made and entered into by and between the

a) Department of Botany
Government Degree College, Kovvur
East Godavari District
and

b) Department of Botany
Government Autonomous College,
near "Y" Junction,
Rajamahendravaram, E.G.Dist.

2. **Purpose.**

The purpose of this MOU is to expose the undergraduate students to diversified intellectual abilities.

3. **Term of MOU.**

This MOU is effective upon the day and date signed and will be executed by the parties from February 2023 and shall remain in full force and effect for not longer than **2 Years.** This MOU may be terminated, without cause, by either party upon **two months** written notice, which shall be delivered by hand or by certified mail to the address listed above.

4. **Responsibilities of parties.**

- The colleges entered into MoU shall exchange the students as per the schedule as resolved in the meeting held on 1 Feb 2023 in the Department of Botany of Government Autonomous College, Rajamahendravaram.
- The incharges of the Department shall be the liaison between the parties.

- The respective college administration shall take the responsibility of students during their stay period in the college and the attendance of the students shall be marked for record.
- The departments shall take care of the academic instructions as per the timetable scheduled for the purpose.

5. Signatures.

In witness whereof, the parties to this MOU through their duly authorized representatives have executed this MOU on the days and dates set out below, and certify that they have read, understood, and agreed to the terms and conditions of this MOU as set forth herein.

The effective date of this MOU is the date of the signature last affixed to this page.

1. Department of Botany

Government Degree College, Kovvur

10/2/2023

Dr. M. Bhupathi Rayalu
M. Sc., Ph.D.,
Asst. Professor in Botany
Govt. Degree College, KOVVUR - W.G.Dist. 534 350

Date:

2. Department of Botany

Government College (Autonomous)
Rajamahedravaram

Lecturer In-Charge
DEPARTMENT OF BOTANY
GOVERNMENT COLLEGE (A),
RAJAMAHENDRAVARAM-533 103.

Date: 10/2/2023

(Dr. K. NAGESWARA RAO)

MEMORANDUM OF UNDERSTANDING

Between
Government Degree College, Kovvur &
Sri Lakshmi Mushrooms, Rajahmahendravaram

1. **Parties:**

DEPARTMENT OF BOATNY
GOVERNMENT DEGREE COLLEGE
KOVVUR, E.G.Dist. – 534 350.

&

SRI LAKSHMI MUSHROOMS
Hukumpet
RAJAHMAHENDRAVARAM, E.G.Dt.

2. **Purpose:**

It is agreed to have mutually beneficial activities between the two organizations. The college will be able to impart quality education to the students by exposing them to the allied areas for the value addition to the topics prescribed in the syllabus and providing opportunity to the students to learn new techniques which are involved; it may help for self employment.

The external department also can utilize the services of the college faculty and students in conducting its extension programmes. Both the organizations came to an understanding on the following activities.

3. **Terms of MOU:**

- ✓ This MOU is effective upon the day and date signed and will be executed by the parties from January, 2023 and remains in full force and effect for not longer than THREE years.
- ✓ This MOU may be terminated, without cause, by either party upon two months written notice.

4. **Responsibilities of the parties:**

- Exchange of resource persons for the expert lectures.
- Assist the students while doing their project work / field work concerned.
- Utilization of student and faculty services at the mushroom cultivation site.

5. **Signatures:**

In witness whereof, the parties to this MOU through their duly authorized representatives have executed this MOU on the days and dates set out below, and certify that they have read, understood, and agreed to the terms and conditions of this MOU as set forth herein.

The effective date of this MOU is the date of the signature last affixed to this page.

1. **Government Degree College, Kovvur, E.G.Dt.**
   Prof. J. Suneetha, PRINCIPAL

Date:

PRINCIPAL
GOVERNMENT DEGREE COLLEGE
KOVVUR, E.G.Dt.

2. **Sri Lakshmi Mushrooms, Rajahmahendravaram**
   Smt. K. Sri Lakshmi

Date: 30/01/2023

LAKSHMI MUSHROOMS
RAJAHMUNDRY.

*****

ఆంధ్రప్రదేశ్ आंध्र प्रदेश ANDHRA PRADESH

85AA 085934

Sl.No. 3607 Date 16/02/2023 Rs. 20/-

Sold to Varla Aruna Kumari D/o Ramayya, Vijayawada

For Whom self.

G. Suresh

G. SURESH
LICENSED STAMP VENDOR
L.No: 05-05-001-2022
Valid from : 2022-2024
KOVVUR-534 350. Cell: 9494626256

Memorandum of Understanding for Academic Cooperation

Between Government Degree Colleges, Avanigadda and Goverment Degree College, Kovvur

1. Parties:

This Memorandum of Understanding (hereinafter referred to as "MOU" is made and entered into by and between the

a) Department of English,
Government Degree College,
Avanigadda, Krishna District

And

b) Department of English,
Government Degree College,
Kovvur, West Godavari District

2 Purpose:

The purpose of this MOU is to promote and enrich teaching and learning process of the faculty of Party 1 and for the quality instructions for the Party 2.

3. Term of MOU:

This MOU Is effective upon the day and date signed and will be executed by the parties shall remain In full force and effect for not longer than 5 years. This MOU may be terminated, without cause, by either party upon two months written notice, which notice shall be delivered by hand or by certified mail to the address listed above.

4, Responsibilities of Parties :

- The faculty and students of Party 1 will teach/train the faculty and students of Party 2, so as to enrich the teaching experience of faculty and learning experience of students of the Party 2.
- The Party 2 may request some of the faculty or students of Party 1 to address the faculty or students of Party 1.
- Mere participation of faculty and students of Party 1 in teaching the faulty and students of Party 2 according to this MOU does not carry any right or any legal entitlement to demand for placement with Party 2.
- The Colleges shall entrust a faculty member in their respective colleges to liaison between the parties.

5. Signatures:

In witness whereof, the parties to this MOU through their duly authorized representatives have executed this MOU on the days and dates set out below, and certify that they have read, understood, and agreed to the terms and Conditions of this MOU as set forth herein.

The effective date of this MOU is the date of the signature last affixed to this page.

a) Department of English,
Government Degree College,
Avanigadda, Krishna District

Principal
GOVT. DEGREE COLLEGE
AVANIGADDA, Krishna Dt. 521121.

b) Department of English,
Government Degree College,
Kovvur, West Godavari District

PRINCIPAL
GOVERNMENT DEGREE COLLEGE
KOVVUR, E.G.Dt.

Academic Collaboration
Between
SGA GOVT DEGREE COLLEGE(A), YELLAMNCHILI
and
GOVERNMENT DEGREE COLLEGE, KOVVURU

The Memorandum of Understanding is entered on the 14[TH]Day of May, 2024into by and betweenSGA GOVT DEGREE COLLEGE , YELLAMNCHILI and GOVERNMENT DEGREE COLLEGE, KOVVURU agree that cooperation in all academic collaborations and Student and Faculty exchange would be mutually beneficial. The areas of cooperation may include, subject to mutual consent, any desirable and feasible activity that would further the goals of each institution. Such interaction may include cooperation in a variety of joint academic and educational activities such as:

- **Faculty and student exchanges**
- **Staff Professional Development Programmes**
- **Collaborative conferences, workshops, and training programmes**
- **Team taught courses, invited talks including online courses and**
- **Visits by faculty, supporting staff and students**

The parties anticipate that a number of these initiatives will occur during the period of this collaboration. However, neither party is obliged to agree any minimum number of activities, nor is this collaboration intended to preclude either party from entering into similar agreements with other institutions.

This letter of collaboration shall be identified as the parent document of any programme agreement executed between the parties. Further, agreements concerning any programme shall provide details concerning the specific commitments made by each party and shall not become effective until they have been reduced to writing, executed by the duly authorized representatives of the parties.

We agreed upon activities, both institutions will make available their facilities and staff. This collaboration will take effect on and will be valid for **five (5) Years** from the date noted in the first line of this document unless terminated by one of the parties. Either party may withdraw from this agreement provided written notification of the withdrawal is given to the other party at least three months prior to the desired with withdrawal date. This collaboration may be renewed for another period of **Five (5) Years** upon mutual written consent of the parties before the expiration date. Each institution will have copies of this agreement.

14/5/2024
Principal
S.G.A. Govt. Degree College
Yellamanchili-531 055
Anakapalli District. (A.P.)

14/5/2024
PRINCIPAL
GOVERNMENT DEGREE COLLEGE
KOVVUR, E.G.Dt.

The below mentioned Departments of the both colleges will be played active role in conducting various programs and events.

1. English
2. Hindi
3. Telugu
4. Commerce
5. Mathematics
6. Zoology
7. Botany
8. Chemistry
9. Computer Science
10. Economics
11. History
12. Physical Education
13. Library

The following authorized individuals have signed the present collaboration on behalf of their respective institutions.

FIRSTPARTY

Signature: 14/5/24

Principal
S.G.A. Govt. Degree College
Yellamanchili-531 055
Anakapalli District.

Name: DR. P.CHANDRA SEKHAR
PRINCIPAL
SGA GOVERNMENT DEGREE COLLEGE(A),
YELLAMNCHILILI

SECOND PARTY

Signature: 14/5/24

PRINCIPAL
GOVERNMENT DEGREE COLLEGE
KOVVUR, E.G.Dt.

Name: Dr. JONNAKUTI. SUNITHA
PRINCIPAL
GOVT. DEGREE COLLEGE.
KOVVURU, EAST GODAVARI

Witness Name:
DR. KARRI SUDHA
INCHARGE, DEPT. OF HINDI
SGA GOVERNMENT DEGREE COLLEGE(A),
YELLAMNCHILI.

Signature: Karri Sudha 14/5/24

Witness Name:
DR.V.KANCHANA MALA
INCHARGE, DEPT. OF HINDI,
GOVT. DEGREE COLLEGE.
KOVVURU

Signature: V. Kanchana Mala 14/5/24

YELLAMANCHILI - 531 055 Dt: 14/5/24