



**PROCEEDINGS BOOK OF
INTERNATIONAL CONFERENCE
ON
EMERGING TRENDS IN BIO-ENGINEERING
AND FOOD TECHNOLOGY
(ETBFT-2025)**

18-19, March 2025

Editors

**Dr. Kakali Bandyopadhyay
Dr. Dolanchapa Sikdar
Dr. Souptik Bhattacharya**

Organized By

Department of Food Technology
(NBA-accredited)
Guru Nanak Institute of Technology
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NAAC A+ institution
An Educational Initiative of JIS Group

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International Conference
On
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(ETBFT-2025)**

**Edited by
Dr. Kakali Bandyopadhyay
Dr. Dolanchapa Sikdar
Dr. Souptik Bhattacharya**

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Guru Nanak Institute of Technology is an Autonomous Institute affiliated with MAKAUT, WB, is instituted with a vision to empower the aspiring professionals with the technological knowledge and professional expertise under the aegis of JIS Group Educational Initiatives in the year 2003. This technical campus offers undergraduate and postgraduate courses under MAKAUT (Formerly known as WBUT) and some courses are NBA Accredited. The Institute is approved by AICTE and accredited by UGC, NAAC and located in one of the prime locations in North Kolkata near Sodepur. The Institute offers latest technology oriented courses as per industry trends and nurtures creativity, innovations and research initiatives both at faculty and student levels to enrich and enhance the teaching learning process.

Website: <https://gnit.ac.in/>



Message from the Managing Director



It gives me pleasure to announce that Guru Nanak Institute of Technology (GNIT) is organizing the International Conference on Emerging Trends in Bio-Engineering and Food Technology. In an era where innovation in biotechnology and food sciences is pivotal to global sustainability, this platform will foster groundbreaking discussions, collaboration, and transformative research. I extend my heartfelt wishes to the organizers, scholars, and participants. May this conference ignite new ideas, inspire solutions, and contribute to a healthier, more sustainable future for humanity. Let us lead with knowledge and drive progress with purpose.

Best wishes for a successful event!

Sardar Taranjit Singh

Managing Director, JIS Group Educational Initiatives

Message from the Director



It is a moment of immense pride as Guru Nanak Institute of Technology (GNIT) hosts the International Conference on Emerging Trends in Bio-Engineering and Food Technology. We live in a time where innovation drives global progress, this conference serves as a vital platform for pioneering research, interdisciplinary collaboration, and transformative ideas. Advancements in bio-engineering and food technology are crucial for sustainable development, and I applaud GNIT for driving academic excellence in these domains. Let this event inspire breakthroughs that redefine the future of science and industry.

Wishing all participants great success!

Sardar Simarpreet Singh

Director, JIS Group Educational Initiatives

Message from the Principal's Desk



Season's greetings and best wishes to all!

Our Institute has crossed several milestones recently and is confidently poised to set new records in academic and extracurricular achievements in 2025 was a landmark in the evolution of India's education system, witnessing transformative changes driven by the National Education Policy (NEP) 2020, ground breaking technological advancements and a deep commitment to inclusivity. This confluence of policy, innovation, and vision marked a decisive leap toward an education system that is truly future-ready and globally competitive.

I strongly believe that this positive momentum will help us to steer our priorities in the right direction. Collaborative work with multidisciplinary work is reflected in the, Organized By: Department of Food Technology. Guru Nanak Institute of Technology is instituted with a vision to empower the aspiring professionals with the technological knowledge and professional expertise under the aegis of JIS Group Educational Initiatives in the year 2003. This technical campus offers undergraduate and postgraduate courses under MAKAUT and some courses are NBA Accredited. The Institute is approved by AICTE and accredited by UGC, with NAAC A+ and located in one of the prime locations in North Kolkata near Sodepur. The Institute offers latest technology oriented courses as per industry trends and nurtures creativity, innovations and research initiatives both at faculty and student levels to enrich and enhance the teaching learning process. Our Institute is autonomous from 2016 with a remarkable timeline achievement in each years.

ETBFT 2025 conference initiates the beginning of collaborative work along with multidisciplinary proposals from various institution round the globe and JIS Group. GNIT plays an important role to bring all academicians, industry expert a platform in the International conference on Emerging Trends in Bio-engineering and Food Technology (ETBFT 2025) on 18-19th March, 2025 which is Organized By: Department of Food Technology. The essence of the JIS Group institutions

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in research work is reflected with a rich educational philosophy – the belief that our diverse backgrounds, talents, and perspectives collectively contribute to the richness of our academic community. As we embark on this two- day journey of conference, we anticipate witnessing an array of research work and novelty from our stakeholders along with researchers from all round the world.

I appreciate each author for submitting their work and to embrace this platform as an opportunity for collective research, learning, and growth. ETBFT 2025 is a canvas where we integrate our novel ideas for sustainable products using bio sensors, organoids, bio-chips, MEMS technology. Let us take this opportunity that this conference ETBFT 2025 will embark a golden path in the research community for evolving a sustainable eco- system in healthcare applications in future days . The conference reflects the excellence of our institute and JIS group educational initiative under the visionary of Sardar Jodh Singh carried over by Sarder Taranjit Singh and our director Sardar Simarpreet Singh . For two days it is a testament of the collective excellence that defines JIS Group

Prof (Dr.) Swarup Kumar Mitra

Principal

Guru Nanak Institute of Technology

Message from the Dean's (Academics) Desk



Dear Esteemed Colleagues, Researchers, and Participants,

It is with great pleasure that I welcome you all to this prestigious International Conference on *Emerging Trends in Bio-engineering and Food Technology*. This conference provides an invaluable platform for the global community of scholars, innovators, academicians, and industry leaders to exchange ideas, showcase cutting-edge research, and explore new frontiers in these rapidly evolving fields.

Bio-engineering and food technology are at the forefront of addressing some of the most critical challenges facing humanity today, from sustainable food production and nutritional security to environmental sustainability and health advancements. As we witness exponential growth in these areas, this conference serves as a timely opportunity to foster collaboration, inspire new approaches, and discuss the future directions of research and innovation.

I would like to extend my gratitude to the organizing committee, speakers, and participants for their dedication to advancing knowledge in these interdisciplinary domains. I am confident that the insights and discussions throughout this event will contribute significantly to the development of innovative solutions that can positively impact society and the world at large.

Let us continue to work together, share our expertise, and push the boundaries of scientific progress to pave the way for a brighter, more sustainable future.

Thank you for your active participation, and I wish you all a successful and enriching experience at this conference.

Warm regards,

Prof. (Dr.) Kakali Bandyopadhyay

Dean-Academics

Guru Nanak Institute of Technology

Kolkata, India

Message from the Dean's (Research and Development) Desk



Dear Esteemed Colleagues, Researchers, and Participants,

The Department of Food Technology of Guru Nanak Institute of Technology (GNIT), organizes a two-day International Conference on *Emerging Trends in Bio-engineering and Food Technology* to be held during 18-19 March 2025. The conference seeks to contribute to presenting novel research results in all aspects of Engineering Technology and Applied Sciences. It also provides the premier interdisciplinary forum for scientists, engineers, and practitioners to present their latest research results, ideas, developments and applications in all areas of Engineering, Management and Applied Sciences. The conference aims to bring together leading academic scientists, researchers and research scholars to exchange and share their experiences and research results about all aspects of Management, Science and Technology. GNIT Kolkata,

India have played a pivotal role in providing a platform for Engineering Science and Education with several collaborative research programme involving scientists, technologists and other scholars from various countries over the years.

GNIT have so far organized and hosted numerous national and international conclaves, conferences and events. GNIT is also involved in collaborative research programmes with renowned universities across the globe in diverse techno commercial and academic verticals. This conference will be extremely useful as it will be attended by Biotechnologist, Food Technologist, Industry Experts and Engineers making it a truly multidisciplinary conference. There will be several invited talks and oral presentations blended with the main thematic discourses. Young professionals are encouraged for international communication and collaboration; promote professional interaction and lifelong learning; recognize outstanding contributions of individuals and organizations; encourage scholar researchers to pursue studies and careers in circuit branches and its applications. The conference will be an ideal confluence for researchers to present their innovations, compare notes, develop new interfaces, benchmark their work, exchange views and widen the scope and range of their research activity through dynamic networking.

GNIT cherishes to collaborate with the most talented and bright scholars and wish you all a fruitful scientific sessions and very pleasant stay at Kolkata.

Prof. (Dr.) Sunipa Roy

Dean-R&D

Guru Nanak Institute of Technology

Kolkata, India

Message from the Desk of the Head of the Department



Dear Esteemed Colleagues, Researchers, and Participants,

It is my great honor and privilege to welcome you all to International conference on Emerging Trends in Bio-engineering and Food Technology (ETBFT 2025)", organized by Department of Food Technology, Guru Nanak Institute of Technology. This conference serves as a platform for scholars, researchers, and industry experts to engage in meaningful discussions, share innovative ideas, and collaborate on pioneering solutions in Modern sustainable food processing techniques, food engineering, state-of the-art micro-biotechnology advancements in human wellness and healthcare, and innovative industrial application strategies to promote community health.

The rapid advancements in food industry allied with other areas highlight the necessity for continuous learning, research, and dialogue. This gathering of scholars and professionals provides an excellent opportunity to explore new ideas, challenge conventional perspectives, and contribute to the ever-evolving body of knowledge in our field.

I commend all authors for their valuable contributions to these proceedings, which reflect the dedication, hard work, and expertise of our academic community. My sincere appreciation goes to the organizing committee, reviewers, and all who have played a role in making this event a success.

Wishing you all a productive and enriching conference.

Dr. Dolanchapa Sikdar

HOD, Dept. of Food Technology
Guru Nanak Institute of Technology
Kolkata-700114, India.

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About the Editors of the Proceedings

Prof. (Dr.) Kakali Bandyopadhyay

Ph.D. (Tech.), M. Tech., B.Tech

Professor and Dean-Academics, Guru Nanak Institute of Technology, Kolkata



Dr. Bandyopadhyay is a Professor and former Head of the Department of Food Technology, GNIT. She is currently the Dean-Academics of Guru Nanak Institute of Technology, Kolkata. Dr. Bandyopadhyay is a distinguished academic and professional in the field of food technology, chemical engineering, and food processing, with a remarkable career marked by extensive research, innovation, and leadership in academia and industry. She is a Life Member of the Oil Technologists' Association of India and the Institute of Engineers of India, and has contributed and collaborated significantly to both national and international scientific communities. She has an extensive publication record, with 46 international journal papers and 13 national journal contributions. Additionally, she has authored two books, and her research has led to one granted patent and six published patents.

Awards & Recognition

Dr. Bandyopadhyay has been recognized with numerous prestigious awards for her academic and professional achievements, including: **Gold Medal Award** (University of Calcutta, 1998), **Senior Research Fellow** (CSIR, Govt. of India, 1999), **Best Presenter** (Indian Chemical Engineering Congress, 2000), **O.P. Narula Young Scientist Award** (Oil Technologists' Association of India, 2003), **Teacher of the Year** (MAKAUT, 2017), **I2OR National Award for Distinguished Teacher** (Ministry of MSME, Govt. of India, 2021), **Dr. S. Radhakrishnan Bharat Shiksha Award** (Bharat Shiksha Awards, 2021).

Google Scholar: <https://scholar.google.com/citations?user=mOWV6jUAAAAJ&hl=en&authuser=1>

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Dr. Dolanchapa Sikdar

Ph.D. (Engg.), M. Tech., B.Tech

Head, Department of Food Technology, Guru Nanak Institute of Technology, Kolkata



Dr. Sikdar has been in teaching profession since 6 years and handled many administrative of the Department. She has completed his M.Tech and PhD (Engineering) from Jadavpur University. Her research interest includes Nanoparticle synthesis, Response surface methodology, food waste valorization, food engineering and food fortification. She works on field like development of functional foods enriched with bioactive compounds, upcycling of food waste and by-products into value-added food ingredients, optimization of preservation methods (freezing, dehydration and fermentation) to enhance shelf life and maintain food quality, utilization of renewable raw materials and bio-based chemicals, waste bioconversion technologies. Dr. Sikdar has published over 20 papers, in refereed journals. She presented her research in various international and national conferences. She also delivered talks in different FDP and MDPs. She has published 5 patents and one book chapter.

Awards & Recognition

She was awarded as Best Project in JIS SAMMAN. Her work was recognized in MHRD workshop. She is acting as convener of the International conference on “Emerging Trends in Bio-engineering and Food Technology (ETBFT 2025)”.

Google scholar link: <https://scholar.google.com/citations?user=jgpR2EEAAAJ&hl=en>

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Dr. Souptik Bhattacharya

Ph.D. (Engg.), M. Tech., B.Tech, AMIE

Professor, Department of Food Technology, Guru Nanak Institute of Technology, Kolkata.



Dr. Bhattacharya of the Department of Food Technology, GNIT is a distinguished academic and professional in the field of Biotechnology, Food technology, and Chemical Engineering, with a remarkable career marked by extensive research, innovation, and leadership in academia and industry. Dr. Bhattacharya is currently the Departmental Research and Development coordinator. He is a Life Member of the Indian Institute of Chemical Engineers, International Association of Engineers, International Academy of Science and Engineering for Development and the Institute of Engineers of India, and has contributed significantly to both national and international scientific communities. He has an extensive publication record, with over 10 international journal papers

(Indexed) and 2 national journal contributions. His research is focused on the application of *Hydrogel*. He has two genome submission at GenBank (Submission id: PP066973.1 and PP067107.1). Additionally, He has authored over 8 book chapters, and his research has led towards two (published) patents. He is an editor of Scientific World Journal (ISSN: 1537-744X) of Wiley in biotechnology division (2024). He is also reviewer of many reputed journals like Journal of Clinical Pharmacy and Therapeutics (Wiley), Bioresource Technology Reports, Food Bioscience, Process Biochemistry, Separation and Purification Technology, Ecotoxicology and Environmental Safety, International Journal of Biological Macromolecules of Elsevier, etc.

Awards & Recognition

Dr. Bhattacharya has been recognized with numerous prestigious awards for his academic and professional achievements, including: **Senior Research Fellow** (CSIR, Govt. of India, 2017), **GATE** qualification, **Excellent paper award** (ICON SWM 2017, Hyderabad, India), **Best presentation award** (ICFMCE 2019, Bangkok, Thailand), **RUSA 2.0 International travel grant** (2019), **Kriti excellence award** (2022), **JIS innovation award** for research (2023), **JIS SAMMAN** for highest publication (2025) and several other best presentation award. He is acting as the Co-convener of the International conference on “Emerging Trends in Bio-engineering and Food Technology (ETBFT 2025)”.

Google Scholar: <https://scholar.google.com/citations?user=lnktYL8AAAAJ&hl=en&authuser=1>

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Foreword by the Editors

It gives us immense pleasure to present the proceedings of the International Conference on *Emerging Trends in Bio-engineering and Food Technology (ETBFT 2025)*, organized by the Department of Food Technology, Guru Nanak Institute of Technology, Kolkata, India, on the 18th and 19th of March, 2025. This event marks an important milestone in fostering collaboration, innovation, and academic excellence in the interdisciplinary fields of bio-engineering and food technology. The rapid advancements in these domains, coupled with their critical roles in addressing global challenges such as food security, sustainability, and public health, underscore the importance of this conference. By bringing together eminent researchers, academicians, industry professionals, and students, ETBFT 2025 serves as a platform to exchange ideas, share groundbreaking research, and discuss emerging trends and technologies that will shape the future. The conference has been meticulously curated to encompass a wide spectrum of topics, including but not limited to food processing and preservation technologies, bioprocess engineering, functional foods, biotechnology applications, sustainability in food systems, and innovations in packaging. The diverse array of submissions received from across the globe reflects the growing interest and dynamic nature of research in these fields. After a rigorous peer-review process, only high-quality papers that align with the theme and objectives of ETBFT 2025 have been included in this compilation.

We are honored to have distinguished keynote speakers and panelists who bring their wealth of expertise and perspectives to this platform. Their contributions, along with those of the authors and participants, are invaluable in creating an intellectually stimulating and collaborative environment. We are confident that the deliberations and interactions at ETBFT 2025 will inspire new ideas, collaborations, and solutions to some of the most pressing challenges of our time. Organizing an international conference of this magnitude is no small feat and we extend our heartfelt gratitude to the organizing committee, reviewers, sponsors, and volunteers whose tireless efforts and unwavering commitment have made this event possible. Their dedication has ensured that ETBFT 2025 is not just a conference but a memorable and enriching experience for all participants. To the readers of these proceedings, we encourage you to delve into the rich content presented here. The papers encapsulate innovative research, practical insights, and emerging trends that hold the potential to make significant contributions to the fields of bio-engineering and food technology. We hope this compilation serves as a valuable resource and inspires further research and innovation.

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As we convene for this conference, let us remember that our shared goal is to contribute meaningfully to society through our work. Whether it is by developing sustainable food systems, advancing biotechnology, or creating innovative solutions for global challenges, our collective efforts have the power to drive progress and make a lasting impact. On behalf of the organizing committee, we welcome all participants and extend our best wishes for a fruitful and engaging conference. May ETBFT 2025 pave the way for new horizons of knowledge and collaboration.

With warm regards,

Prof. (Dr.) Kakali Bandyopadhyay

Dr. Dolanchapa Sikdar

Dr. Souptik Bhattacharya

ETBFT-2025

About the Department of Food Technology



It is really a matter of great pleasure to welcome you in the Department of Food Technology of Guru Nanak Institute of Technology which has sustainably emerged as one of the premier educational institute in the field of Food Technology in West Bengal. The department has NBA accreditation since 2014. Since its inception in 2006 with an intake of 60 students the department has undergone continual improvement by organizing several EDP, Seminar, conference, workshop, and symposium. We offer a blended learning management system to bring together the progressive sustainable management & technical skills of the industry along with academic expertise of highly experienced and Ph. D. faculty members to disseminate knowledge on the various newer advances and developments in the Food Processing Sector and to emphasize on the different Processing Technologies and its relevance not only to the state level but also to the national and international level.

Furthermore students of the department published research papers in different reputed National and International journals, presented Research paper in National/International seminar/ conferences, workshop, and symposium with the guidance of faculty members and awarded also in different oral/poster/ quiz/ Competition held in IIT-KGP, JU, BHU, FOSET, etc.

Since its establishment in 2006, the department has continuously strived for improvement, organizing various programs such as entrepreneurship development programs (EDP), seminars, conferences, workshops, and symposiums. This demonstrates a commitment to providing students with holistic development. Some noteworthy accomplishments by the Department include securing a Rs. 50 lakhs grant from the Ministry of Food Processing Industries, Government of India, for infrastructural development, receiving a Rs. 18 lakhs grant from MODROB-AICTE, and obtaining a Rs. 4.0 Lakhs grant from the Department of Food Processing Industries & Horticulture, Government of West Bengal, for establishing a Food Processing Training Centre. In addition, the Department has signed MOUs with reputed industrial ventures such as Paushtik Life, SHRM BIOTECHNOLOGY PVT. LIMITED, M/S Crushiers Fruit Juice CO., Wisdom Group, Smart Management Consultancy and Vedaantic Organic Research Foundation. Besides, the Department has collaborated with esteemed International and National institutes like The Puntland State University, Somalia and EMCTD.

In essence, the Department of Food Technology at Guru Nanak Institute of Technology remains steadfast in its commitment to delivering a holistic and industry-relevant education to its students. I'm excited to be a part of this institution and contribute to the academic and research endeavors here.

The Conference Coordinators of the Food Technology Department:



Prof. (Dr.) Kakali
Bandyopadhyay
Dean-Academics and Professor



Dr. Dolanchapa Sikdar,
Head of the Department



Dr. Shairee Ganguly,
Faculty



Dr. Souptik Bhattacharya,
Faculty



Mr. Saikat Mazumder,
Faculty



Ms. Riya Dasgupta,
Faculty



Ms. Jayshree Majumdar,
Faculty



Mr. Amit Barman,
Technical Assistant



Mr. Shubhobrata Saha,
Technical Assistant



Ms. Monika Paul,
Technical Assistant

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Keynote Lecture-1

Enzymatic solution to brew beer with Millets

Jaydeep Chatterjee, M. Brew.

Senior lead Application Scientist, ASPAC

Food Biosciences, IFF

*Corresponding Author: Email: Jaydeep.chatterjee@iff.com

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Millet is a group of small-grained cereal food crops that are highly tolerant to drought and other extreme weather conditions and are grown with low chemical inputs such as fertilizers and pesticides. Most millet crops are native of India and are popularly named as nutri-cereals as they provide most of the nutrients required for the normal functioning of the human body. Based on their grain size, millets are classified into major and minor millets. Millet comes in many varieties with different qualities, which can lead to inconsistent results while using it as raw material to make beer.

Due to the relatively low natural enzyme content present in millet, it is challenging to achieve:

- Iodine negative responses
- High extract yield
- Consistent mash separation
- Adequate Free amino nitrogen levels
- Highly fermented extract

Sorghum & Millet have one of the highest gelatinization temperatures of the brewing raw materials, so the thermostable α -amylase, is essential here (especially for high tannin sorghum). On top of this, compared to any other adjunct, sorghum & millet have a particularly robust protein matrix around the starch, normally resistant to breakdown. This cell membrane matrix must be degraded in the cooker to facilitate access of the α -amylase to the starch and IFF's protease is a proven solution due to its thermostability. IFF proteases applied to the cereal cooker process at 60-70 °C also facilitate energy savings, capacity utilization and increased extract recovery. Finally, at higher inclusions of sorghum/millet, saccharification enzymes brought by the addition of malt are insufficient to achieve the desired real degree of fermentation in time. This is when supplementation with IFF's attenuation enzyme solutions is required. These enzymes will increase the conversion of starch to glucose and/or maltose, increasing the fermentable extract.

Keynote Lecture -2

Fermentative production of asparaginase enzyme and it's application for acrylamide mitigation

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Abstract:



Acrylamide is a chemical compound that is produced in high temperature processed food which has carcinogenic effects on human as well as on animals. Many processes are used to reduce the formation of acrylamide in food stuffs. It has been also found that asparagine is the major ingredient for the formation of acrylamide in cereal food products. Increased amount of asparagine in various cereals can enhance the production of acrylamide. To reduce acrylamide in different baked and fried products the free asparagine content need to be reduced by the enzyme asparaginase that hydrolyses asparagine to aspartic acid and ammonia. In the present study fifteen organisms were isolated from soil sample capable of producing L-Asparaginase enzyme. After screening the strain marked as MR S 10⁻⁴ was selected as the most potent one. The morphological and biochemical test of the strain was performed and it was identified as *Bacillus paramycoides* MR S 10⁻⁴. Using fermenter the strain was capable to produce 116 IU/ml in the selected medium when aeration rate of 1.5 L/min, agitation speed of 150 rpm and medium volume of 4 L. The enzyme can be produced in large quantity, purified and applied to raw materials before application of high temperature treatment like baking or deep oil frying to reduce its Asparagine content. As a result lesser quantity of acrylamide will be formed.

Keywords:

Acrylamide; asparaginase; baking, frying, enzyme

Keynote Lecture -3

Nutrigenomics-Based Processed Food Shaping the Future Personalized Health Care and its Contribution in Indian GDP

Satyabrata Ghosh, Paramita Biswas

M/S Anigiene Agro Biotech Pvt Ltd, STEP IIT Kharagpur

Abstract:



The intersection of nutrigenomics and food science is ushering in a new era of personalized nutrition, where processed foods can be designed to meet individual genetic needs. Nutrigenomics, the study of gene-diet interactions, provides critical insights into how nutrients influence gene expression and metabolic pathways, enabling the development of precision foods tailored to genetic profiles. As global health challenges such as obesity, diabetes, and cardiovascular diseases rise, the integration of nutrigenomics into processed food development presents a promising solution for preventive healthcare and optimal nutrition.

Key words: Nutraceutical, Food Processing, Nutrigenomics, GDP

List of Full paper

ETBFT-24-001

Smart Innovative Multipurpose Food Supply Chain Management System and Sustainable Energy and Society development.

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Abstract

The complexity of the food supply chain (FSC) has increased significantly as global demands for efficiency, sustainability, and food safety continue to rise. To address these challenges, the Smart Innovative Multipurpose Food Supply Chain Management System (SIM-FSCMS) emerges as a promising solution. This paper explores the integration of cutting-edge technologies—such as the Internet of Things (IoT), artificial intelligence (AI), blockchain, and renewable energy—into the food supply chain, enhancing its productivity, traceability, and sustainability. Furthermore, the paper discusses how SIM-FSCMS can drive societal development by improving food security, reducing waste, and supporting sustainable energy practices, all while promoting a more efficient and transparent supply chain.

Keywords

Smart Supply Chain, Sustainable Energy, IoT, AI, Blockchain, Food Security, Multipurpose System, Sustainability, Societal Development, Efficiency.

Introduction

The food supply chain (FSC) is an essential component of modern society, facilitating the movement of food from producers to consumers. However, traditional food supply chains often suffer from inefficiencies, lack of transparency, food waste, and difficulty ensuring sustainability. As global challenges grow, the need for a more efficient and sustainable system becomes clear. This is where Smart Innovative Multipurpose Food Supply Chain Management Systems (SIM-FSCMS) can make a significant difference. By leveraging advanced technologies like IoT, AI, blockchain, and renewable energy, SIM-FSCMS aims to transform the food supply chain into a more efficient, transparent, and environmentally sustainable system. This paper delves into the design and potential impact of such a system on the food industry and society.

Literature Review

The current food supply chain faces several issues, including inefficiency in logistics, lack of traceability, and environmental concerns. Previous studies have shown the potential of IoT in agriculture, where real-time monitoring of crops and environmental conditions improves yields and minimizes resource wastage. AI technologies have been used to forecast demand more accurately, enabling better production and distribution planning. Blockchain technology enhances transparency and ensures food safety by allowing all stakeholders to trace products from farm to table.[1]

Moreover, renewable energy solutions, such as solar and wind, are being integrated into agricultural and food processing operations to reduce dependence on non-renewable resources. However, despite the advancements in these individual technologies, few studies have proposed a comprehensive system that integrates all of them into a single multipurpose solution. There is a need for research that focuses on the holistic integration of these technologies to address multiple challenges in the food supply chain, while also fostering sustainable energy practices.[2][3]

Research Gapping

Although there has been substantial research on the individual components of smart supply chains, such as IoT, AI, and blockchain, the literature lacks a unified approach that combines all these technologies into a single, multipurpose system. Furthermore, there is limited research on the socio-economic and environmental impacts of such integrated systems. This paper aims to bridge this gap by proposing a comprehensive system that not only enhances the efficiency of the food supply chain but also promotes sustainability and contributes to societal development.[4]

Objective

This paper aims to:

1. Develop a Smart Innovative Multipurpose Food Supply Chain Management System (SIM-FSCMS).
2. Integrate IoT, AI, blockchain, and sustainable energy solutions into a cohesive system.
3. Assess the environmental and socio-economic impacts of SIM-FSCMS.
4. Evaluate how the system can improve food security, reduce waste, and promote sustainable practices in the food supply chain.
5. Explore the broader role of SIM-FSCMS in advancing sustainable energy and societal development.

Future Scope

The future of SIM-FSCMS holds great potential for widespread adoption and expansion, particularly in the following areas:

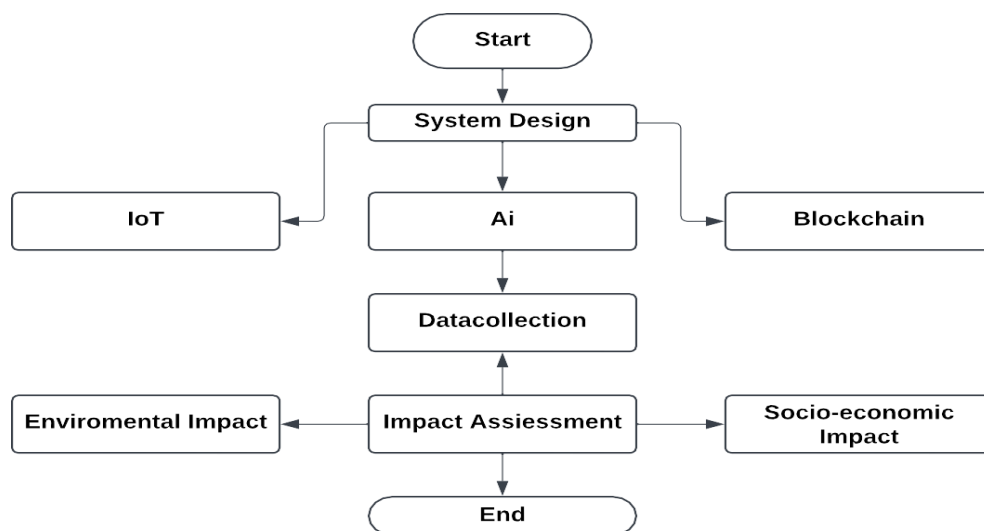
1. Global Food Security: The system can help address food security challenges by optimizing food production and distribution, ensuring equitable access to food resources.
2. Energy-Efficient Supply Chains: The integration of renewable energy solutions can lead to entirely sustainable and energy-efficient supply chains.
3. Smart Cities: SIM-FSCMS can be integrated with urban infrastructure to create smart, interconnected food systems that contribute to sustainable urban development.
4. Global Standards: The development of global standards for smart food supply chains could simplify international food trade and enhance food safety.

Methodology

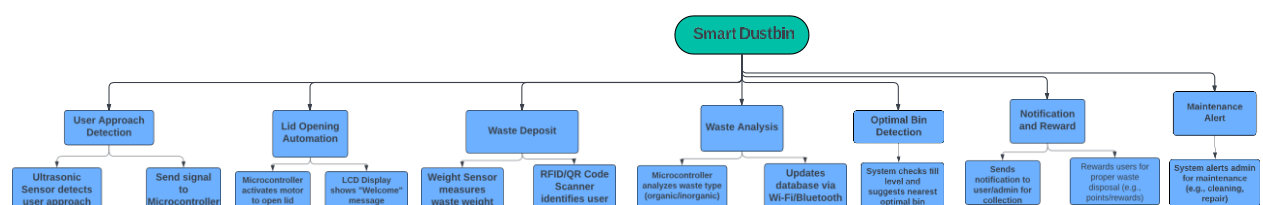
In the research technique, both qualitative and quantitative methods are used:

1. **System Design:** A prototype of the SIM-FSCMS will be developed, incorporating IoT for real-time data collection, AI for demand forecasting and decision-making, and blockchain for ensuring transparency and traceability.
2. **Data Collection:** Data will be collected from different stages of the food supply chain, including production, processing, and distribution, to evaluate the system's efficiency and sustainability.
3. **Impact Assessment:** The environmental and socio-economic impacts of SIM-FSCMS will be assessed using life cycle analysis (LCA) and economic modeling, to measure the potential benefits in terms of resource usage, carbon footprint, and cost savings.

Project Layout Diagram



Flow Chart:-



Advantages and Disadvantages

Advantages

- **Efficiency:** The use of real-time data and predictive technologies improves the overall efficiency of the supply chain.
- **Transparency:** Block chain ensures full traceability of food products, enhancing consumer confidence in food safety.
- **Sustainability:** The integration of renewable energy reduces the carbon footprint of the entire food supply chain.
- **Food Security:** Improved logistics and inventory management help reduce food waste and ensure the availability of food r.

Disadvantages

- **Initial Investment:** The upfront costs of implementing a smart supply chain system can be significant, particularly for small-scale producers.
- **Adoption Barriers:** Small farmers and producers may face challenges in adopting advanced technologies due to financial or technical constraints.
- **Data Privacy:** The use of IoT and blockchain technologies requires careful handling of data to prevent privacy issues and data breaches.

Conclusion

The Smart Innovative Multipurpose Food Supply Chain Management System (SIM-FSCMS) has the potential to revolutionize the food industry by improving efficiency, transparency, and sustainability. By integrating IoT, AI, blockchain, and renewable energy solutions, SIM-FSCMS can contribute to a more sustainable food system, reduce food waste, and improve food security. While there are challenges related to cost, technology adoption, and data privacy, the long-term benefits of such a system are clear. The development and implementation of SIM-FSCMS can play a crucial role in shaping a more sustainable, efficient, and equitable global food supply chain.

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Emerging Trends in Bio-Engineering Generation and Distribution for Development of Rural Village

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Abstract:

A survey showed that 70 % of rural villages are unpowered, restraining India's economic development. It is essential to overcome these problems. A recent study shows that fossil fuel storage in India is nearly 100 years after that, and no fuel is available in India for power generation. So, we need to switch to the bio-engineering generation. In rural areas, most people live below the poverty lines, so it is a dream for them to utilize paid fossil fuels energy; our responsibility is to progress the rural villages, which is possible only when power is generated by biofuels, mainly available in rural areas. Emerging trends in bio-engineering have significant implications for the development of rural villages, particularly in addressing challenges related to energy, agriculture, health, and infrastructure. These advancements aim to improve rural communities' sustainability, efficiency, and self-sufficiency. Here are some key emerging trends in bio-engineering that could revolutionize the generation and distribution of resources in rural areas: Bioenergy and Biogas Generation. Rural areas full of agricultural residues, forestry products, and organic wastes can be utilized for bioenergy generation. Technologies that convert biomass into electricity, heat, and biofuels are becoming more efficient and accessible. Not only bio hydropower generation should utilize bidirectional power flow, which makes society sustainable development, which is a new age requirement. Recent technologies will play a vital role in sustainable green energy generation. Here we will developed a proto type where biodegradable wastes are collected from different sources and mixed composite with biowastes and bio liquid will utilized as fertilizer as well as green energy generation.

Keywords: Innovative waste management, biodegradable collections, multipurpose chamber uses, electricity generation, fertilizer applications, soil management systems, Biogas products. Adriano program, IOT applications.

1. Introduction:-

Waste management is very important to clean our home, city as well as country and world. Now days we are giving more focus for waste management system for that reason Govt invest money for this management but it is restricted only for some cities or smart cities. It is true that (by prediction) with in 2030, almost two-third of world's population will live in cities. So it is required to develop sustainable solutions of urban development for people whose are live in urban as well as rural, interior villages. So in cities huge production of uncontrolled garbage's will make urban life unhealthily, unhygienic, unsecure. As urban sectors are setting all facilities of waste management's but rural areas are lacking that type of facilities .They does not get simple living facilities beyond of

poverty line interior rural area are not getting facilities of electricity and cooking gas too .As a result they destroy forests which will effect everybody's life in the Earth. Due to deforestation environment is also changing. Now it is time to save our inhabitants and protect our green environment. So for that reason we are developing eco friendly green innovative dustbin which can be use by both sectors of human lives and solve all kind of problems of rural and urban inhabitants as well as we can protect our green environment.

2. Related works:-

M.Kalpna and J.Jayachitra[1] describes Intelligent Bin Management System for Smart city using mobile Applications. Harshit Chaugh [2] describes IOT based Smart Bin. Narayan Sharma[3] describes Smart Bin ,in references everywhere we have seen that work is progress only waste management's not beyond of this. No one discussed further innovation by solving of waste problem and how can we developed renewable power generation and solve crisis of cooking gas by biogas as well as how we can easily uses our biodegradable wastes to fertilization ,green bricks industry etc and huge contribution to making digital smart clean India.

3. Existing System:-

The efficiency of collecting the garbage is poor in Indian cities compared to other countries. Thus Indian government struggling to manage the garbages produces by inhabitants. Indian govt has also spend huge money in rural and urban development of power and cooking gas(L.P.G) but still we are provide sufficient amount power and cooking gas to every nook and corner of our villages and cities. So multitasking is more advantageous then single tasking for that reason due to lots of disadvantages of our excising dustbins we develop IOT based full controlled multitasking dustbin which can solve above discussed problems very efficiently.[4] [5]

4. Proposed System:-

In this scheme we change our simple biodegradable dustbin to smart innovative eco environment friendly dustbin. Where biodegradable wastes will collect from different single houses, commercial places and mixed some amount of composed power and wait for 15 days and liquid water comes via inside small filter plate and collect this water in first two chambers one chambers are directly used for fertilization of individual gardens, peddy fields, road side gardens according to installation place and other portion will collect another chamber and uses for electricity, we see that only 5ml waste liquid gives 1.5V(D.C) and then passed for fertilization or if we use one chamber then after produce electricity we use this liquid for fertilization and android or Ardino or IOT programming will give a alert to fulfill of depth of inside garbage ,according to this we will manage our bins for fill up after 1st installation 40 days biogas is also generated and then we can use this gas for cooking and electricity purpose also. This bin is automatic control by robotic technology by *Ardino* programming. So one bin we can use multiple purposes and wastes are also valuable that we can get power, fertilizer, bio gas etc which can give us a revolution advantages if we implemented it in bulk ways by using recent technologies, we will contribute the sustainable development of Green Energy. Our research also contribute the green energy generation and recycle of wastes of food product.[6]

Comparison/New Innovation:-

We think that our modern app based innovative eco dustbin will give every solution of discussed problems of rural and urban sectors which are absents general and recent bins.

Hard ware Implementation List:-

1) Dustbin ii) Two Chamber iii) pipes iv) Zinc and Copper v) Bread Board vi) Adriano ii) Ultrasonic sensor viii) Compose

Circuit diagram:-

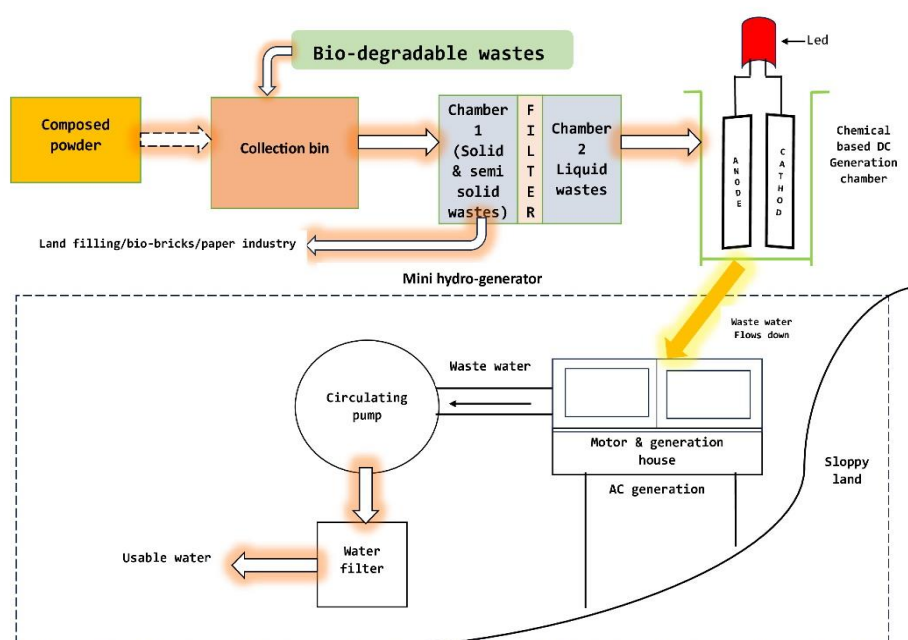


Fig-1 Simple Innovative multipurpose Dustbin.

Working Principle:-

First of all, we will take garbage from our Kitchen (mainly vegetable waste) then we will add this garbage in dustbin. After the dustbin is full, we will add third garbage in dustbin, After the dustbin is full, we will leave it for minimum 15 days. After 15 days, the liquid is formed and is stored at the bottom of the dustbin with the help of filter attached under the dustbin. After liquid is stored in two chambers one of the chamber is arranged with two Zinc and copper plates and led to connected with the plate when plates are fully dissolved in liquid then due to exchanges of electrons in the plate electricity will produced and led will glow and liquid from another chamber is taken and used as fertilizer. Biogas is also generated after 40 days. We will collect the biogas and connect a burner to the dustbin and the biogas will burn and electricity is also generated via biochemical reaction or mini ,micro hydro process.

Experimental diagram:-



Advantages

- 1) Less time and fuel consumption as the trucks go only to filled containers. Our smart operating system enables two ways communication between the dustbins deployed in the city and service operator. Therefore the focus is only on collection of route based fill level containers as sensors installed in the containers provide real time information on the fill level and if required to collect automatically or manually
- ii) Urban service provider and rural individual houses or villages scheme will be benefited.
- iii) Applying this technology to the city optimizes, management, resources and costs and make it a smart city/smart village/smart environment
- iv) It increasing urban parking places as well as road space of footpath.
- v) It keeps the surroundings clean and green, free from bad odor of wastes emphasizes on healthy environment and keep city/village beautiful.
- vi) This type of dustbin reduces manpower required to handle the garbage collection.

Future Scope

This dustbin will be further developed by cloud computing. In proposed model we connected single dustbin to cloud to get the data further we will connect the entire dustbin together.

Data of dustbin can be checked in cloud database further we will design a web portal to connect the entire dustbin together. Notification of dustbin is done by email and sms. This work can be done in huge area also.

Business Relations

The smart, sensor based dustbin will judge the level of waste in it and send the message directly to the municipal corporation. It emphasizes on Digital SAMRT CLEAN INDIA

Conclusion

We have been implemented the real time waste monitoring garbage system with the smart bin to

check the levels of garbage's in dustbin whether the dustbins are full or not. In this system the information of dustbin can be accessed by user /authorities from anywhere by using android app. When garbage levels reached the conditions details of bin will be sent to the authorities via email and app and this system will reduce cleaner routine check of garbage in bin.

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ETBFT-24-004

Exploring the Potential of Spent Coffee Grounds Oil: Characterization and Opportunities

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Abstract

Increasing environmental and economic concerns associated with waste management have spurred interest in the extraction of spent coffee grounds (SCG), a common byproduct of coffee brewing. This study investigates the extraction and characterization of oil from SCG, aiming to identify potential applications for this renewable resource. Using a solvent extraction method, oil was obtained from SCG, and its yield was calculated. Chemical and physical properties, including free fatty acid content (FFA), acid value (AV), saponification value (SV), and, elemental composition of oil extracted from SCG were investigated. Structural confirmation of SCG oil was performed by FTIR-ATR. The findings reveal that spent coffee grounds oil contains a significantly favorable fatty acid profile. These characteristics suggest that the oil could be suitable for various applications, including as a biofuel and a sustainable component in the paint, cosmetics, and lubricants industries. However, limited research and lack of evidence of successful practical applications in the field mean further comprehensive studies in this specific area are required.

Keywords: Spent Coffee Grounds (SCG), Solvent Extraction, Biofuel, Sustainable Waste Management

Abbreviations: SCG, Spent Coffee Grounds; SCGO, Spent Coffee Grounds oil; FFA, free fatty acid; AV, acid value; SV, saponification value; SFE, supercritical fluid extraction.

1. Introduction:

Coffee is one of the most widely consumed beverages globally and ranks as the third most popular drink worldwide. According to the International Coffee Organization, global coffee consumption surpassed 10.16 billion kilograms in 2019-2020, with Europe leading at 32.71%, followed by Asia and Oceania (21.9%), North America (22.15%), South America (16.02%), Africa (7.07%), and Central America and Mexico (3.23%). In Morocco alone, coffee consumption exceeded 35 million kilograms during the same period [1,2]. However, this massive consumption generates significant waste, including plastic cups and spent coffee grounds (SCG). Studies show that processing one ton of raw green coffee produces approximately 650 kg of SCG, a byproduct often discarded despite its potential value [3].

Improper management of SCG can lead to substantial environmental issues. It contains phytotoxic substances and organic acids that can degrade soil and water quality, inhibit crop growth, and contribute to greenhouse gas emissions like methane and carbon dioxide when sent to landfills, exacerbating global warming [4,5]. Additionally, improper disposal of SCG can harm human and

environmental health [6]. However, SCG is not merely waste; its chemical composition is rich in sugars, proteins, antioxidants, polyphenols, and oils, making it a valuable resource for sustainable applications [7-9]. The high antioxidant content of SCG oil (SCGO) makes it suitable for use in cosmetics and personal care products. It can be incorporated into creams, lotions, and soaps for its moisturizing and anti-aging properties [10].

In recent years, SCG has gained attention as a non-conventional source of oil, offering a sustainable alternative to traditional oil sources for biofuel [11,12]. Unlike conventional resources, SCG is abundant, cost-effective, and readily available, making it an attractive option for oil extraction. There are many reports on the application of SCGO in biofuel but a lack of characterization of oil to identify the other potential application fields. The oil derived from SCG has beneficial properties suitable for various applications, including biofuels, cosmetics, and food products [11-14]. By using SCGO, we can address environmental concerns, reduce waste, and promote resource efficiency, aligning with the principles of a circular economy.

Nowadays Coffee seed oil, derived from Coffee plant seeds, is gaining attention for its unique composition and versatile applications. Extracted via methods such as solvent extraction, supercritical fluid extraction (SFE), and mechanical pressing, it yields up to 15% oil, while SCG oil yields are lower (5-10%) due to partial oil loss during brewing [15,16]. Coffee seed oil is rich in fatty acids, including palmitic acid (32%, enhancing stability), linoleic acid (36%, an omega-6 fatty acid with cardiovascular benefits), and oleic acid (11%, known for its antioxidant properties [17]. In contrast, SCGO has a similar fatty acid profile but often contains additional bioactive compounds such as polyphenols and antioxidants, as brewing enriches these components [17]. SCG oil is more sustainable, as it utilizes waste, aligning with circular economy principles, whereas coffee seed oil relies on raw beans, which are comparatively costlier.

This work investigates the extraction and characterisation of SCGO and its prospective applications, illustrating the transformation of SCG from waste into a useful resource, so contributing to a more sustainable future.

2. Materials & methods:

2.1 Materials:

The SCG was collected from a local coffee shop in Kolkata. Solvents such as hexane, ethanol, and all reagents were of analytical grade and procured from Merck India Ltd., Mumbai.

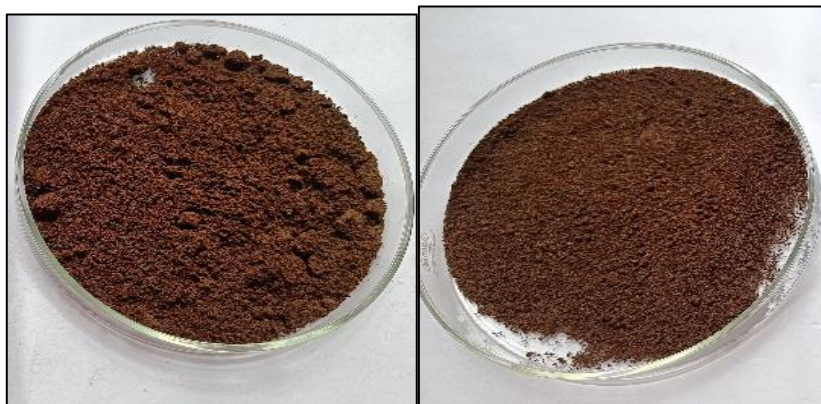


Figure 1. Wet and dried SCG (from left)

2.2 Extraction Methods of SCGO:

The extraction of oil from SCG can be accomplished using solvent extraction. In this method, the oil is extracted using hexane, in a Soxhlet extractor. The process begins with the cleaning and drying of the SCG, followed by the standardized ISO Method 659:2009 [18]. The extraction process was carried out for at least 10 cycles to ensure complete extraction. Once the extraction was finished, the solvent was evaporated, and the extracted oil was then dried and measured [19]. The oil content was calculated using the following formula:

$$\text{Oil content (\%)} = (W_2 - W_1) / W_0$$

W_2 = weight of round bottom flask with extracted oil

W_1 = weight of empty round bottom flask

W_0 = weight of sample taken



Figure 2: SCG oil

3. Results and discussion:

3.1 Oil Content in SCG:

The oil content of spent coffee grounds was found to be **12%** on a dry weight basis. This yield is similar to the oil content reported earlier [20]. The color of the oil was found intense brown.

3.2 Physiochemical characteristics:

Table 1: Physiochemical characteristics-

Properties	SCG oil
Acid value	7
Iodine value (g I ₂ per 100 g)	46
Saponification value	235
Free fatty acid (% as oleic acid)	3.5 %
Specific gravity	0.92
Refractive index	1.4695

The acid value quantifies the concentration of free fatty acids in fat or oil. It is expressed as the number of milligrams of potassium hydroxide (KOH) required to neutralize the free fatty acids in 1 gram of the sample [21]. From Table 1, an acid value of 7 suggests a moderate level of free fatty acids.

The iodine value measures the degree of unsaturation (double bonds) in the fat or oil. It is expressed as the grams of iodine (I₂) that react with 100 grams of the sample [21]. An iodine value of 46 indicates that the oil is relatively low in unsaturation, meaning it has fewer double bonds and is suitable for non-yellowing coating.

The saponification value is the number of milligrams of potassium hydroxide (KOH) required to saponify (convert into soap) 1 gram of fat or oil [21]. The saponification value of 235 suggests that the oil has a low molecular weight, i.e.; it contains a significant amount of short-chain fatty acid.

3.3 Fatty acid composition of SCG oil:

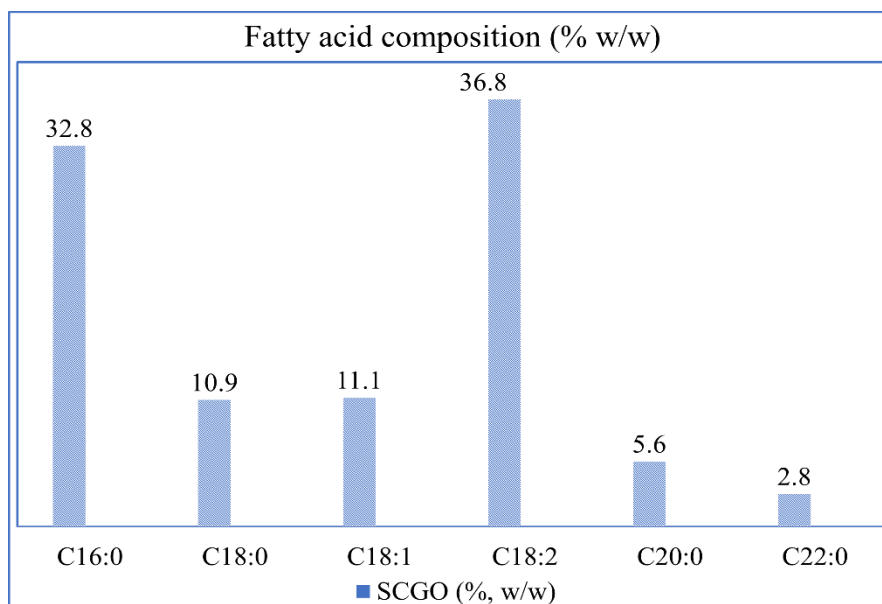


Figure 3: Fatty acid composition of SCG oil

From figure 3, the oil contains a significant amount of palmitic acid (C16:0) (32%), a saturated fatty acid that contributes to a higher melting point and solidity at room temperature, enhancing its frying properties [22]. It also contains linoleic acid (C18:2) (36%), a polyunsaturated omega-6 fatty acid that remains liquid at room temperature and offers health benefits, such as supporting heart health [23]. Linoleic acid is widely used in the coating industry for producing alkyd resins and eco-friendly paints due to its polymerizing properties [24], and in the biodiesel industry as a key component of vegetable oils for sustainable fuel production through transesterification [25]. Additionally, oleic acid (C18:1) (11%), a monounsaturated omega-9 fatty acid, is present, known for its stability and cardiovascular benefits [26,27].

3.4 Structural analysis:

ATR-FTIR analysis of SCGO identified key functional groups. Methylene rocking vibrations at 741-745 cm^{-1} , C-O-C ether stretching between 1073-1267 cm^{-1} , and C-H bending in alkanes at 1461 cm^{-1} . The ester ($>\text{C}=\text{O}$) stretch was sharp at 1736 cm^{-1} , aliphatic C-H stretching appeared at 2855-2926 cm^{-1} , and alkene C-H stretching was noted at 3011 cm^{-1} [19,28-31].

From FTIR data, it may conclude that the extracted oil contains esters with unsaturation present in a long carbon chain (Figure 4).

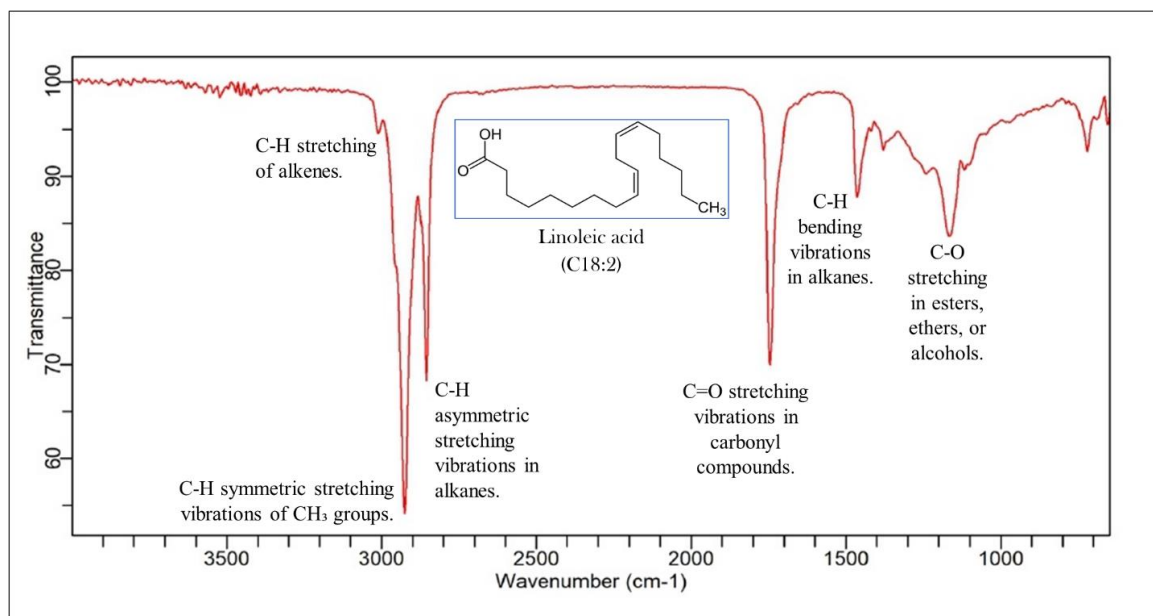


Figure 4: FTIR data of SCGO

4. Conclusion:

The study highlights the potential of SCG as a valuable and sustainable source of oil, offering a promising solution to both environmental and economic challenges associated with waste management. Through solvent extraction, oil was successfully obtained from SCG, with a yield of 12% on a dry weight basis similar to previous studies [20]. The extracted oil exhibited favourable physicochemical properties, including a moderate acid value, low iodine value, and a significant presence of beneficial fatty acids such as palmitic acid, linoleic acid, and oleic acid. These characteristics make SCG oil suitable for a variety of applications, including biofuels, cosmetics, the food industry, and the coating industry.

Their valuation can play a crucial role in sustainable waste management and the development of green technologies, paving the way for a more sustainable and resource-efficient world.

5. Acknowledgment

The authors express their gratitude to the University of Calcutta, Kolkata, for financial support. Apex Chemicals India Pvt Ltd for providing technical assistance.

6. Statement and Declaration of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Preparation of millet based fortified soup powder

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Abstract:

The present study was carried out with the objective to develop Instant Soup from millets, dehydrated vegetables, sugar, salt and powders like onion, garlic, ginger, black pepper, cucumber peel. These herbal formulation increases antioxidant quality of soup. The selected powders were pre-processed, milled and blended in various proportions to formulate instant soup. The product samples that were prepared were assessed for sensory evaluation, proximate composition, and shelf life. The nutritional analysis results indicate that the addition of millets and other ingredients substantially enhances the sensory and nutritional advantages. Preparing this soup mix is extremely easy, which makes it a very convenient and healthy choice. The fat content of fortified soup powder is high than the market available soup powder and control soup powder which ranges between 8.52 ± 0.003 . The polyphenol content of fortified soup powder is also high which comes from mainly cucumber peel powder, carrots and ragi flour which ranges between 0.48 ± 0.0023 . The protein content is also high which is 6.93 ± 0.032 . The fortified soup powder is gluten and lactose free and can be consumed by people allergic to gluten and lactose.

Keywords: Instant soup mix; millets; formulations; nutritional analysis; fortified

1. Introduction

Millets are small grains belonging to the Poaceae grass family. These small, yearly cereal grasses produce small seeds and are able to grow well in poor quality soil. Several of them have been modified to thrive in tropical and arid climates [Hulse, Laing, & Pearson, 1980][1]. Sorghum (Jowar), pearl millet (Bajra), foxtail millet (Kakum), proso millet (Chena), tiny millet (Kutki), kodo millet (Kodon), barnyard millet (Sanwa), and brown top millet are millet varieties [Gopalan, Rama Sastri, & Balasubramanian, 2009] [2]. Ragi, also called finger millet (*Eleusine coracana* L.), is found in numerous regions of India. In some regions of eastern and central Africa and India, millet has historically been an important staple food [FAO, 1995][3]. Finger millet grains have many advantage such as it has a low glycemic index, are gluten-free, and are easily digestible. Due to its low glycemic index, individuals with diabetes and celiac disease can consume grain as it helps in regulating blood glucose levels [Jideani & Jideani, 2011][4]. In comparison to other cereal grains, dietary fibre, carbohydrates, iron, and calcium are more concentrated in the grains [Sood et al., 2016][5]. The active ingredient in *C. sativus*, known as cucurbitacins, has shown cytotoxic effects. (Stratil et al.)(2006)[6]. Cucumber peel is not toxic as it contains maximum amount of polyphenol in water medium and can be utilized for fortifications in vegetable soups.[7]. Ready to enjoy quick meals, dehydrated soup mixes consist of various elements, primarily including cornstarch,

seasonings, salt, flavors, and flavor enhancers [Hafeel et al., 2013][8]. Soup is often utilized to assist with the recovery process, particularly when the individual is limited to consuming only liquids. Soup can be utilized as a starter to boost appetite and aid in the flow of digestive juices in the stomach (Singh and Chaudhary, 2015)[9]. Hence, to increase the antioxidant properties of a gluten-free diet, finger millet is utilized in soup powder combined with cucumber peel powder and other ingredients. Furthermore, minimizing waste is achieved by utilizing cucumber peel.

2. Methods

In this experiment the cucumber peels were dried primarily using a tray dryer, but alternative methods such as drying in the sun, in a hot air oven and in the microwave were also considered. After drying, the cucumber peels were individually ground into a fine powder and mixed with pre-dried salt, millet flour, various spices and other vegetable ingredients to make a soup powder. The soup powder was wrapped in polypropylene bags for storage and testing. To assess the product's quality, a sensory analysis was conducted using a 9-point hedonic rating scale. This scale enabled an assessment of the soup powder's overall taste, texture, and sensory appeal. The implementation of these standardized processes ensured that the product adhered to the necessary quality and safety requirements, while also offering significant understanding on the efficiency of the drying and processing methods employed in the experiment [10].

2.1. Total Sugar Content

The Lane-Eynon method is a titration technique used to determine the concentration of reducing sugars in a sample. The burette is used to add the carbohydrate solution to the flask with boiling copper sulphate solution and methylene blue indicator. The reducing sugars are interacted with the copper sulphate in the container. After all the copper sulphate has reacted, the indicator changes to white color. The amount of sugar solution required to reach the endpoint is taken into consideration. Because the reaction is not stoichiometric, it is necessary to make a calibration curve using standard solutions with known carbohydrate concentrations.[11].

2.2. Fat Content

The most common method for quantitatively determining the fat content of a sample is by extracting it with a solvent that is attracted to fats. The unprocessed fat is gathered and documented immediately, without first being digested. Solid/liquid extraction is the extraction technique that is most widely used. The prepared sample is extracted using the solvent. After removing, the dried leftover is measured and the liquid is removed by evaporation. The gap between the starting sample weight and the final weight is used to calculate the percentage of fat present. The traditional Soxhlet method takes several hours to completely extract all particles from the distilled solvent's reflow. [11].

2.3. Protein Content

Kjeldahl method is used for the determination of protein content. The protein amount is calculated by nitrogen concentration present in the food sample. It consists of three steps:- digestion with sulphuric acid, distillation of the digested sample with steam, titration of the distillate.[11].

2.4. Crude Fibre Content

Use a grinder to grind the sample until it passes through a No. 30 mesh screen. Use ether to extract the 2 g sample, then move the leftover material to the digestion flask. Connect the 200 ml of heated sulfuric acid (1.25%) to the heat source and reflux condenser. Till the sample is completely wetted at the sides, rotate the flask periodically. Make sure that no material is left on the flask's sides. As soon as possible, strain through a linen cloth and wash in boiling water until the water is clear of acid. Re-wash the residue in the flask using 200 ml of hot, 1.25% sodium hydroxide solution. Tighten the flask's reflux condenser and boil rapidly for precisely thirty minutes. As soon as possible, remove the flask and pass the contents through a sintered crucible. Entire residue should be carefully transferred to the hot water flask. Rinse with ether after using ethyl alcohol. Next, dry to constant weight (W1) at 1000°C. After the material has been sintered, move the crucible to a muffle furnace set at 5250°C and ash it. Weigh and cool (W2). Crude fibre is shown by the weight reduction.[11].

2.5. Polyphenol Content

The FC method is a SET test that relies on the alkaline interaction of phenolic compounds with the FC reagent. This reagent is a yellow combination of phosphomolybdate and phosphotungstate that produces a strong blue complex with a broad absorbance band in the 600–800 nm region when reduced by the phenolic groups through spectrophotometric analysis. Results are given in terms of gallic acid equivalent (GAE) concentration. The measured absorbance is proportional to the polyphenol content in the sample, which is typically evaluated using a calibration curve of gallic acid.[12].

3. Result and Discussions

The fat content of fortified soup powder is high than the market available soup powder and control soup powder but people can think that it will harm their health but in actual it will not affect the health. This high fat arises from the coconut milk powder that we have in our soup powder which is a rich source of medium-chain triglycerides. From journal study we can say medium chain triglycerides is very much good for health or we can say it is a healthy fat as they metabolize quickly and gets converted to energy. Along with this it also contains lauric acid a type of fatty acid which act as antibacterial components. We are using coconut milk powder because it can be ingested by lactose sensitive persons. The protein content is also very high in fortified soup powder which helps in increase intestinal calcium absorption, glycemic regulation and many more health benefits.[13]. The polyphenol content of fortified soup powder is also high which comes from mainly cucumber peel powder, carrots and ragi flour. Since the control soup does not contain any cucumber peel and ragi flour hence the polyphenol content is quite low. Polyphenol act as an antioxidant which prevents oxidation of the free radicals. They offer several health benefits like enhance cholesterol profile,

blood pressure, systemic inflammation etc. [14]. The fortified soup powder is gluten free due to ragi flour and lactose free due to incorporation of coconut milk powder hence it can be consumed by people allergic to gluten and lactose.[15].

Parameters	Results(g/100g)		
	Market soup powder	Fortified soup powder	Control soup powder
Total Sugar	3.8±0.02	2±0.001	3.5±0.002
Protein	3.8±0.003	6.93±0.032	5.05±0.01
Fat	4±0.02	8.52±0.003	6.5±0.32
Crude Fibre	4±0.001	5.2±0.001	4.8±0.03
Polyphenol	0.05±0.023	0.48±0.0023	0.32±0.02

Fig. 1: Comparison of Market, Fortified and Control soup powder

4. Conclusion

Total Sugar Content of Fortified soup powder is low (2±0.001). Protein content is high is compared to market and control soup powder (6.93±0.032). Fat content is high but it helps to metabolize quickly (8.52±0.003).Crude Fibre and Polyphenol content is also high (5.2±0.001 and 0.48±0.0023 respectively) which makes the fortified soup powder a better choice than the market and control soup powder.

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**EFFECT OF DIFFERENT DRYING METHODS ON DRYING KINETICS AND
MODELLING OF GREEN BANANA PULP**

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ABSTRACT

The banana (*Musa* sp.) stands as one of the most extensively cultivated tropical fruits globally, offering a rich array of fibers, vitamins (including C, B6, and provitamin A), and essential minerals such as potassium, phosphorus, magnesium, and zinc. Additionally, it contains bioactive compounds, notably phenolic compounds and resistant starch (RS), which may play a significant role in promoting health benefits linked to gastrointestinal issues, glycemic and insulin metabolism, weight management, and complications related to renal and liver function in the context of diabetes. Bananas, owing to their perishable nature and vulnerability to post-harvest loss, necessitate strategies to prevent microbiological growth and spoilage, prolong shelf life, minimize packaging, and improve storage for efficient transportation; diverse drying methods can effectively diminish the moisture content of food products. Understanding the essential transport mechanism and precisely recreating or scaling the entire process to enhance or control operational parameters depends on the thin-layer drying of materials. Research demonstrates that employing experimental drying techniques without quantitatively assessing drying kinetics can substantially impact dryer efficiency, elevate production costs, and degrade the quality of the dried product. The development of mathematical models to determine the drying kinetics of agricultural products is crucial, as an effective model is required for process design, optimization, energy integration, and control. The coefficient of determination (R^2) should converge towards one according to the statistical criteria for evaluating optimal models, but other statistical metrics will display values nearing zero. This study seeks to determine the optimal drying model for raw banana pulp by analyzing drying kinetics using multiple approaches, including microwave drying, freeze drying, tray drying, and vacuum drying.

Keywords: Green Banana Pulp, Food waste, Drying Kinetics, Thin Layer, Mathematical Modeling.

1. INTRODUCTION:

Fruit being one of the most essential factors of a healthy diet because of their content of vitamins and minerals, fiber, and several non-nutrient substances as bioactive composites, ingestion of at least 400 g(about five portions) of fruits and vegetables per day according to World Health Organization(WHO) is recommended (1). One of the primary concerning factors for advanced mortality is a low fruit input, which also raises the threat of habitual ails and bad health. Accordingly, eating fruits on a

regular base can lower the possibility of developing certain lifestyle diseases like diabetes, heart complaint, gastrointestinal diseases, and some types of cancer (2,3).

One of the most extensively grown tropical fruits worldwide is the banana (*Musa sp.*). Over a thousand different types of bananas are grown worldwide. Because of its high product per hectare and resistance to environmental changes, the *Musa Cavendish* is the most capitalized banana variety, counting for nearly 45 of the global request. The plantain, which includes up to 100 cultivars, is the other major variation group of bananas (4). About 110 million tons of bananas are produced annually, which accounts for 15 of the world's total fresh fruit product.(5) Still, nearly one- third of all bananas gathered is lost since the population substantially consume ripe bananas. Ripe bananas are prone to mechanical damage and are perishable during the development process, which makes their storing process and transport delicate.(6) Nearly 20% of banana product is not capitalized due to size and appearance excrescencies, adding their loss.(7). As a result, fruit processing was developed to address issues like poor transportation, a lackluster structure, and the perishable nature of the yield, which causes significant losses for the farmer. There's a significant loss during the post-harvest glut, and constantly, some of the produce has to be left to spoilage.(8) Optimizing banana processing has been delved to increase the bioavailability and use of the nutrients set up in this fruit, emphasizing the use of green banana (GB) products, and to drop waste generation(about 1/4 of the banana fruit is rejected annually).(9)

Green bananas are considered to be a good source of fiber, minerals(potassium, phosphorus, magnesium, zinc), vitamins(Vit C, B6, provitamin A), and bioactive substances similar phenolic composites and resistant bounce(RS), all of which can give health benefits grading GB as a functional food.(10)

The pulp of the fruit has 20 – 25 of the high carbohydrate content that characterizes the callow stage of bananas. The maturity of the polysaccharides are converted into answerable sugars during the climactic. Total phenols and flavonoids, including epicatechin, galocatechin, catechin, dopamine, and tannin, are abundant in green bananas. Green banana pulp is the most abundant source of galocatechin and dopamine, two antioxidant chemicals.(11)

Bananas are climactic fruits with a soft texture that are simple to decay after harvesting, leading to conspicuous changes in texture, nutritive content, and sensitive rates. The shelf life and profitable value of bananas can be increased through farther processing, and drying is one of the most popular processing ways. The abecedarian thing of drying food goods is to remove enough water from the solid to vastly limit microbial corruption and deterioration brought on by chemical responses.(12) Drying processes can prop in lowering the humidity position of food constituents to protract shelf life, help microbial development and deterioration, reduce packaging, and enhance storehouse for accessible conveyance. Understanding the introductory transport medium and duly simulating or scaling up the entire process to optimize or control the functional parameters depend on the accoutrements thin-layer drying. According to research, counting purely on experimental drying ways without taking the kinetics of drying into account mathematically can have a substantial impact on dryer effectiveness, raise product costs, and degrade the quality of the dried product. The development of different models to determine the drying kinetics of agrarian products is pivotal since an effective model is needed for process design, optimization, energy integration, and control. The

measure of determination (R^2) must be near to concinnity according to the statistical criteria used to estimate the best model (s), but the other statistical measures will have values that tend toward zero.(13)

The substance of this study is to find the best- fitted drying model for the raw banana peel through drying kinetics under different drying processes i.e microwave oven drying, freeze drying, tray drying and vacuum drying.

2. MATERIALS & METHOD:

2.1 PREPARATION OF SAMPLES:

2.1.1 RAW MATERIALS:

Trials were performed on green bananas (*Musa sp.*) purchased at a local market, Jadavpur, e chemicals necessary for the trials are purchased from verified vendor.

2.1.2 PREPARATION OF SAMPLE:

The green bananas were first washed well with tap water to remove the dust and any impurities adhered to the outer surface of it. The peels were removed carefully using a peeler and the pulp was cut into small pieces (2-3 mm thickness). It was then measured and blanched at 85 degree C using KMS at 1% concentration. Different drying techniques are used to study drying kinetics. (14)

2.2 DRYING PROCESS OF GREEN BANANA PEEL

2.2.1 Freeze-drying (FD)

Fresh green banana peels were frozen in an ultra-low temperature freezer at -40°C for 4 hours. (New Brunswick Scientific, England, C340-86). For 4.5 hours, FD was performed in a freeze dryer at a pressure of 14 Pa and a temperature of -45°C . (15,16)

2.2.2 Microwave drying (MD)

The MD was done using a home microwave oven. The operating frequency was kept constant at 2450 MHz, with power and irradiation time adjustments. MD ran from 4.5 to 22.5 minutes at five different power levels: 900, 600, 450, 300, and 180 W. (16)

2.2.3 Tray drying (TD)

This tray dryer (SS-24, Mac Pharma Tech, India) has 12 trays, each measuring 0.75×0.35 m. The air velocity was kept at 1.5 m/s and the temperature was kept at 60°C for three hours for the entire drying operation. (15)

2.2.4 Vacuum drying (VD)

VD was carried out in a vacuum dryer (VS-1202 V5, ICT, India) at a temperature of 60°C and pressure of -760 mmHg for 2.30 hours. (17)

2.3 DRYING KINETICS:

Throughout the drying process, temperature, moisture, and diffusivity were kept constant and shrinkage was negligible. Six thin layer drying models (18) are widely used to explain the drying kinetics of Green banana pulp (Table 1). This model has been taken from the general solution of Frick's law with some simplification and was established to improve the existing drying system or to control the drying process. (19,20) The parameters used for the models were (1) k-drying constant (1/min), dimensionless drying constant, n-dimensionless drying constant, and (2) constant (1/min). The better suitable model was ascertained by the equivalence of the less sum of square error (SSerror), root means square error (RMSE), and coefficient of determination (R²) value. The best fitting model was determined by comparing the sum of square error: (15,16)

$$SS_{error} = \sum (y_i - \hat{y})^2 \quad \text{equation 1}$$

where y_i is the i th observed response value and $\hat{y}$ is the mean response. (15,16)

TYPE OF MODELS	EQUATIONS
Lewis	$MR = \exp(-kt)$ (eq-2)
Henderson-Pabis	$MR = a \exp(-kt)$ (eq-3)
Logarithmic	$MR = a \exp(-kt) + c$ (eq-4)
Page	$MR = \exp(-kt^n)$ (eq-5)
Midilli	$MR = a \exp(-kt^n) + b$ (eq-6)
Wang and Singh	$MR = 1 - at - bt^2$ (eq-7)

TABLE:1 THIN LAYER MODELS USED

3 RESULTS AND DISCUSSIONS:

DRYING KINETICS:

Moisture was removed totally in the falling rate period during each drying operation, from an initial moisture content of 17.28 g moisture/g dm to a final moisture content of 0.0214 g moisture/g dm. Extensive literature indicates that nearly all of the biological product drying happens during the declining rate period. Similar to a prior study, the drying of green banana pulp occurred throughout the declining rate period in this investigation. (21). Total time duration recorded in the case of FD,TD,VD and MD 800,640,480,320 and 160 are 525 min,206 min,140 min,3.51 min,5.24 min,6.11 min,7.28min and 19.50 min respectively. Six different thin layer models (Equations 2-7 , Table 1) were applied to MR data of dried Green Banana Pulp, and results suggested a good agreement between experimental and predicted values for all models. The choice of the best model is determined by statistical indicators that gauge the predictability of the model rather than by the quantity of constants.(22) Among all equations, the wang and singh (equation-7) model had the lowest SSE values (0.0568–0.00315), indicating that the model was the best for describing the drying

process of green banana peel, similar results has been reported in Drying Characteristics and Assessment of Physicochemical and Microstructural Properties of Dried Culinary Banana Slices by Khawas et. al. 2015. (23) The fitting of MR vs drying time data for different drying processes with the Wang & Singh equation is given in Figure 2. Figure 1 A, B shows that there is good fit of experiment.

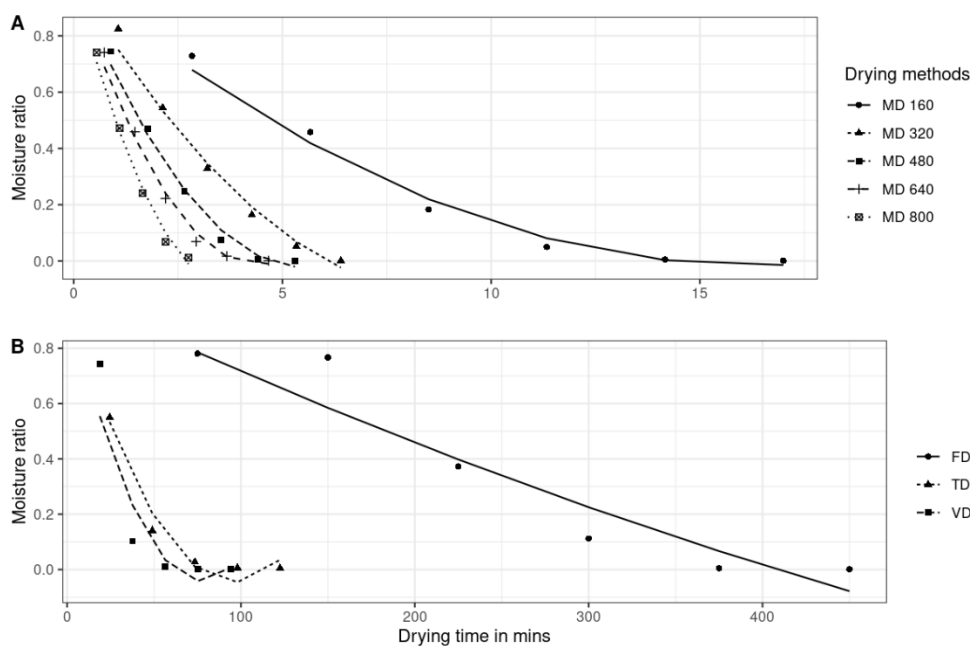


FIGURE 1A & B: THE FITTING OF MR VS DRYING TIME

4 CONCLUSION:

Due to its historical use as food and medicine in several parts of the world, green banana pulp are inexpensive, flexible products with the potential to be turned into useful foods. The Wang and Singh model has been determined to be the most accurate thin layer drying model for examining the banana peel's drying kinetics based on the experimental data. Out of the six models that were examined, this one had the lowest SSerror and R² value. This aids in meeting modern production procedures, such as statistical processing for the appropriate conclusion of the drying process, in addition to measuring the ideal drying environment. It will also work well as a helpful reference tool for drying equipment modeling and design.

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Valorization of *Citrus sinensis* Peel for Development of Nutritionally Enriched Whipped Cream Powder

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Abstract:

Citrus sinensis is a fruit that is often used to produce juice, pulp, jam, and marmalade in the food processing industry. Around 50%-60% of this processed fruit is wasted citrus peel. These peels which are disposed of in huge amounts contain a lot of nutrients like vitamin C, fibres, and plant compounds like polyphenols, carotenoids, and flavonoids. It has been found that the peels contain a higher amount of phenolic compounds compared to the edible portion of the fruit. This study aimed to develop a fortified version of the whipped cream powder by incorporating *Citrus sinensis* peel powder into it. This fortification resulted in a whipped cream powder which was nutritionally superior to the non-fortified one. Along with nutrition, the functional and sensory attributes of the fortified product were also found to be better. The whipped cream made from the powder had a yellowish-orange hue along with a mild orange flavor. Both of these attributes of the final whipped cream helped eliminate synthetic food coloring agents and essences. Moreover, all phenolic compounds and other nutrients are well preserved in the whipped cream since no sort of heat treatment is applied in the process. Thus, through this innovative approach, we aimed to prove that food waste can be valorized to produce fortified products that not only adhere to a more environment-friendly scenario but also align themselves with the consumer's demand for health, sustainability, and functionality at low cost.

Keywords: cream; whipped cream; by-product; fortification; waste management;

1. Introduction

Fortification, aimed at improving nutritional quality, addresses nutrient deficiencies and enhances the value of food products^[1]. As consumers prioritize health-conscious, natural foods with fewer additives, this study explores creating artificial coloring and flavor-free whipped cream powder using orange peel powder.

Whipped cream is a form of double cream, heavy cream, or similar high-fat cream that has been beaten with a whisk or mixer till it is light and foamy and can maintain its shape. This transformation involves trapping air bubbles in a fat globule network. During whipping, air-water boundary tension draws fat and proteins, causing the fat globules to lose their membrane and spread out^[2]. Quality whipped cream achieves overrun exceeding 80–90%^[3], making it ideal for decorating cakes, desserts, fruit salads, ice cream, and milkshakes. Cream with less than 22% fat is unsuitable for whipping. Oranges, rich in nutrients and phytochemicals, generate substantial waste, with 50–60% of processed fruit discarded as peels, seeds, and membranes^{[4][5]}. The orange peel, which is the

principal food waste from oranges, contains flavonoids that have antioxidant effects. Citrus peel extracts' antioxidant effects are principally due to the presence of naringin and glycosides hesperidin^[6]. Orange peels are also known to contain other phenols, such as phlorin and coniferin. Beta-carotene, a carotenoid in orange peels, is a vital precursor to vitamin A. It functions as an antioxidant, supporting human health by reducing oxidative stress. Its health benefits include lowering the risk of cardiovascular diseases and certain cancers^[7]. The daily recommended consumption of vitamin A for women is 700 µg, for men, it is 900 µg, and for children, it is 300 to 600 µg.^[8]

2. Methods

The oranges, ready-made whipped cream, powdered milk, and other ingredients like GMS (Glycerol Monostearate), and Xanthum gum used in whipped cream preparation were obtained from the local market, in Sodepur, West Bengal.

2.1. Preparation of orange peel powder

The oranges were thoroughly washed under running water to remove any dirt, pesticides, or contaminants from the surface and then peeled. Only the orange-colored zest part was peeled while avoiding the bitter white pith underneath. This was done to prevent any alteration in the taste of the final orange peel powder. Next, the fruit peels were sliced into small pieces and placed on a tray. This was then placed in a tray dryer at 67°C for 24 hrs. The dried peels were ground and then sifted to obtain fine particles. The obtained powder was then sealed in vacuum bags and stored in the freezer at -18°C for further use.^[9]

2.2. Preparation of orange peel-fortified whipped cream powder

Icing sugar and prepared orange peel powder were added to milk powder. GMS powder was used as an emulsifier, and Xanthum gum powder was used to give the cream elasticity. Citric acid was added to help preserve the whipped cream powder. The mixture was then blended in a blender and then transferred into vacuum-sealed pouches.

2.3. Preparation of the whipped cream using fortified whipped cream powder

20g of the fortified whipped cream powder was taken. 5 g of butter was added to it along with 3 tablespoons of chilled water. One entire egg white was added to the cream to increase its fluffy texture. The whipped cream was made by whisking the mixture with a hand blender for 30 minutes. The whisking speed should be slow at the beginning and should gradually increase as the mixture thickens. The whisking was continued till the desired creamy texture was obtained.



Fig. 1: Fortified whipped cream powder and whipped cream made from fortified whipped cream powder

2.4. Rheological analysis of the whipped cream made from fortified whipped cream powder

The power law model is frequently applied to describe the rheological flow characteristics of non-Newtonian fluids, which are typically shear-thinning. The power law is expressed as below.

$$\tau = k(dv/dy)^n \quad (i)$$

In this equation, k is flow consistency index, τ represents shear stress, dv/dy stands for shear rate or velocity gradient, and n represents the flow behavior index. This power law was used to study the behavior of the whipped cream made from fortified whipped cream powder with the help of Brookfield Rheometer. ^[10]

2.5. Determination of beta carotene content

The β -carotene was extracted by soaking 0.5 g of the sample in 25 ml of acetone at room temperature without light. The mixture was then stirred magnetically for 30 minutes. The extracts were then centrifuged at 5000 RPM for 10 minutes, followed by the collection of supernatant. The volume was adjusted to 50 mL by adding the extracting solvents. Finally, the absorbance of the extracts was evaluated with a UV-Vis spectrophotometer with a wavelength of 450 nm. ^{[11][12]}

2.6. Chemical Analysis

The ash content of the fortified whipped cream powder was estimated by the process as described by George, Sony, et al., 2023^[13]. The moisture content was estimated by Zambrano, Marina Vera, et al, 2019^[14]. The polyphenol content was estimated by a UV-vis spectrophotometer described by Petra Matić, Marija Sabljčić, Lidija Jakobek, 2017^[15]. Lactose content was determined by the Lane-Eynon method by Da Silva, Luana Cristina A., et al. ^[16]

3. Result and Discussions

3.1. Rheology and analysis

Rheology is the study of the flow and deformation of materials, especially liquids and soft solids, in the presence of applied forces or stresses. The flow behavior is shown in Fig. 2. The rheological analysis revealed calculated values for k (flow consistency index) and n (flow behavior index). The value of n was determined to be 0.056, indicating it is less than 1. This proves that whipped cream made from fortified whipped cream powder shows pseudo-plastic behavior. The consistency index of the fortified whipped cream powder was found to be 13.26.

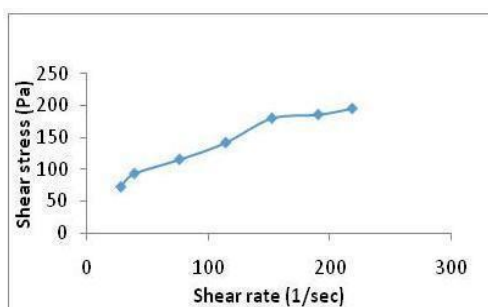


Fig. 2: Flow behavior of whipped cream made from fortified whipped cream powder

3.2 Polyphenol content and beta carotene content of orange peel powder, fortified whipped cream powder, and market-bought whipped cream powder

The polyphenol content of orange peel powder, fortified whipped cream powder, and market-bought whipped cream powder in methanol were estimated. This shows that the whipped cream powder fortified with orange peel powder has a higher beta carotene as well as polyphenol content in comparison to the market-bought whipped cream powder.

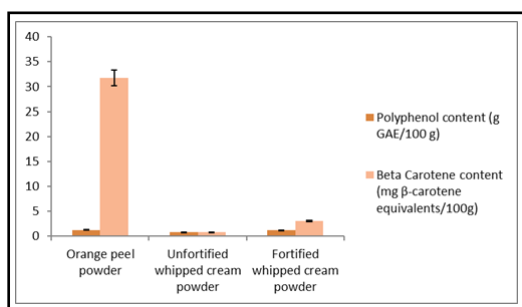


Fig. 3: Polyphenol content and Beta Carotene content of orange peel powder and whipped cream samples

3.3 Chemical analysis

Chemical analysis of both the whipped cream samples were done and presented in Table I. It was observed that the lactose content of the fortified sample decreased, but the polyphenol content increased.

Table 1: Chemical analysis

Sample	Moisture content (%)	Ash content (%)	Polyphenol content (g GAE/100g)	Lactose content (%)
Unfortified whipped cream powder	5.1±0.12	6.02±0.35	0.77 ±0.2	38.0±0.13
Fortified whipped cream powder	5.59.0± 0.3	3.5±0.32	1.16±0.35	36.0±0.25

Results in the form of mean± s.d.,

4. Conclusion

We have enhanced our whipped cream powder by integrating orange peel powder, enriching it with beta-carotene and polyphenols. This infusion provides natural flavor and color and highlights the nutritional benefits of beta-carotene and polyphenols. β -carotene, a natural pigment abundant in orange peels, imparts vibrant yellow and orange hues to a variety of fruits and vegetables. This compound serves as a precursor to vitamin A within our bodies. β -carotene is an effective antioxidant, protecting the body from the detrimental effects of free radicals. β -carotene is known to degrade during any type of heat treatment. However, since no heat treatment is involved in the preparation of whipped cream, no such degradation will occur. Thus, the valuable properties of antioxidants will remain intact in the final product. Therefore, by incorporating orange peel powder into the whipped cream powder we have prepared a fortified version of whipped cream powder that has a natural yellowish-orange hue when made into the cream along with a typical inherent orange flavor and essence, making it a good alternative to people who are allergic to artificial food additives.

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**ISOLATION AND APPLICATION OF LACCASE ENZYME IN AZO DYE
BIOREMEDIATION**

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Abstract:

The potential of laccases for the bioremediation of azo dyes was explored through the isolation of microorganisms from soil samples contaminated with Tartrazine, Sunset yellow, Ponceau 4R and Rhodamine b. The Soil sample was obtained from the prepared contaminated soil and it was subjected to serial dilution and pour plating on agar media. The bacterial colonies that emerged were collected and evaluated for their capacity to decolorize the dyes mentioned earlier. Different bacterial isolates demonstrated varying degrees of efficiency in decolorizing these dyes. Laccase screening was done using Guaiacol 0.01% for 48 hours and the culture turned brown showing the presence of Laccase. Volume of the nutrient media was 100ml; time 48 hours; pH 7. For 50 ppm, the percentage of dye removal for the following azo dyes were as follows, Tartrazine 54%; Sunset Yellow 27.79%; Ponceau 4R 25.5%; and Rhodamine B was 5.4% reflecting the diversity of microbial species with potential applications in dye bioremediation. The ability to break down azo dyes is essential for environmental sustainability, as these compounds are widely utilized in industries such as textiles and food processing, yet they pose toxicity risks to aquatic organisms and humans. The results indicate that bacterial laccases produced by specific isolates may serve as effective agents in bioremediation strategies aimed at detoxifying wastewater contaminated with azo dyes, thereby aiding in pollution mitigation and environmental conservation. Further, optimization and characterization of the laccases involved in this process could facilitate their use in extensive bioremediation initiatives.

Keywords:

Laccase; Azo-dye decolourization; Guaiacol assay; Bacteria.

1. Introduction

Lack of access to safe and clean water for drinking and other uses is one of the biggest health issues facing the world today. Industrial dyes are among the other common substances that degrade water quality and render natural water sources unfit for human consumption. Synthetic dyes (such as azo dyes, indigo dyes, reactive dyes, anthraquinone dyes, and others) have become more and more in demand in recent years, particularly in the textile and clothing industries as well as the food, cosmetics, and pharmaceutical sectors. According to Slama et al. (2021), the reasons behind this increased demand are i) the production costs of these dyes are significantly low, ii) they have high colour stability, iii) they have resistance to some major factors (such as oxygen, light, and pH)

compared to natural dyes and some others. It has been reported that the wastewater mixed with several discharged toxic dyes shows noticeable colours even if the concentration of these dyes is more than 1 mg/L. Reportedly, the effluents of the textile and its associated industries release a concentration of around 300 mg/L because around 10-15% of the total used dyes are lost into the effluents, therefore, these are directly contributing to environmental pollution. In recent years, enzymes have gained great importance in industries, laccases are one among them which are widely present in nature. Laccase (benzenediol: oxygen oxidoreductase; EC 1.10.3.2) is a blue-copper oxidoreductase that catalyzes the oxidation of a wide range of substrates including phenolic compounds with the concomitant reduction of molecular oxygen to water. MCOs contain a minimum of four Cu's divided into Type 1 (T1), Type 2 (T2), and binuclear Type 3 (T3) Cu sites that are distinguished based on unique spectroscopic features. Substrate oxidation occurs near the T1, and electrons are transferred approximately 13 Å through the protein via the Cys-His pathway to the T2/T3 trinuclear copper cluster (TNC) where dioxygen reduction occurs.[1][5][6][7][8]

2. Methods

2.1. Preparation of sample and isolation

The soil was collected from waste-area and it was induced with various dyes like Tartrazine, Sunset Yellow, Ponceau 4r, RhodamineB, each with a concentration of 100 ppm. The induced soil was kept undisturbed for about 15 days. After 15 days isolation of soil organisms was done. A total of 15 strains were isolated.

2.2. Inoculation of samples

Two concentrations of 100ppm and 50ppm of each azo dye were taken and the 15 different strains were inoculated in each 250 ml Erlenmeyer flasks containing 50 ml nutrient media broth. The cultures were then placed in the rotary shaker incubator for 48 hours at 37°C and control was also taken for each dye which contained no inoculum. After 48 hours the media was centrifuged at 5000 rpm for 10 mins and supernatant was collected. The absorbance was then measured using a UV-Vis Spectrophotometer. The percentage of decolourization of each strain was calculated in respect to the control.[3]

2.3. Optimization of incubation period

Nutrient media of 50 ml was taken in 250 ml Erlenmeyer flasks and inoculated with all the 4 strains with maximum dye removal for their respective dye and were placed in rotary shaker for the following hours 24, 48, 72, 96 and the readings were observed in a UV-Vis Spectrophotometer in respect to the control of the 4 specific dyes separately after centrifugation at 5000 rpm for 10 mins. [3][4]

2.4. Optimization of percentage of inoculum

Nutrient media of 50 ml was taken in 250 ml Erlenmeyer flasks and inoculated with all the 4 strains with maximum dye removal for their respective dye in the different concentrations as follows 1%, 2%, 3%, 4%, 5%, 6% and were placed in rotary shaker for 48 hours and the readings were observed

in a UV-Vis Spectrophotometer in respect to the control of the 4 specific dyes separately after centrifugation at 5000 rpm for 10 mins. [3][4]

3. Result and Discussions

3.1. Decolourization of dyes

The percentage of decolourization observed for 50 ppm concentration of each dye were 54% for Tartrazine; 25.79% for Sunset yellow; 25.5% for Ponceau 4R and 5.4% for Rhodamine B.[9]

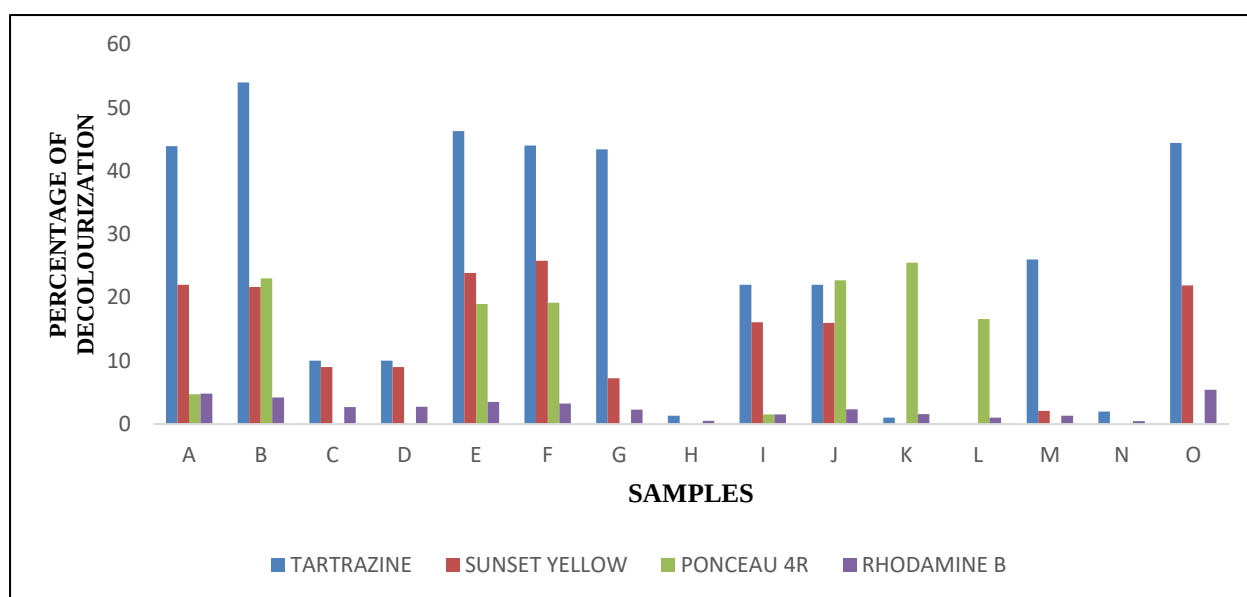


Fig1: Graph showing the percentage of decolourization in respect to the sample

3.2. Screening of bacterial laccase

Agar plates were made for each sample which showed the maximum decolourization for their respective dye and they were kept in the incubator for 24 hours at 37°C kept in the incubator for 24 hours at 37°C. After 24 hours 0.01 % Guaiacol was added to the culture plates and kept in the incubator for 48 hours and the culture turned brown showing the presence of Laccase[2]



Fig 2: Brown colour observed in the culture plate in respect to the control plate after 48 hours after adding Guaiacol showing the presence of Laccase enzyme.

3.3. Parameter Optimization

The incubation period which showed the maximum enzyme production was 48 hours and the inoculum percentage which showed the maximum enzyme production was observed at 2% for Sunset Yellow, Tartrazine and 3% for Rhodamine B and Ponceau 4R.

4. Conclusion

The enzyme laccase, which is generated by bacteria and fungus, has shown great promise for use in industrial settings because of its potent decolorizing abilities. Particularly, bacterial laccases have benefits like increased stability and wider operating settings, which make them appropriate for a range of industrial applications. In industries where the removal of colorants and contaminants is critical, such as textiles, paper, and wastewater treatment, their capacity to oxidize a broad variety of phenolic compounds makes them indispensable.

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ETBFT-24-014

Milk clotting and caseinolytic activity of enzyme extracted from *Moringa oleifera* leaves

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Abstract:

Finding new sources of milk clotting enzyme is crucial for cheese preparation because of the high cost, scarcity of pure calf rennin, religious prohibitions against the use of animal rennin (such as in Islam and Judaism), safety concerns (such as Bovine spongiform encephalopathy) and dietary restrictions (such as vegetarianism). The present work demonstrates milk clotting and caseinolytic activities of crude enzyme extracted from *Moringa oleifera* leaves. The sample was dried using three types of drying processes (Sun drying, drying by hot air oven and drying by tray dryer). The crude extraction was conducted using 50 mM potassium phosphate buffer (pH 7.5). The protein concentration of the crude extract was highest in the case of the tray-dried sample while it was lowest in the case of the sample dried by hot air oven. Milk clotting activity was determined by using 10% skim milk (w/v) in 0.01M CaCl₂ solution (pH 6.5) as a substrate at 35°C. The highest value of milk clotting activity was obtained in the sample dried by tray dryer while the lowest was detected in sun-dried sample. Caseinolytic activity was determined by using azocasein as a substrate. Moreover, the highest value of caseinolytic activity was recorded in the case of tray-dried sample while the lowest value was obtained in sun-dried sample. It was concluded that crude enzyme extracted from *Moringa oleifera* leaves can act as a substitute for pure calf rennin for cheese preparation and tray dryer is a convenient way for drying the sample.

Keywords: *Moringa oleifera*; Types of drying; Protein concentration; Milk clotting activity; Caseinolytic activity.

1. Introduction

In the food industry, plant proteases are frequently employed for a variety of purposes, including brewing, meat tenderization, milk coagulation, and digestive aids. Proteases are also employed to alter the functional characteristics of dietary proteins, such as coagulation and emulsification and to enhance their nutritional value, solubility and digestibility. The flavour properties of cheese are greatly influenced by naturally occurring proteases. They are used to change the functional characteristics, decrease the allergic qualities, and accelerate the ripening of cheese [1]. Rennet is a key ingredient in the process of milk coagulation, which is a crucial step in the production of cheese. The most common milk product (75%) sold in the market is rennet coagulated cheese. However, as it produces an appealing texture and a strong aroma in cheese, calf rennet is primarily utilized as a milk clotting enzyme in cheese making. Thus, finding new sources of milk clotting enzyme is crucial because natural calf rennet is expensive, scarce, and prohibited in some religions (such as Islam and

Judaism), for safety reasons (such as bovine spongiform encephalopathy) and for dietary reasons (such as vegetarianism) [2].

Plant proteases are involved in a number of biological activities as they catalyze the hydrolysis of peptide bonds. Various food processing industries employ this feature to manufacture different products. Protease's action destabilizes casein micelles, which causes milk to clot. The k-casein hydrophilic domain preserves the structure of the α -casein and β -casein, which are localized within the micelles. Milk separates into solid and whey phases as a result of the hydrolysis of this k-casein, which causes micelle collapses and exposes α -casein and β -casein to calcium. Protease of *Moringa oleifera* promotes extensive hydrolysis of k-casein and low degradation of α - and β -caseins, which has significant potential for cheese preparation [3]. When used to make cheese, coagulating agents derived from plant extracts have poor organoleptic qualities, such as a bitter flavour and an unappealing texture for customers. Thus, it is essential to look for a new plant source that has the ability to coagulate milk without changing the organoleptic properties of cheese [4].

Native to the sub-Himalayan regions of South-east Asia, *Moringa oleifera* is a significant crop in India. The tree grows quickly and every part of it is edible. This tree has a significant impact on preventing malnutrition since it provides all of the important macro and micronutrients that humans and cattle require. It also prevents a lot of ailments because of its antimicrobial properties. Despite its many applications, different parts of *Moringa oleifera* are utilized for milk coagulation due to the high concentration of the protease enzyme they contain [5].

2. Methods

2.1. Collection of plant material

Moringa oleifera leaves used in the study were freshly collected from Kanchrapara, North 24 Parganas, West Bengal and transported to the laboratory for subsequent analysis.

2.2. Preparation of *Moringa oleifera* sample

Moringa oleifera leaves were manually decorticated, properly cleaned with distilled water and dried through three different types of drying method (i.e. Sun drying, drying by hot air oven and drying by tray dryer). In case of hot air oven and tray dryer, 70°C temperature was used. Dried samples were ground into fine powder with the help of mortar and pestle.

2.3. Extraction of crude extract from *Moringa oleifera* leaves

By slightly modifying the extraction method used by Abdoulaye et al. (2023), 10gm of dried powder sample was immersed into 200 ml of potassium phosphate buffer (50 mM, pH 7.5) for 24 hours at 4°C. The homogenate was filtered by using Whatman no.1. filter paper and the filtrate was centrifuged at 10000 rpm for 15 minutes at 4°C. This supernatant was considered as crude protease extract [6].

2.4. Determination of Total protein concentration

Total protein concentration of crude extract was determined by the method of Lowry et al. (1951), using BSA (1000 µg/ml) as standard [7].

2.5. Determination of Milk clotting activity

Milk clotting activity of crude extract was determined according to the method of Arima et al.(2007) and expressed in terms of Soxhlet units (SU). One SU is defined as the amount of enzyme which clots 1ml of a solution containing 0.1gm skim milk powder and 0.00111gm CaCl₂ in 40 minutes at 35°C [8].

2.6. Determination of Caseinolytic activity

Caseinolytic activity of crude extract was determined by using the method applied by Pontual et al. (2012), where azocasein (Sigma-Aldrich, USA) was used as substrate [3].

3. Result and Discussions

Moringa Oleifera leaves are reported to contain protease but there are no studies where different drying techniques were employed to dry the leaves. Drying is a crucial stage in sample preparation because it also determines enzymatic activity. In this study three types of drying techniques were applied and various experiments were conducted by using crude extract to determine the most efficient method of drying.

3.1. Total protein concentration of *Moringa oleifera* leaves

Standard graph was prepared by using bovine serum albumin (1000µg/ml) as standard. Total protein concentrations of three types of dried samples were measured and mean of triplicate values was considered as result. After using Folin-Ciocalteu reagent, absorption (at 750nm) was measured and it was found that the total protein concentration of the crude extract of *Moringa oleifera* leaves was highest in the case of the tray-dried sample (5.347mg/ml) while it was lowest in the case of the sample dried by hot air oven (2.929mg/ml). Protein content of sun-dried sample was 4.636mg/ml. Therefore it is observed that in the case of hot air oven, protein degradation has occurred due to constant high temperature and low circulation of air.

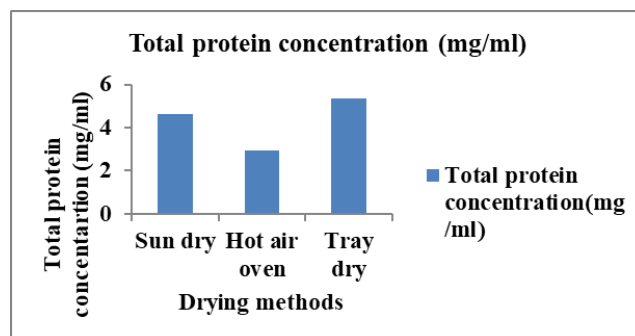


Fig.1: Total protein concentration of samples

3.2. Milk clotting activity of *Moringa oleifera* leaves

Milk clotting activity of crude extract is CaCl_2 dependent. α and β casein are released when CaCl_2 creates bridges between the positive and negative charges on casein micelles, forcing them to break. This results in the formation of curd because of the interaction between these proteins and calcium [3]. Milk clotting activity was detected by prior heating of milk sample at 35°C and the pH was maintained at 6.5 (normal pH of milk). The highest value of milk clotting activity of crude extract was obtained in the sample dried by tray dryer (3.831 SU/ml) while the lowest was detected in sun-dried sample (2.408 SU/ml). Milk clotting activity of hot air oven dried sample was 3.553 SU/ml (mean of triplicate values was considered as the result). Therefore tray dryer acted as most efficient method to provide highest milk clotting activity. On the other hand, sundry causes loss of enzymatic action due to prolonged drying time, oxidation reactions and UV radiation.

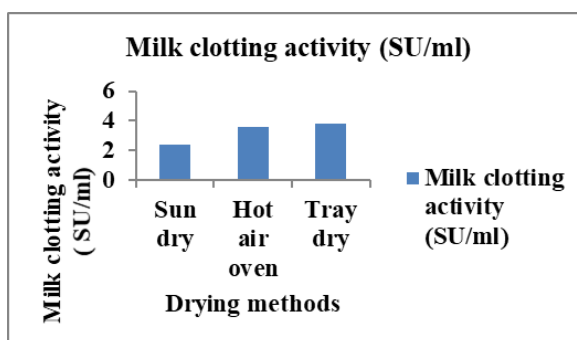


Fig.2: Milk clotting activity of samples

3.3. Caseinolytic activity of *Moringa oleifera* leaves

Caseinolytic activity is the ability of an enzyme to break down the casein, which is the main protein present in milk. An enzyme with a higher caseinolytic activity forms higher yield of curds in cheese making [5]. The pH of azocasein was maintained at 7.5 by using 0.1M sodium phosphate buffer and the absorbance was measured at 366nm. By considering mean of triplicate values, it was found that the highest value of caseinolytic activity of crude extract was recorded in the case of tray-dried sample (0.294U/ml) while the lowest value was obtained in sun-dried sample (0.092U/ml). Caseinolytic activity of hot air oven dried sample was 0.170U/ml. As per the evidence, the tray dried sample was as effective for caseinolytic activity as it was for milk clotting.

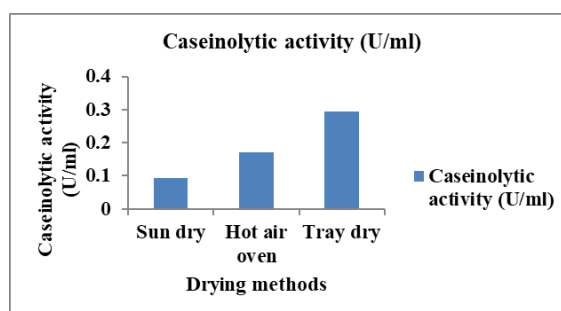


Fig.3: Caseinolytic activity of samples

4. Conclusion

Crude extract of *Moringa oleifera* leaves contain milk clotting and caseinolytic activities. Therefore, it can act as a potential new source of milk coagulation in cheese production and act as a substitute of calf rennet in dairy industry. The data showed that samples dried by tray dryer provide the highest milk clotting and caseinolytic activities than samples dried by other drying techniques. It is found that tray dryer is the most convenient method for drying of *Moringa oleifera* leaves which provide the highest enzymatic activity. Further research is needed for *Moringa oleifera* leaf extract to be purified so as to obtain the optimal milk clotting and caseinolytic activity values.

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Microbial production of Lactase from five different sources and its parameter optimization

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Abstract:

Lactose is a disaccharide consisting of galactose and glucose molecules linked by a β (1–4) glycosidic bond. Lactase enzyme belonging to β -galactosidases help in hydrolysis of lactose to glucose and galactose. Lactose intolerance is a condition when our body can't break down or digest lactose, the sugar in milk. It causes uncomfortable symptoms after one eat dairy products. Many people have difficulty in digesting lactose called as Lactose Intolerance. Lactase (β galactosidase) is an enzyme that catalyzes the hydrolysis of lactose into glucose and galactose. The objective of this study is to isolate microorganisms from five sources (Icillus, Bifilac, Amul curd, Mother dairy curd, Yakult) that can produce lactase. The organisms were being cultured at their optimum condition for growth and effectiveness. Our study aimed to optimize production conditions such as Inoculum Percentage (1%, 2%, 3%, 4%, 5%), pH (6, 6.5, 7, 7.5, 8) and Volume of media (100ml, 150ml, 200ml, 250ml, 300ml) to maximize lactase production and enhance its efficiency in reducing lactose content. The assessment was done using a titrimetric method where Benedict solution was used that can estimate residual lactose. For Icillus, the optimal conditions were 3 ml (3%), pH 6.5, and volume 150 ml. For Bifilac, 3 ml (3%), pH 6.5, and volume 100 ml. For Amul Curd, 3 ml(3%), pH 7, and volume 150 ml. For Mother Dairy Curd, 3 ml(3%), pH 6.5, and volume 150 ml. For Yakult, 2 ml(2%), pH 6.5, and volume 100 ml. On taking a lactose concentration of 5% (5 gm) the removal of lactose at optimum conditions for Icillus: 4.39 % max removal, Bifilac: 4.35% max removal, Amul curd: 4.39% max removal, Mother dairy curd: 4.38% max removal, Yakult: 4.28% max removal. Further parameter optimization and characterization of lactase can contribute to advancing microbial enzymology, offering potential applications in improving digestive health, managing lactose intolerance, and addressing gastrointestinal discomfort globally.

Keywords: Lactase; lactose removal; lactose intolerance; bacteria.

1. Introduction

Enzymes are proteins that act as biological catalysts by accelerating chemical reactions. Enzymes acts on substrates forming enzyme substrate complex, thereby converting to products. Almost all metabolic processes in the cell need enzyme catalysis in order to occur at rates fast enough to sustain life. Like all catalysts, enzymes increase the reaction rate by lowering its activation energy. An enzyme's activity is altered when its optimal temperature, pH, and other factors. Many enzymes become (permanently) denatured when exposed to excessive heat, losing their structure and catalytic properties.[7] Lactose is a disaccharide consisting of *galactose and glucose molecules linked by a $\beta(1-4)$ glycosidic bond*. Lactase enzyme belonging to β -galactosidases help in hrdrolysis of lactose to glucose and galactose [2]. Microbial production of lactase refers to the process of using microorganisms such as bacteria or yeast to synthesize the particular enzyme. Compared to traditional extraction methods, microbial production offers several advantages. It is more efficient, cost-effective,scalable, ensuring a consistent supply of lactase enzymes for dietary supplements and food processing industries. In this project lactase was extracted from 5 different microbial sources and its activity on lactose hydrolysis was studied. [6] [8]

2. Methods

2.1 selection of sample and isolation of the microorganism

Both food source as well as medicinal source was selected to isolate the microorganism that can produce lactase. Sources were- Icillus (liquid emulsion), Bifilac, Amul Curd, Mother Dairy curd, Yakult. These different sources were firstly bought from the market and serial dilution was carried in all the samples (10^{-1} to 10^{-5}). A nutrient media was prepared using peptone powder, beef extract, sodium chloride, distilled water, and agar.[5] It was then autoclaved. Then inoculation from the serially diluted samples were done under sterile conditions in the laminar airflow. The organisms were allowed to grow on petri plates inside the incubator for 24 hrs at 37°C . [4] Subculturing of the isolated organisms were done in agar slants. A total of 15 subculture slants were obtained from the mother culture plates having dilution of 10^{-3} to 10^{-5} .

2.2 estimation of residual lactose using titrimetric method:

Each of the isolated organisms were separately grown in a nutrient medium in presence of 5% lactose for 24 hr and 48 hours at 37°C . Turbidity of the media in the conical flasks confirmed the growth of microorganisms, Then the sample was taken for centrifugation at 4500 rpm for 10 minutes. The supernatant collected from each sample was used as the titrating sample in each assay. Residual lactose content of the fermented broth was measured in titrimetric method using Benedict's reagent [9]. The amount of lactose reduction occurred by the isolated organism is given below:

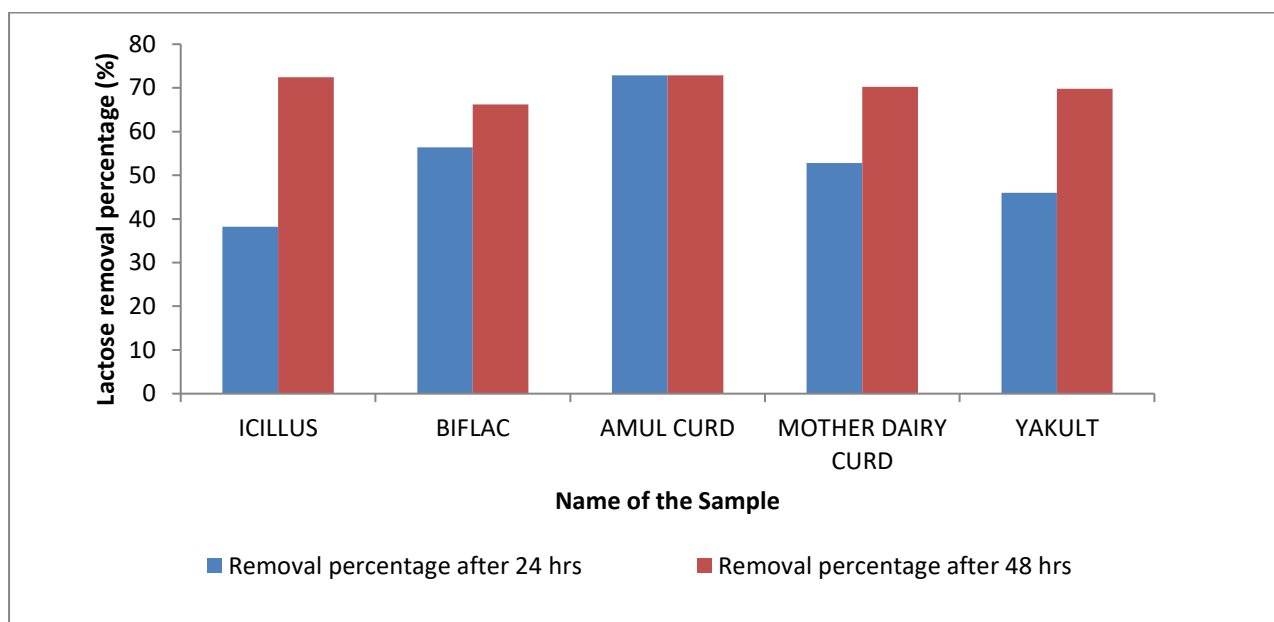


Fig: Lactose reduction by each sample at 24 hours and 48 hours incubation.

2.3 optimization of process parameters for maximum production of lactase enzyme by the isolated microbial strains:

Different parameters were taken to check the optimal condition for lactase production:

1. Inoculum concentration: 1%, 2%, 3%, 4% and 5%
2. pH: 6, 6.5, 7, 7.5 and 8

A nutrient broth media was made where 5% lactose monohydrate was added. The sterilized medium was inoculated by the isolated microbial strain with variations in inoculum concentration, pH and medium volume to get the optimal condition. All the flasks were incubated for 24 hours at 37°C. Then it was centrifuged and residual lactose content was estimated as per 2.2.

3. Result and Discussions

This study optimized parameters for microbial lactase production from Icillus, Bifilac, Amul Curd, Mother Dairy Curd and Yakult identifying.

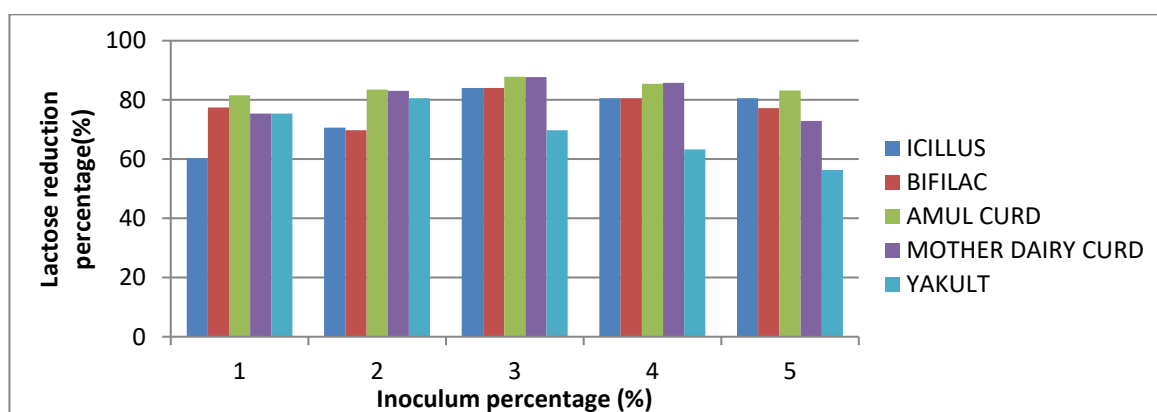


Fig: Optimization of inoculum percentage

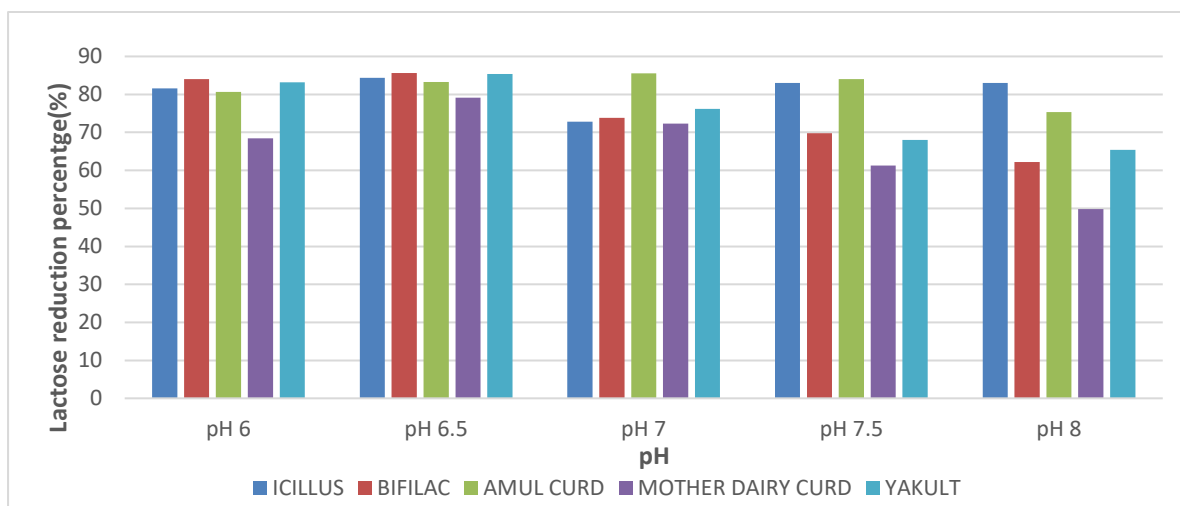


Fig: Optimization of pH

* For Icillus, the optimal conditions were 3 ml(3%) inoculum concentration, pH 6.5.

* For Bifilac, 3 ml(3%) inoculum concentration, pH 6.5.

* For Amul Curd, 3 ml(3%) inoculum concentration, pH 7.

*For Mother Dairy Curd, 3 ml(3%) inoculum concentration, pH 6.5.

*For Yakult, 2 ml(2%) inoculum concentration, pH 6.5.

These parameters effectively produced a significant more amount of lactase thereby reducing the lactose monohydrate content .

4. Conclusion

From the above study we could come to a specific optimum parameter of inoculum percentage and pH for all the five different samples. More of parameter optimization is to be done in the further study.[1] These particular parameters yielded optimal lactase activity efficiently by the microbial strains, having maximum lactose monohydrate reduction. It suggests promising future applications in various industrial, GOS, health, biosensors, and food related fields. [1] [10]

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ETBFT-24-016

Microbial production of Naringinase enzyme by an isolated *Aspergillus niger* strain (accession no. PP446800), and optimization of process parameters

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Abstract:

The major problem faced by citrus fruit industries is bitterness. Naringin, a flavonoid, presents in citrus fruits, causes bitterness during juice extraction. Bitterness can be reduced by hydrolyzing naringin to naringenin using naringinase enzyme and improve its consumer acceptability. Production of naringinase enzyme by isolated microbial strain from various citrus fruit waste is commercially cost effective as industrial waste material can be reused to grow naringinase producing microorganism for enzyme production. Naringinase producing microbial strain were collected from composted soil and cultured on Nutrient and Czapek Dox agar media separately for bacterial and fungal growth. Suitable strains were isolated by further sub culturing. Primary screening was done by FeCl₃ and quantitative analysis of naringinase content of the microbial strain was done by Davis spectrophotometric method in terms of naringin. A fungal strain labelled B2C2 identified as *Aspergillus niger* (accession no. PP446800) selected as the best source of naringinase enzyme among 15 bacterial and 17 fungal strains. The objective of this present study is to optimize process parameters of naringinase enzyme production by isolated strain B2C2 identified as *Aspergillus Niger* (accession no. PP446800) for getting best enzyme activity. Various process parameters were optimized and after optimization it was found that the strain was able to produce almost 120 IU/ml of enzyme in the selected medium when inoculated with 3% inoculums in 50ml, pH 5 medium taken in a 250 ml Erlenmeyer flask and incubated at 30°C with 110 rpm agitation speed for 7days.

Keywords: Naringin; naringinase; enzyme activity; Davis spectrophotometric method, process parameter.

1. Introduction

Citrus fruits contain naringin, which is a bitter substance, and causes bitterness during juice extraction. The bitterness can be reduces by hydrolyzing naringin with naringinase and improve its consumer acceptability [1]. Citrus juice can be debittered by hydrolysing naringin with naringinase. Because naringinase therapy improves the organoleptic qualities while maintaining the health-promoting qualities, it is a promising technique [2]. Naringinase is debittering enzyme which is used in the commercial production of citrus juices. It breaks down the compound naringin that gives citrus juices its bitter taste. It is a multi-enzyme complex which possesses alpha-L-rhamnosidase and beta glucosidase activities [3].Naringin hydrolysis happens in two stages. First, a-L-rhamnosidase

hydrolyses naringin to produce prunin and rhamnose, which have a lower bitterness value than naringin [4]. In the subsequent stage, b-D- glucosidase hydrolyzes prunin into naringenin and glucose. Moreover, prunin and rhamnose have some roles like reducing cholesterol and having anti-inflammatory, anti-cancer, anti-bacterial, anti-oxidation, and anti-viral activity. Glycoside compounds such as naringin, hesperidin, ter-phenyl glycosides, rutin, quercitrin, diosmin, and with terminal α -rhamnose and β -glucose are the substrates of naringinase [5]. Microbial sources of enzymes are preferable to animal or plant sources. Low production costs, simple large-scale production in industrial fermenters, improved genetic modification potential, and rapid growth are all clear benefits [6]. Microbial Naringinase is a recognised product of microorganisms. *Lasiodiplodia theobromae*, *Aspergillus niger*, *Aspergillus oryzae*, *Aspergillus usamii*, *Aspergillus flavus*, *Cochiobolus miyabeanus*, *Coniothyrium diplodiella*, *Penicillium decumbens*, *Rhizoctonia solani*, and *Rhizopus nigricans* are just a few of the fungi identified to generate [3,4], while *Bacillus* sp., *Burkholderia cenocepacia*, *Clostridium stercorarium*, *Lactobacillus acidophilus*, *Sphingomonas paucimobilis*, and *Thermomicrobium roseum* are a few of the very few known bacterial strains [3]. A fungal strain labeled B2C2 identified as *Aspergillus niger* (accession no. PP446800) selected as the best source of naringinase enzyme among 15 bacterial and 17 fungal strains. The objective of this present study is to optimization of process parameters of naringinase enzyme from isolated strain B2C2 identified as *Aspergillus Niger* (accession no. PP446800) for getting best enzyme activity. The optimization study of process parameter i.e. pH, temperature, fermentation period, inoculums percentage, age of inoculum and medium volume for measure the optimal conditions for maximum yield or quality of the naringinase enzyme produced by isolated strain.

2. Methods

2.1 Preparation of inoculums:

The selected fungal strain B2C2 strain identified as *Aspergillus niger* (accession no. PP446800) was grown in the Czapek Dox broth at 27°C for 5 days [7]. The media volume was taken 50ml, and agitation rate was maintained at 60 rpm. and used as inoculums.

2.2 Preparation of growth media:

Growth media was prepared by czapekdox broth media containing 0.1% Naringin.

2.3 Optimization of pH

A growth media (as 4.2) of varying pH levels (3.0- 7.0) was prepared and inoculation was done from inoculums. The inoculums percentage was maintained at 2% and media volume was taken 50ml, Incubation was done at 27°C for 5 days. Agitation rate was maintained at 60 rpm. After 5 days the cell mass was separated from the media by centrifugation and the clear supernatant was used to measure the enzyme activity by Davis Spectrophotometric method.

2.4 Optimization of Temperature

A growth media (as 4.2) of pH5 was prepared and inoculation was done from inoculums. The inoculums percentage was maintained at 2% and media volume was taken 50ml, Incubation was

done at varying temperature (22°C -37°C) for 5 days. Agitation rate was maintained at 60 rpm. After 5 days the the enzyme activity was measured by Davis Spectrophotometric method.

2.5 Optimization of Inoculums percentage

A growth media (as 4.2) of pH5 was prepared and inoculation was done from inoculums. The inoculums percentage was maintained at different percentages of inoculum (1%, 2%, 3%, 4%, and 5%) and media volume was taken 50ml, Incubation was done at 30°C for 7 days. Agitation rate was maintained at 60 rpm. After 7 days the cell mass was separated from the media and the enzyme activity by Davis Spectrophotometric method.

3. Result and Discussions

Figure 1 showed that the maximum amount of enzyme was produced at pH 5.0 and it was accepted as optimum pH for further optimization process. The maximum enzyme production of 119 IU/mL was achieved at this pH as the growth of the organism was also maximum at pH 5. At pH below or above 5, both the growth of the organism and the amount of enzyme production get decreases. pH change can affect enzyme production in the range 4 to 6, but below pH 4 , yield were low due to production of citric acid at lower pH level and the media become very much acidic. [8]

Figure 2 showed that the maximum amount of enzyme was produced at 30°C while the pH of the medium was kept constant at optimized pH value which was pH 5.0. The maximum enzyme production of 128 IU/mL was achieved at this temperature as the growth of the organism was also maximum at 30°C. At temperatures below or above 30°C, both the growth of the organism and the amount of enzyme production get decreases. [9].

Figure 3 showed that both enzyme production and cell mass production was maximum in presence of 3% inoculums. The reason might be as the growth of the organism was maximum at that inoculums percentage so enzyme production was also maximum and it was 164 IU/mL. With further increase in inoculums percentage, the media volume restricts the growth of the organisms and due to lack of nutrients the enzyme activity decreases. Microbial naringinase enzyme production get reduces beyond optimum Inoculums percentage. [10]

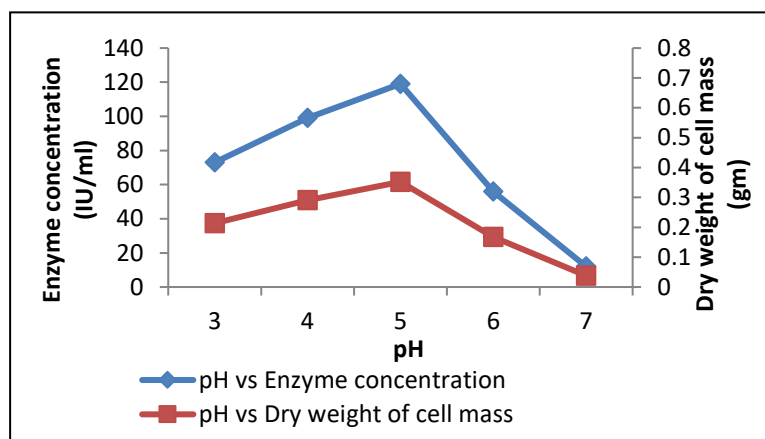


Fig 1: Optimization of pH for maximum enzyme production and cell mass production by the isolated strain

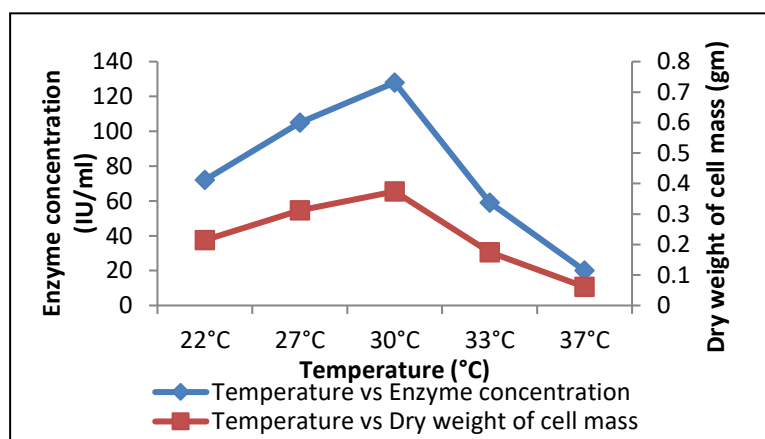


Fig 2: Optimization of temperature for maximum enzyme production and cell mass production by the isolated strain

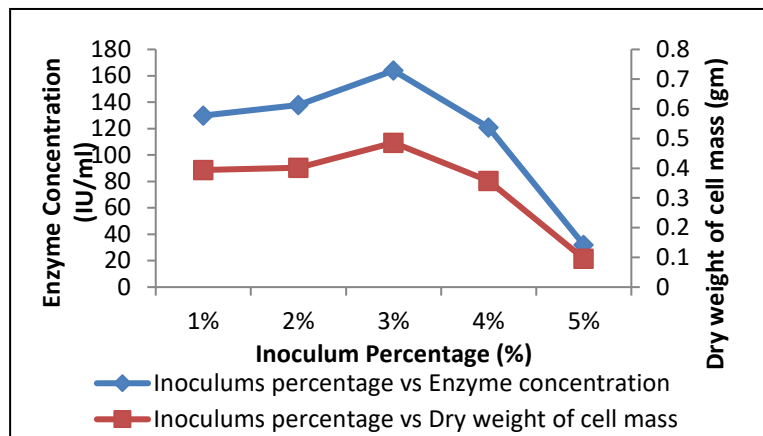


Fig 3: Optimization of inoculum percentage for maximum enzyme production and cell mass production by the isolated strain

Conclusion

From this study it has been concluded that microbial Naringinase produced by the selected strain B2C2, identified as *Aspergillus niger* (accession no. PP446800) can be increased by optimizing the process parameters. After optimization it was found that the strain was able to produce almost 164 IU/ml of enzyme in the selected medium when inoculated with 3% inoculum in 50ml, pH 5 medium taken in a 250 ml Erlenmeyer flask and incubated at 30°C with 60 rpm agitation speed for 7 days.

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Edible Film from Flaxseed Mucilage: Formulation and Characterization

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Abstract:

This research focuses on creating a biodegradable edible film from flaxseed mucilage. Research into biodegradable alternatives is expanding to lessen the environmental impact of synthetic packaging. Edible films are made from film-forming ingredients obtained from natural polymers, which provide sustainable solutions. Flaxseed mucilage has an excellent film-forming property that has been investigated in this study. This is composed of polysaccharides, proteins, minerals, and lipids. The edible film was developed by extracting mucilage from flaxseed and preparing the film-forming solution, followed by maintaining pH and the addition of glycerol, which acts as a plasticizer. Additionally, the films were enriched with natural blue color from blue pea flowers, which are high in anthocyanins, providing aesthetic and antioxidant properties. The solution was cast on a petri dish and dried to form a uniform film. The developed film exhibited good structural uniformity, flexibility, and promising mechanical properties. Several tests have been conducted with the film for characterization. Thickness results showed that the film measured 0.4 ± 0.1 mm. The moisture content measured from 30% to 33%, and water solubility measured from 58.14% to 62.45%. The tensile strength was observed at a maximum of 1.2 MPa. Adding blue pea extract increased the polyphenol content, enhancing the film's functional properties. Research into these films is indicated as a means to utilize agricultural byproducts and natural polymers to reduce plastic waste. Further study is recommended on scaling, shelf-life enhancement, and barrier properties. This multidisciplinary approach integrates food technology and material science, underlining environmental sustainability and resource valorization.

Keywords:

Flaxseed mucilage; Edible film; Biodegradable packaging; Natural polymers; Blue pea flower.

1. Introduction

Edible films are thin, biodegradable coatings manufactured from food-grade materials that help to preserve food, improve safety, and increase package sustainability. Films made from agricultural leftovers are a global trend and a crucial issue in promoting environmental conservation and green products [1]. Hydrocolloids, such as proteins and polysaccharides, often have good gel qualities, and so coatings have an impact on the food's surface structure, improving hydrophobicity and minimizing holes surfaces and fractures. Mucilages are widely used as natural hydrocolloids in the food industry and as raw materials for film production. Mucilage is a gelatinous material or hydrocolloid that forms strong connections between polysaccharides and proteins, when combined

with water, it produces a viscous solution [2]. This can be extracted from different seeds like flaxseeds, chia seeds, okra, etc. In this research, we will use flaxseed mucilage as a raw material.

Flaxseed (*Linum usitatissimum*) mucilage contains a heterogeneous polysaccharide consisting of galacturonic acid, xylose, galactose, arabinose, and glucose, linked with glycosidic linkages [3]. It can be extracted by soaking the seeds in water for few hours, followed by constant stirring and separating the seeds from the mucilage. It has the potential to enhance water binding and emulsification properties. Flaxseed mucilage has been employed as a sustainable option for food coating and packaging because of its film-forming ability, low manufacturing cost, and ease of extraction [4, 5]. Biodegradable packaging, including edible films and coatings, is created from edible components and considered primary packaging. The packaging is made of a thin coating of edible substance that may be applied on a food product or formed into a film for packaging without damaging the food inside. Additionally, incorporating nutrients like vitamins and minerals into the film matrix might improve the nutritional value of the food product [6]. Bio color produced from natural sources (colorful flowers, fruits, etc.) can be used in film to make it more appealing to customers. It also contributes to the film's antioxidant functions because the biocolor contains anthocyanin, carotenoids, and other pigments that have antioxidant and antibacterial properties [7, 8].

This study focuses on the process utilized to manufacture edible film based on flaxseed mucilage, as well as its characterization. The picture has undergone several characterization tests. The tensile strength and thickness are estimated to determine the physical strength of the film. Water solubility and moisture content of the film are investigated, which may influence shelf life. Estimating the polyphenol content of the film is significant since it contributes to the quality and flavor of the food. The change in characteristics is also measured after adding biocolor to the edible film.

2. Materials and Methods

The flaxseeds (*Linum usitatissimum*), food-grade glycerol, and sodium hydroxide were purchased from the local market in Kolkata, India. The Blue pea (*Clitoria ternatea*) flowers were collected from the nearest garden in Kolkata, India.

2.1. EXTRACTION OF MUCILAGE FROM FLAXSEEDS

To extract mucilage from flaxseeds, they were first cleaned and soaked in distilled water (1:15 w/v) overnight. The soaked flaxseeds are stirred in a hot plate magnetic stirrer (REMI 2MLH) at 700 rpm and 75(±5) °C for at least 2 hours. The resultant solution was then filtered through a cotton cloth to remove the seeds. Thus, we obtained a thick and viscous mucilage solution.

2.2. EXTRACTION OF BIOCOLOR

The biocolor was produced from blue pea flowers using the aqueous extraction method. First, blue pea flower petals were finely chopped in distilled water and heated in a water bath at 50 (±5) °C for

10-20 minutes. The extracted color was then filtered to obtain fresh blue color, containing anthocyanin pigment.

2.3. DEVELOPMENT OF FILM FORMING SOLUTION

A measured amount of flaxseed mucilage was taken into a beaker. To ensure efficient mixing, the beaker was placed on a magnetic stirrer and stirred at 750 rpm at $70 \pm 5^\circ\text{C}$. The pH of the solution was adjusted to 9 by progressively adding 0.1 (M) NaOH solution, which was thoroughly agitated for 30 minutes at the same rpm and temperature. Next, 4% glycerine was added to the solution and agitated for 30 minutes at the same rpm and temperature. This mixture was cast on a Petridis for film formation, resulting in sample-1 (S1). During the stirring of the same sample, a few drops of bio color produced from blue pea flower were applied for blue color. After mixing, the solution was cast onto petridish. This is our sample 2 (S2).

2.4. FILM FORMATION

After casting on petridish, the samples were dried in 40°C in a conventional oven for 24 hours. After drying, the films are detached from the petridish.



Figure 1: Edible film without color (S1).



Figure 2: Edible film with color (S2).

3. Characterization

3.1. THICKNESS

The thickness of the edible film was measured by the screw gauge at 10 different points, and the mean value was calculated.

3.2. MOISTURE CONTENT

Moisture content was evaluated by eliminating the free moisture from the film sample using a Hot Air Oven for 4-5 hours at 105° C. Next, the moisture content in dry basis and wet basis were calculated by these formulas.

$$\text{Moisture content in dry basis} = \frac{M_i - M_f}{M_f} \times 100 \% \quad (i)$$

$$\text{Moisture content in wet basis} = \frac{M_i - M_f}{M_i} \times 100 \% \quad (ii)$$

Where, M_i = initial weight of the sample.

M_f = final weight of the sample.

3.3. WATER SOLUBILITY

First, a hot air oven was used to dry the edible film sample. Then the sample was soaked for 24 hours in 50 ml of distilled water after drying. The water was then removed using filter paper, and a tray drier was used to dry the wet sample and filter paper. The weight of the insoluble portion was then determined by measuring the sample's ultimate weight. The provided formula was used to assess the solubility.

$$\text{Water solubility} = \frac{W_i - W_f}{W_i} \times 100 \% \quad (iii)$$

Where, W_i = initial weight of sample

W_f = final weight of sample

3.4. TENSILE STRENGTH

The film sample's tensile strength (TS) was measured on a spring scale. Initially, a certain length and width of film was cut, and the hook of the spring scale was used to clip one side of the strip. The other side was then clipped and dragged until the strip of film broke. The scale displayed the weight in grams. The formula for estimating tensile strength was calculated by first converting the gram unit to the Newton unit.

$$\text{Tensile strength (TS)} = \frac{\text{Force}}{\text{Area}}$$

(iv)

3.5. POLYPHENOL CONTENT

A double-beam UV-Vis spectrophotometer (Jasco V630) was used to measure the edible film sample's polyphenol content. A certain volume of the sample was first immersed in methanol for the whole night. After that, methanol was separated to remove the crude sample from the film. Then, 4 ml of Na₂CO₃ solution and 5 ml of Folin-Ciocalteu solution (1:10) were added to two test tubes. The blank solution was made by adding 0.5 mL of ethanol to the first test tube, and the crude sample was made by adding 0.5 mL to the second test tube. Both samples were then left in the dark for 40 minutes. Following the auto-zeroing of the system with the blank solution in the cuvette, another solution from the second test tube was added, and the absorbance was measured at a wavelength of 765 nm. After using the standard curve equation to calculate the polyphenol content, additional calculations were made. In terms of Galic Acid Equivalent (GAE), the quantity of polyphenol in a gram of sample is stated.

4. Result and Discussion

4.1. THICKNESS

The mean thickness of the edible film sample is 0.4 (± 0.1) mm.

4.2. MOISTURE CONTENT

The water-holding ability of the protein matrixes and mucilage in the edible film samples is what causes the observed moisture content. The film material's ability to retain water is caused by interactions between polysaccharides and proteins. The study shows that moisture content of S1 is 25-30%, whereas moisture content of S2 is 30-35%.

4.3. WATER SOLUBILITY

The hydrophilic polysaccharide structures of flaxseed mucilage and the moisture sorption and water binding capabilities of N-H groups may be the cause of the water solubility, which was found to be 58.14 (± 5.00). Water was thus drawn into the polymer matrix, increasing its hydrophilicity.

The edible films' high water solubility is also reflected in their high moisture content.

4.4. TENSILE STRENGTH

The TS is basically the same for S1 and S2 because S2 only had color added, which would not have increased the strength. To improve the mechanical properties and reinforce the film's structure. The study's most significant finding is that edible films' tensile strength values must meet a minimum standard based on the Japanese industrial standard, which is 0.3923 MPa.

4.5. POLYPHENOL CONTENT

The number of phenolic components and antioxidant properties in raw flaxseed mucilage may be higher, but heat treatment during processing lowers these levels. Compared to samples without color, those with color added have a higher polyphenol content. The high concentration of phenolic compounds in S2 is caused by the presence of anthocyanin pigments. The study shows that polyphenol content of S1 is 0.02 whereas polyphenol content of S2 is 0.03.

Table 1: Result of different testing.

Sl.no	Characteristics	S1	S2
1.	Moisture content (%)	25-30	30-35
2.	Tensile strength	1.0-1.2	1.1-1.2
3.	Polyphenol content (% Gram of Galic Acid Equivalent)	0.02	0.03

5. Conclusion

This work successfully generated edible films with flaxseed mucilage and natural color from blue pea flowers, revealing the promise of sustainable biopolymers for creative packaging. Flaxseed mucilage was used as a film-forming agent, demonstrating compatibility with natural additives to produce a useful and visually pleasing material. Blue pea flower extract added bright color and possibly bioactive qualities. The refined technique resulted in a homogenous and sturdy structure with high tensile strength, flexibility, and aesthetic appeal. This study emphasizes the viability of using agricultural wastes for eco-friendly packaging, promoting future research into barrier characteristics, scalability, and shelf-life improvements.

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**Isolation and Characterization of Notorious Food-Borne Bacterial & Fungal Pathogens from
Chocolates of Three Popular Brands of India: A Novel**

Look Through

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Abstract:

A study questioned the assumption that cocoa and low water activity limit contamination in Indian chocolate bars (C1, C2, C3). Each chocolate bar was tested as follows: intact refrigerated (C1 Intact ref, C2 Intact ref, C3 Intact ref), half-eaten refrigerated (C1Href, C2Href, C3Href), or half-eaten at room temperature (C1HRT, C2HRT, C3HRT). After five days, isolation and characterization of notorious food-borne bacterial and fungal pathogens were carried out on them. Tests showed the presence of colonies from C3HRT on Eosin Methylene Blue (EMB) agar plates, typical of *Enterobacter* species, a common food contaminant. Preliminary identification of species of *Staphylococcus* was made from greyish black to completely black colonies with prominent halos on Baird Parker Agar (BPA) plates; *Pseudomonas* was made from green colonies on Hektoen Enteric Agar (HEA) plates; and *Alcaligenes* from bright-orange (salmon) colonies on HEA plates. Growth in glucose-free nutrient broth (GFNB) tubes, followed by staining to reveal endospores, indicated the presence of *Bacillus* species. Potentially harmful *Enterobacter*, *Pseudomonas*, *Alcaligenes*, *Bacillus*, and *Staphylococcus* (like *S. aureus* and *S. epidermidis*) were finally confirmed by characteristic biochemical tests. Besides, highly menacing food-borne fungal pathogens, including species of *Penicillium*, *Aspergillus* and *Alternaria*, were also isolated on Yeast Extract Peptone Dextrose Agar (YPDA) plates and presumptively identified microscopically. Antibiotic susceptibility tests (ASTs) of the confirmed bacterial pathogens recorded the highest (80%) resistance against amoxicillin (AMX). Thus, our key findings of high microbial activity and the presence of some of the deadliest food-borne pathogens, including some drug-resistant ones, challenge the long-nurtured notion stated earlier and establish the fact that the overall microbiological quality of the chocolates depends much on their mode of storage.

Keywords: antibiotic susceptibility tests; chocolates; food-borne bacterial and fungal pathogens; MPN index; total heterotrophic count

1. Introduction:

Chocolate is a confectionary item made from roasted and ground cocoa beans in the form of a liquid, solid, or paste [1]. Chocolates of various kinds and tastes are a very popular delicacy among the kids. The idea that chocolates, mainly the ones that have a high content of cocoa and an inherently low water activity (aw), are, by nature, safe from any kind of microbial contamination has always been a belief with respect to food safety in the confectionary industries. In line with this, white chocolates are expected to be most prone to microbe-mediated spoilage, followed by milk- and dark chocolates. This very idea is challenged in this article, which drives one to rethink if chocolates are at all as microbiologically safe as it was previously thought and how storage conditions impact their microbiological profile so that dire consequences do not befall the consumers. In this novel research, a very first of its kind, nine chocolate bars, three from each of three famous brands, were purchased locally. They were bought, after being categorized according to their cocoa content, the one with the highest being dark chocolate, followed by milk- and white chocolates. To include more diversity in the bacteria, each type was exposed to different storage conditions. One bar was refrigerated, another refrigerated after a portion of it was consumed, and the last was left at room temperature after partial consumption, all for a uniform time period of 5 days. This experimental setup provided a method to ascertain the sanitary quality of chocolates with regard to pathogenic microbe load and to determine how different storage procedures can influence contamination by microbes. While carrying out the experiment, the total heterotrophic count (THC) of bacteria and fungi in terms of colony-forming unit (CFU)/ml of each chocolate sample was ascertained, followed by isolation, identification, and characterization of pathogens from there. Since coliforms and species of *Staphylococcus*, *Salmonella*, *Shigella*, and *Bacillus* are some common food-borne pathogens, particularly in dairy-based ones like chocolate, the experiment used special pre-enrichment and selective media and chemical reagents for the purpose. Also, in the present era of a super-swift escalation of multi-drug-resistant (MDR) pathogens, antibiogram analysis was performed to ascertain the antibiotic resistance/sensitivity of the pathogenic isolates so that treatment options can be made more effective and streamlined.

2. Materials and Methods:

2.1 Sample collection

Nine chocolate bars, three each from three different popular brands of India, namely white chocolate (C1), milk chocolate (C2), and dark chocolate (C3), i.e., with increasing amounts of cocoa, were purchased from local grocery shops in Kolkata and transported carefully to the laboratory for analysis within 6 h of collection [2].

2.2 Sample preparation

From each of these three categories (C1-C3), one was refrigerated as an intact chocolate bar (C1 Intact ref, C2 Intact ref, & C3 Intact ref), one was refrigerated as a half-consumed chocolate bar (C1Href, C2Href & C3Href), whereas the remaining one was kept as a half-consumed chocolate bar at room temperature (C1HRT, C2HRT & C3HRT). After five days, isolation and characterization of notorious food-borne bacterial and fungal pathogens were carried out from these nine samples. For this, each sample was finely ground or pulverized, and 5 gm of this was then individually mixed well with 50 ml of sterile saline (0.9% NaCl) to prepare a stock solution of concentration 0.1 gm/ml, put

in a rotary shaker at room temperature for 2 h for maximum possible homogenization, and then refrigerated (at 4 °C) overnight for the settling down of larger particles and the separation of a comparatively clearer layer at the top, with which further tests were performed [2].

2.3 Total heterotrophic count

2.3.1 Total Bacterial Count

100 µl clear aliquot of the saline suspension prepared earlier was spread onto solidified Nutrient Agar (NA) plates and incubated overnight at 37 °C, following which the total heterotrophic count (THC) of bacteria in terms of CFU/ml was calculated [2].

2.3.2 Total Fungal Count

100 µl clear aliquot of the saline suspension prepared earlier was spread onto solidified Yeast Extract Peptone Dextrose agar (YPDA) plates and incubated for 72 hours at 30 °C, following which the THC of fungi in terms of CFU/ml was calculated [2].

2.4 Isolation of Pathogens

2.4.1 Isolation of Coliforms

2.4.1.1 Presumptive Test and MPN Index determination

Isolation of fecal coliforms was done by a standard Presumptive test. For each sample, 1 tube containing 10 ml sample, 10 ml 2X Lactose Broth (LB) and Durham's Tube, and 2 tubes, one containing 1 ml sample, 9 ml 1X LB and Durham's Tube, and another containing 0.1 ml sample, 9.9 ml 1X LB and Durham's Tube, were incubated in a rotary shaker overnight at 37 °C in order to check for turbidity, acid, and gas production, from which the MPN count/100 ml (MPN Index) was to be ascertained [3].

2.4.1.2 Confirmed Test

From the 2X 10 ml samples that tested positive, a loopful of the culture was streaked onto solidified selective and differential Eosin Methylene Blue (EMB) agar plates and incubated overnight at 37°C, following which the cultural characteristics (colony color and morphology) of fecal- and non-fecal coliform colonies were checked for [3].

2.4.1.3 Completed Test

Colonies of coliforms were picked up from the EMB agar plates, half of each re-inoculated into tubes containing 5 ml 1X LB and Durham's tube, the other half streaked onto solidified NA slants, and incubated overnight at 37 °C, following which turbidity, acid, and gas production were checked

for in the LB tube, and Gram staining was performed to confirm the Gram Character and morphology of the coliform isolates microscopically [3].

2.4.2 Isolation of *Staphylococcus* species

100 µl clear aliquot of the saline suspension of each sample was added to 5 ml of the pre-enrichment Trypticase Soy Broth (TSB) supplemented with 6.5% sodium chloride, and incubated in rotary shaker overnight at 37°C. Next day, one loopful of all cultures was streaked onto selective Baird Parker Agar (BPA) plates and incubated overnight at 37°C, following which the colony colour and morphology of *Staphylococcus* species colonies was checked for [4, 5].

2.4.3 Isolation of *Salmonella/Shigella* species

100 µl clear aliquot of the saline suspension prepared earlier was added to 5 ml of the pre-enrichment Selenite-Cystine broth (SCB), and incubated in rotary shaker overnight at 37°C. Next day, one loopful of all cultures was streaked onto selective Hektoen Enteric Agar (HEA) plates and incubated overnight at 37°C, following which the colony colour and morphology of *Salmonella/Shigella* species colonies were checked for [4, 5].

2.4.4 Isolation of *Bacillus* species

100 µl clear aliquot of the saline suspension prepared earlier was added to 5 ml of Glucose Free Nutrient Broth (GFNB), and were incubated in rotary shaker for 15 days at 37°C, following which the Gram Character and morphology of the cells (by Gram staining) and the presence of endospores (by Malachite-Green Method of Endospore staining) of *Bacillus* species was checked microscopically [3].

2.5 Identification and Characterization of Pathogens

2.5.1 Conventional Microbiological procedure

Gram staining was performed according to the standard protocol, and Gram character and morphology of the cells of the pathogenic bacterial isolates confirmed microscopically. Lactophenol Cotton Blue (LPCB) method of fungus staining was performed to confirm the morphological details of the pathogenic fungal isolates [3].

2.5.2 Routine Biochemical tests

The bacterial pathogenic isolates were identified and characterized by a battery of standard biochemical tests, including starch hydrolysis (SH), urea hydrolysis (UH) and gelatin hydrolysis (GH), nitrate reduction (NR), catalase production (CP), oxidase production (OP), C-source (glucose, sucrose and fructose) use (growth in Triple Sugar Iron Agar, TSI) and H₂S production (in TSI agar),

and Indole-Methyl Red-Voges Proskauer-Citrate (IMViC) tests [3-12]. Due to time constraints, ribotyping could not be carried out for any pathogenic isolate.

2.6 Antibiotic resistance determination by Antibiotic Susceptibility Test (AST) and antibiogram analysis

Antibiotic resistance of the pathogenic bacterial isolates to eight different antibiotics was determined from the respective antibiograms obtained from antibiotic susceptibility test (AST) performed according to the standard Kirby-Bauer Disc diffusion method [13]. The five different, commercially available antibiotic-impregnated discs used included the newer generation amoxicillin (AMX, 30 µg/disc) and ciprofloxacin (CIP, 5 µg/disc), and the conventional streptomycin (S, 25 µg/disc), tetracycline (TE, 30 µg/disc), and vancomycin (VA, 30 µg/disc).

A fresh culture of each of the pathogen isolates was prepared in nutrient broth (NB) after overnight incubation in a rotary shaker at 37°C, matching an optical density of 0.5 McFarland standard (at 625 nm) and corresponding to 10⁸ CFU/ml. 100 µl of each culture was inoculated separately on the surface of solidified sterile Mueller Hinton Agar (MHA) plates, and discs of each antibiotic were then carefully dispensed on the surface of the seeded agar plates [14]. After 30 minutes, the plates were inverted and incubated at 37°C for 24 h. Following incubation, the diameter of the zone of growth inhibition (in mm) around each disc was measured to estimate antibiotic resistance of the bacterial isolates according to standards of the Clinical and Laboratory Standards Institute (CLSI) [15-19].

Statistical analysis

All results were expressed as mean ± SEM (Standard Error of Mean) for individual experiments. Each experiment was performed three times (n=3), and the mean value from all sets of those experiments was presented. Student's t-test was performed as applicable in each case, and the values were found to be significant at 5% probability level.

3. Results and Discussion:

3.1 Total heterotrophic count

The observations revealed a shocking level of contamination in majority of all the chocolate samples.

3.1.1 Total Bacterial Count

The THC of bacteria was found to be a staggering 2960 CFU/ml for the C2HRT sample, followed by 2440 CFU/ml for the C3HREF sample (Fig.1). This observation challenges the prevailing notion that the presence of cocoa and low *a_w* in chocolates limit their microbial spoilage, particularly evident in case of a huge contamination in even the dark chocolate sample (C3). The colony types varied from white, raised (major) to yellow (minor) surface and sub-surface colonies across the different samples.

3.1.2 Total Fungal Count

The total fungal count for C1HRT was seen to be the highest with 200 CFU/ml (Fig. 1). In the other fungal plates, single isolated CFUs could not be demarcated, apart from plates C2HRT and C3Href, where the THC count was 90 CFU/ml and 20 CFU/ml, respectively.

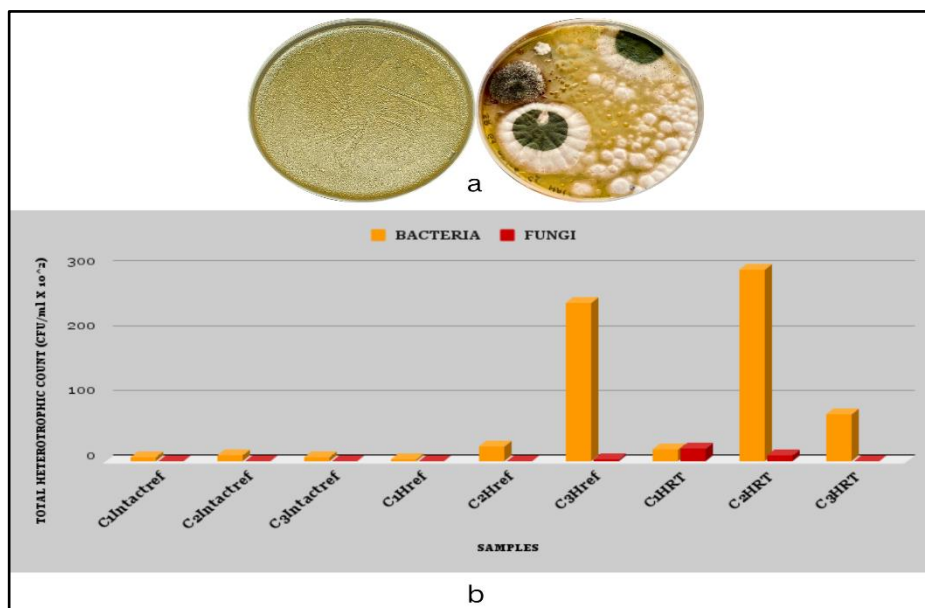


Fig.1: THC of Bacteria and Fungi from different chocolate samples: a (left to right): C2HRT plate with 296 CFUs and C1HRT plate with 200 CFUs; b: graphical representation of THC of Bacteria (left) and Fungi (right)

3.2 Pathogens

3.2.1 Coliforms

3.2.1.1 Presumptive Test and MPN Index determination

The results obtained indicated a maximum of 6 MPN count/100 ml (MPN Index), typifying meager coliform contamination [2].

3.2.1.2 Confirmed Test

Confirmed test showed 26 brown colonies typical of *Enterobacter* species from C3HRT, while C1HRT had 42 medium-to-large, blue-black colonies with a greenish-metallic sheen typical of *Pseudomonas* species on the EMB agar plates [3].

3.2.1.3 Completed Test

Dense turbidity, copious acid and gas production (all >80%) in the LB tubes, and Gram-staining observations confirmed the presence of non-fecal coliforms in the samples [3].

3.2.2 *Staphylococcus* species

In line with the understanding that *Staphylococci* are one of the leading pathogens that can proliferate in dairy products, the presence of colonies of colour ranging from greyish black to completely black, some of which surrounded by distinct halos, indicated the presence of *Staphylococcus* species [2, 3]. C1 Intact ref showed the highest contamination with 1480 CFU/ml, followed by C1HRT with 1360 CFU/ml. This enormous spoilage complies with the fact that white chocolates have cocoa butter, milk solids, and sugar as the principal ingredients, all of which are conducive to bacterial contamination.

3.2.3 *Salmonella/Shigella* species

C1HRT showed a 360 CFU/ml on HEA plate, including both salmon colonies with black centre (major) and light-green colonies with black centre (minor). C3HRT showed a 440 CFU/ml on HEA plate, including both light-green colonies with black centre (major) and salmon colonies with black centre (minor). The salmon-colonies with black centre are typical of *Enterobacter* species, while light-green colonies with black centre, of *Alcaligenes* species [2, 3]. The colony types thus negated the presence of species of *Salmonella* and *Shigella*.

3.2.4 *Bacillus* species

Gram-staining of the culture from the 15-day old GFNB tubes, and Malachite-Green Method of Endospore staining indicated contamination by endospore-forming *Bacillus* species [3].

3.3 Identification and Characterization of Pathogens

3.3.1 Conventional Microbiological procedure

3.3.1.1 For pathogenic bacterial isolates

Gram staining to reveal the Gram character and morphology of the pathogenic isolates confirmed the cells from the NA slants of the Completed test and HEA plates as Gram-negative short rods in single arrangement, from the BPA plates as Gram-positive cocci in grape-like cluster arrangement, whereas those from the GFNB tubes as Gram-positive rods in chain arrangement [3].

3.3.1.2 For pathogenic fungal isolates

From the morphological observations of the respective specimens of three, typical chosen colonies from the YPDA plates, upon LPCB staining, the presence of three fungal species were presumptively confirmed, namely those of *Penicillium*, *Alternaria*., and *Aspergillus*.

The specimen from the white-bordered, suede-like, olive-green fungal colony from C2HRT(2) plate, with a brush-like appearance (penicillus), exhibiting a multicellular mycelium made up of highly branched, septate, long and hyaline hyphae, and spherical conidiospores (conidia) produced

exogenously from the specialised cells called phialides, have been presumptively identified to be species of *Penicillium*, the causative agent of Penicilliosis [20, 21].

For the second specimen from the white-bordered, powdery, black fungal colony from both C2HRT(1) and C3Href plates, a tubular, septate, hyaline, and branched mycelium, a straight hyphal branch called a conidiophore that enlarges at the apex giving rise to a spherical structure with a layer of phialide cells called a vesicle, and clustered chains of exogenous reproductive structures developed from sterigmata called conidia were observed. The species identified presumptively was that of *Aspergillus*, the causative agent of Aspergillosis [22].

The third specimen from the greyish, floccose fungal colony from C1HRT(2) plate exhibited branched acropetal conidiophores and multicelled, obclavate to obpyriform conidiospores (conidia) characterized by short conical beaks. The species was presumably that of *Alternaria*, the causative agent of subcutaneous phaeohyphomycosis and mycotic keratitis [23].

3.3.2 Routine Biochemical tests

The pathogenic bacterial isolates were identified and characterized by the set of standard biochemical tests mentioned above (Table 1).

Table 1: Biochemical tests and their results

Sample	IT	MR	VP	CT	CaT	OT	NR	UT	SH	CoT	GH	TSI	Pathogen confirmed
C1HRTE	-	-	+	+	++	-	+	-	-	NA	-	R/R	<i>Enterobacter</i> sp.
C1HRTH (1)	-	-	-	+	+++	+	-	-	+	NA	+	R/Y	<i>Pseudomonas</i> sp.
C1HRTH (2)	-	-	-	+	++++	+	-	-	-	NA	-	R/R	<i>Alcaligenes</i> sp.
C1HRFB (1)	N	N	N	N	+++	-	+	+	-	+	-	R/Y	<i>Staphylococcus aureus</i>
C1HRFB (2)	N	N	N	N	+++	-	+	+	-	-	-	R/Y	<i>Staphylococcus epidermidis</i>
C3HRTG	N	N	N	+	+++	-	+	-	-	NA	+	P/Y	<i>Bacillus</i> sp.

C1HRTE = C1HRT from EMB plate; C1HRTH (1) = C1HRT light green colony with black centre from HEA plate; C1HRTH (2) = C1HRT salmon colony with black centre from HEA plates; C1HRFB (1) = C1HRef greyish black colony with a clear halo from BPA Plate; C1HRFB (2) =

C1HRef dark grey colony without halo from BPA plate; C3HRTG = C3HRT growth from GFNA slant, IT = Indole Test; MR = Methyl red Test; VP = Voges Proskauer Test; CT = Citrate Test; CaT= Catalase Test; OT = Oxidase Test; NR = Nitrate Reduction Test; UT = Urease Test; SH = Starch Hydrolysis; CoT = Coagulase Test; GH = Gelatin Hydrolysis; TSI = Triple Sugar Iron Test; + = Weakly Positive; +++ = Strongly Positive; – = Negative; NA = Test Not Applicable; P = Pink; Y = Yellow; R = Red.

3.4 Antibiotic resistance determination by Antibiotic Susceptibility Tests (AST) and antibiogram analysis

The results of the AST (Fig.2) and subsequent antibiogram analysis of the typical pathogenic bacterial isolates revealed wide variations in their drug resistance patterns. Very alarmingly, 80% of the isolates (*Pseudomonas* species, *Alcaligenes* species, *S. aureus*, and *Bacillus* species) exhibited complete resistance against amoxicillin (AMX). 20% of the isolates (*Pseudomonas* species) exhibited complete resistance against vancomycin (VA). As a note of caution, the pathogenic strain of *Pseudomonas* species isolated emerged to be a MDR, with resistance against both AMX and VA.

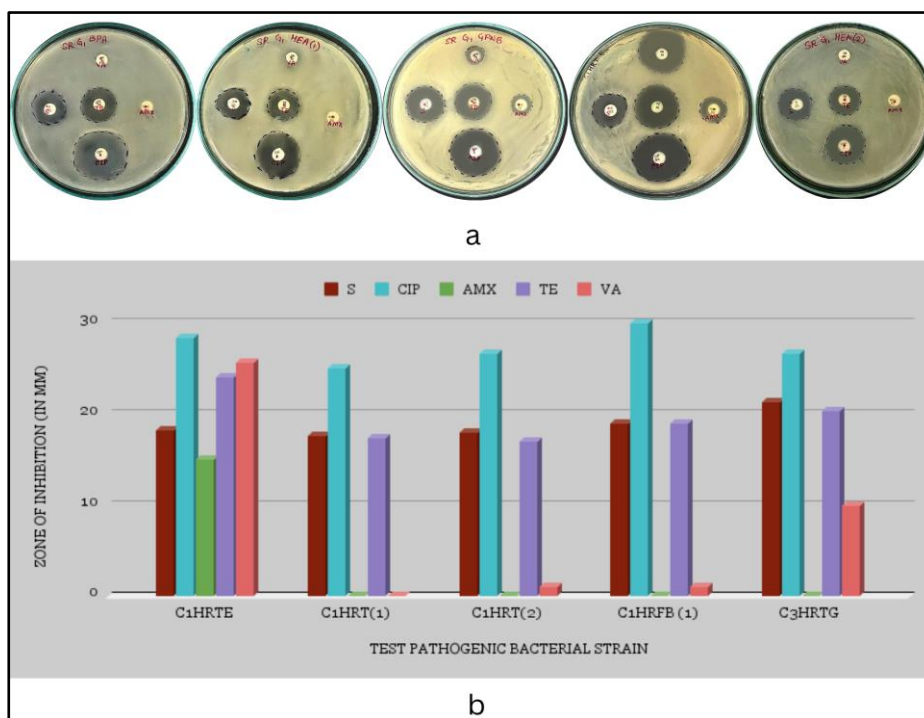


Fig.2: Antibiogram analysis: a: Zones of Growth Inhibition in MHA plates of 5 different pathogenic bacterial isolates; b: the corresponding bar diagram, indicating antibiotic resistance among the strains.

This antibiogram analysis highlighted the appropriate treatment that can be temporarily provided against such notorious chocolate-borne pathogens, such as DR *Pseudomonas* species, *Alcaligenes* species, *S. aureus* and *Bacillus* species (viz. ciprofloxacin, streptomycin, tetracycline, and

vancomycin), and MDR *Pseudomonas* species (viz. ciprofloxacin, streptomycin, and tetracycline). Thus, proper drug management practice will take care of public health and help reduce the increasing incidences of multidrug resistance among similar pathogens in the future.

4. Conclusion

This research, a very first of its kind, sheds light on the overall microbiological quality of chocolates of reputed brands sold in Kolkata while also highlighting the importance of proper storage exercises to eliminate risks of contamination. This novel study shatters the common belief that cocoa and low water activity restrict microbial spoilage in chocolates, as the findings say otherwise in terms of high loads of both bacterial and fungal food-borne pathogens. Thus, it recalls for an efficient re-evaluation of food safety standards with regard to the confectionery industry in order to ensure ultimate protection of the consumers against fatal food-borne diseases that can be associated with chocolates, a favorite among kids. In addition to this, the antibiotic susceptibility test performed to check the overall resistance profile of the pathogenic isolates helped strengthen the idea that the majority of the pathogens are completely resistant to the antibiotics tested and may lead to drug-resistant infections upon ignorant consumption of such contaminated chocolates.

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Investigating the Physiological and Clinical potencies of few commercially - available, non-conventional Citrus Fruits: The First Reports

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Abstract:

The present study, a very first of its kind, used methanolic extracts of peel and pulp, and natural juices of each of the non-conventional citrus fruits such as grapefruit (*Citrus. paradisi*), malta (*C. sinensis* L. *Osbeck*), mandarin (*C. reticulata*) and pomelo (*C. maxima*) for evaluation and comparison of the relative abundances of the major bioactive compounds like total Vitamin C (Iodometric titration assay), flavonoids (Quercetin method) and total phenolics (Folin-Ciocalteu-Gallic acid method), radical-scavenging (antioxidant) properties (DPPH-assay), and antimicrobial potencies (Agar-Cup method). Results indicated that natural pomelo juice has the highest contents of Vitamin C (45.6%), flavonoids (9.04 mg Quercetin Equivalent/ml) and total phenolics (3.86 mg Gallic Acid Equivalent/ml), besides having the best radical scavenging ability (78.83%). This novel preliminary screening indicated a great potential for the development of antioxidant formulations from pomelo in future. Results of experiment on antimicrobial properties of all the fruit samples against standard drug-resistant (DR) pathogenic strains of Vancomycin^r Amoxicillin^r (VA^r AMX^r) *Escherichia coli* (VA^r AMX^r), Amoxicillin^r (AMX^r) *Klebsiella pneumoniae*, Ampicillin^r Erythromycin^r (Amp^r Ery^r) *Terribacillus halophilus* and Ampicillin^r Methicillin^r Clindamycin^r Nalidixic acid^r (Amp^r Met^r Clind^r NA^r) *Comamonas aquatica* indicated that the peel and pulp extracts were highly effective against all the bacteria, with pomelo peel and pulp extracts being highly active (minimal inhibitory concentration or MIC between 0.05-0.1 g/ml) against the VA^r AMX^r *E. coli*, and malta and grapefruit peel and pulp extracts being highly active (MIC between 0.05-0.1 g/ml for both) against the AMX^r *K. pneumoniae*, thus throwing light on possibilities of development of green pharmaceuticals from those in near future for fighting global health challenges.

Keywords: antimicrobial potencies; citrus fruits; flavonoids; phenolics; radical-scavenging (antioxidant) properties; Vitamin C

1. Introduction

Citrus fruits are rich natural reserves of phytochemicals which vastly confer beneficial therapeutic effects on the physiological system [1]. Several vitamins have been reported to be abundant in citrus fruits like Vitamin B complex, Vitamin C, Vitamin E which boosts the activities of the immune

system [2]. Bacterial species that have been studied to be inhibited by citrus fruit extracts include *Bacillus cereus*, *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Escherichia coli*, *Klebsiella pneumoniae*, *Terribacillus halophilus*, *Streptococcus pneumoniae*, *Streptococcus pyogenes* etc [3]. Among the various phytochemicals extracted from citrus fruits, the antioxidant mechanisms involving phenolic compounds like flavonoids in addition to vitamins (particularly, ascorbic acids) have been studied meticulously [2,4]. Furthermore, with the advent of multi drug resistance especially among bacterial pathogens, the search for novel drug like molecules is at an all-time high. Under such background, this research aims to solidify the position of citrus fruit bioactive principles in therapeutic approaches and as bactericidal agents.

2. Materials and Methods

2.1 Sample collection

4 fresh, well-grown and intact non-conventional citrus fruit samples, namely, grapefruit (*Citrus paradisi*), malta (*C. sinensis* L. Osbeck), mandarin (*C. reticulata*) and pomelo (*C. maxima*) were purchased from local markets of Kolkata, and transported carefully to the laboratory for analysis.

Test bacteria

Standard drug-resistant (DR) pathogenic strains of Vancomycin^r Amoxicillin^r (VA^r AMX^r) *Escherichia coli* (VA^r AMX^r) and Amoxicillin^r (AMX^r) *Klebsiella pneumoniae* were collected from The Central Drug Laboratory (CDL), Kolkata, whereas Ampicillin^r Erythromycin^r (Amp^r Ery^r) *Terribacillus halophilus* and Ampicillin^r Methicillin^r Clindamycin^r Nalidixic acid^r (Amp^r Met^r Clind^r NA^r) *Comamonas aquatica* were collected from Canning Station road-associated municipal wastewater, Canning, South 24-Parganas. All strains used were ribotyped ones, with genome sequences available on NCBI GenBank database.

2.2 Sample preparation

Each fruit was washed thoroughly using distilled water, cut open using a clean, sterilized knife, and peeled, with the pulp removed and natural juice extracted from the pulp in a blender. The corresponding peel and the pulp were sun dried for 3-4 days and ground to a fine powder, 1 mg of each of which was added to 10 ml of methanol to make a methanolic extract (0.1 mg/ml), and refrigerated along with the juice prior to analysis. All the 12 samples (methanolic extracts of peel and pulp samples, and freshly extracted juice, from each fruit) were then analyzed for evaluation and comparison of the relative abundances of the major bioactive compounds like total Vitamin C, flavonoids and total phenolics, radical-scavenging (antioxidant) properties, and antimicrobial potencies.

2.3 Vitamin C content

Ascorbic acid determination was carried out by the Iodometric titration method, using a standard vitamin C solution [5]. For 5 ml of both the standard and the samples, 50 ml iodine solution (initial volume I) was used for titration, in the presence of 10 drops of 1% starch as the indicator, until the first blue-black colour appeared at the end point of titration. The final volume (F) of the iodine solution was noted in each case, and the volume of iodine consumed (X ml for the standard vitamin C, and V ml for the sample) for titration calculated (I-F). Then, vitamin C content in each sample

was calculated as below:

$$\text{Concentration of Vitamin C (x g) in 5 ml of the sample} = \frac{\text{X ml iodine solution}}{\text{0.25g vitamin C standard}} = \frac{\text{Y ml iodine solution}}{\text{x g vitamin C}}$$

$$\text{Concentration of Vitamin C in g/L} = \left(\frac{x \times 1000}{5} \right) \text{ g/L} = 200x \text{ g/L}$$

$$\text{So, Percentage of Vitamin C (\%)} = \frac{200x \text{ g/L}}{\text{Vitamin C Standard concentration in g/L}} \times 100 = \frac{200x}{50} \times 100 = 400x \%$$

2.4 Flavonoid content

The flavonoid content in each sample extract and juice were determined by Quercetin method [6], using a Standard Curve of five different concentrations of quercetin, including 0.1 mg/ml, 0.5 mg/ml, 2.5 mg/ml, 5 mg/ml and 10 mg/ml. 20 µl of each standard concentration of quercetin and 150 µl of 5% sodium nitrite solution were mixed, and incubated for 5 mins at room temperature. 2500 µl of 10% aluminium chloride solution was then added to prepare a 2670 µl of final reaction mixture, followed by incubation for 6 mins at room temperature. The same steps were repeated for each sample, the absorbance read at 510 nm, and the flavonoid content calculated in mg Quercetin Equivalent (QE)/ml of the sample from the quercetin Standard Curve.

2.6 Total phenolic content

The total phenolic content (TPC) of each of the samples was determined by Folin-Ciocalteu (FC)-Gallic acid method [7], using a Standard Curve of five varying concentrations of gallic acid, including 0.025 mg/ml, 0.05 mg/ml, 0.1 mg/ml, 0.5 mg/ml, 1.0 mg/ml, 2.5 mg/ml and 5.0 mg/ml. 100 µl of 50% FC reagent was added to 100 µl of each standard concentration of gallic acid, followed by incubation in dark for 3 mins. Then, 2000 µl of 2% sodium carbonate solution and 800 µl of deionized water was added to prepare a 3000 µl of final reaction mixture. The test tubes were heated in a boiling water bath for 1 min, and cooled. The same steps were repeated for each sample, the absorbance read at 760 nm, and the TPC calculated in mg Gallic Acid Equivalent (GAE)/ml from the gallic acid Standard Curve.

2.7 Radical scavenging (RSC) activity

To determine the radical scavenging (RSC) (antioxidant) activity (%) in each sample by DPPH-assay, 2,2-diphenyl-1-picrylhydrazyl (DPPH) reagent was used [8]. 20 µl of each sample was added to 1980 µl of methanol and 1000 µl of 0.12 mg/ml DPPH solution to prepare 3000 µl of final reaction mixture, and incubated in dark at room temperature for 20 mins. The absorbance was measured at 517 nm, and RSC activity (%) was calculated by using the formula:

$$\text{RSC activity (\%)} = \frac{(\text{Absorbance of DPPH solution at 517 nm without sample} - \text{Absorbance of DPPH solution at 517 nm with sample}) \times 100}{\text{Absorbance of DPPH solution at 517 nm without sample}}$$

2.8 Antimicrobial properties

Antimicrobial potencies of each type of extract and natural juice of each type of fruit were assessed for by the standard Agar-Cup method [9]. Methanolic extracts of peel and pulp of each fruit of concentration 0.2 g/ml were prepared, and serially diluted to concentrations 0.1 g/ml and 0.05 g/ml. 100 µl of each overnight-grown pure nutrient broth culture of the test bacteria was spread on nutrient agar plate, and the inoculum allowed to dry. For the methanolic extracts of the peel and pulp, 7 wells were dug out in each plate, 6 for 3 different concentrations of the peel and pulp extracts, the rest reserved for a positive control (methanol). For all these extracts, and the undiluted natural juice, 30 µl was added to the respective wells, followed by refrigeration for 30 minutes to allow proper diffusion into the medium. All the plates were then incubated overnight at 37°C, following which the diameters of the zones of growth inhibition were measured in mm.

Statistical analysis

All results were expressed as mean $\pm$ SEM (Standard Error of Mean) for individual experiment. Each experiment was performed three times ($n=3$), and the mean value from all set of those experiments was presented. Student's t-test was performed as applicable in each case, and the values were found to be significant at 5% probability level.

3. Results and Discussions

3.1 Vitamin C content

Iodometric titration results for each methanolic extract of peel and pulp, as well as natural juices of the 4 different fruits indicated that juice samples have a higher vitamin C content in general, with pomelo juice having the highest (45.6%). The pulp extracts of pomelo, malta and mandarin showed the least vitamin C content (6.68%) of all the samples (**Fig.1**).

3.2 Flavonoid content

Flavonoid content determination by Quercetin method revealed a higher content of total flavonoids in the natural fruit juice samples, with pomelo juice showing the highest (9.04 mg QE/ml). Malta pulp extract showed the least flavonoid content of 5.47 mg QE/ml (**Fig.1**).

3.3 Total phenolic content

TPC was evaluated by Folin-Ciocalteu-Gallic acid method, in which of all the samples, pomelo juice showed the highest TPC of 3.86 mg GAE/ml, and malta pulp showed the least of 2.07 mg GAE/ml, followed by pomelo pulp and mandarin pulp (**Fig.1**).

3.4 Radical scavenging (RSC) activity

DPPH-assay showed an appreciable RSC (antioxidant) activity in all the samples, where pomelo juice displayed the highest activity of 78.83% and mandarin juice showed the least activity of 58.20% (**Fig.1**).

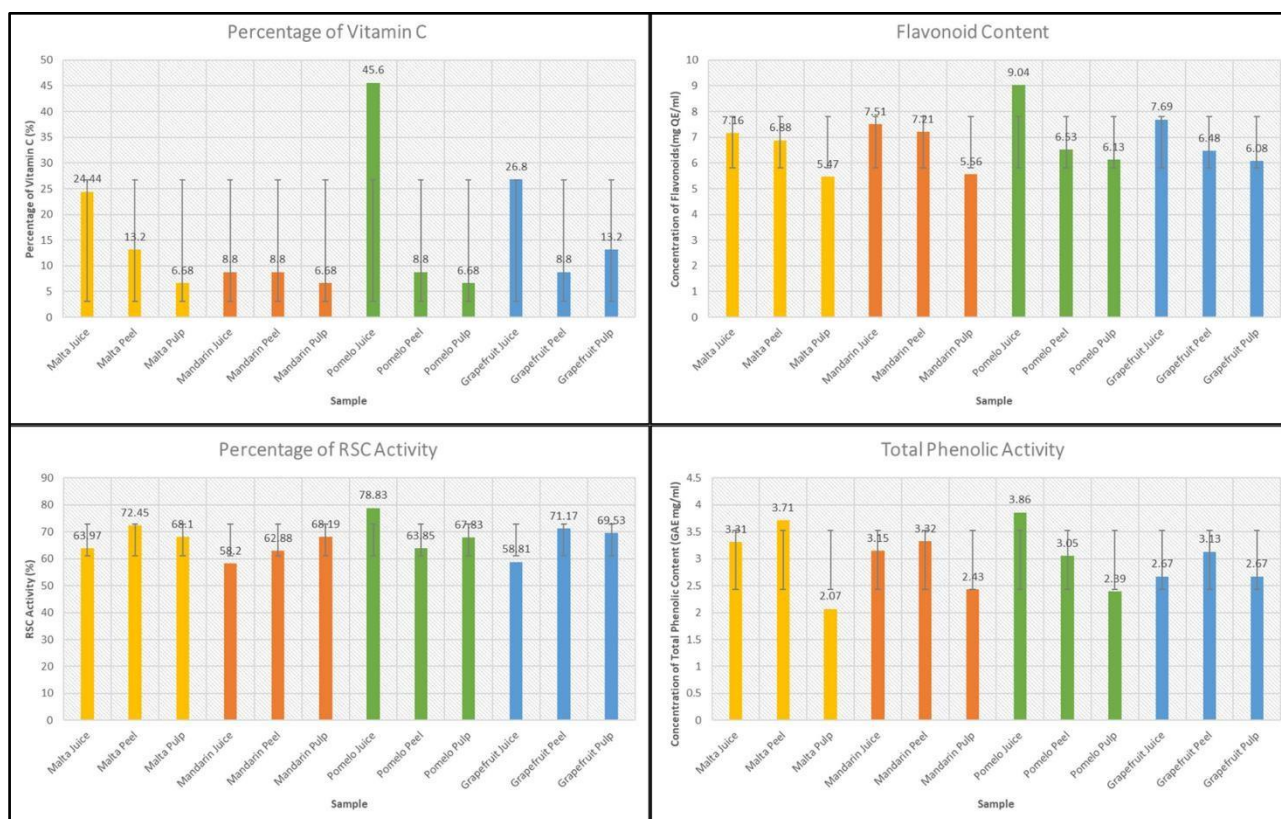


Fig.1 Evaluation and comparison of the relative contents of the major bioactive compounds (Vitamin C, flavonoid and total phenolic), and radical-scavenging (antioxidant) properties of different fruit extracts and natural juices

3.5 Antimicrobial properties

Agar-Cup method of antibiotic assay was performed with the methanolic extracts of peel and pulp as well as natural juice samples of the different fruits, and tested for their efficacies against the test pathogenic bacterial strains. Diameters of the zones of growth inhibition in each case were measured in mm, which revealed that the peel and pulp extracts were significantly effective against all the test bacteria (**Table 1, Fig.2**). The pomelo peel and pulp extracts were highly active against the AMX^r *E. coli* with a minimal inhibitory concentration (MIC) between 0.05-0.1 g/ml, and malta and grapefruit peel and pulp extracts against the AMX^r *K. pneumoniae* with a MIC between 0.05-0.1 g/ml for both. Malta peel and pulp extracts, as well as grapefruit pulp extract, were observed to be active against Amp^r Met^r $Clind^r$ NA^r *C. aquatica*, with a MIC between 0.05-0.1 g/ml. Also, malta pulp, mandarin peel and pulp, and grapefruit peel and pulp extracts were active against Amp^r Ery^r *T. halophilus*, showing a MIC between 0.05-0.1 g/ml. Interestingly, AMX^r *K. pneumoniae* showed significant sensitivity to juices of malta and pomelo as well.

Table 1: Diameters of the zones of growth inhibition (in mm) against test bacterial strains by different fruit extracts and juices

Diameter of the zones of growth inhibition (in mm)													
Test Bacterial Strain	Sample Type	Mandarin			Malta			Pomelo			Grapefruit		
		0.2 g/ml	0.1 g/ml	0.05 g/ml	0.2 g/ml	0.1 g/ml	0.05 g/ml	0.2 g/ml	0.1 g/ml	0.05 g/ml	0.2 g/ml	0.1 g/ml	0.05 g/ml
		Average			Average			Average			Average		
VA ^r AMX ^r <i>Escherichia coli</i>	Peel	14.33	0	0	12.33	0	0	15.67	11.33	0	12	0	0
	Pulp	12	0	0	14.33	0	0	14	12	0	13.67	0	0
Amp ^r Met ^r Clind ^r NA ^r <i>Comamonas aquatica</i>	Peel	13.67	0	0	14	11	0	14	0	0	13.67	0	0
	Pulp	12.67	0	0	13	11	0	12	0	0	14	11.67	0
Amp ^r Ery ^r <i>Terribacillus halophilus</i>	Peel	14	11.67	0	13.67	0	0	14	0	0	14.67	10	0
	Pulp	13.33	0	0	14.67	12	0	14.67	0	0	12.33	10	0
AMX ^r <i>Klebsiella pneumoniae</i>	Peel	13	0	0	12.67	11	0	14.67	0	0	12.33	10.67	0
	Pulp	12	0	0	12	11.67	0	14	0	0	12.33	11.33	0
Test Bacterial Strain	Sample Type	Mandarin			Malta			Pomelo			Grapefruit		
VA ^r AMX ^r <i>Escherichia coli</i>	Juice	0			0			0			0		
Amp ^r Met ^r Clind ^r NA ^r <i>Comamonas aquatica</i>	Juice	0			0			0			0		
Amp ^r Ery ^r <i>Terribacillus halophilus</i>	Juice	0			0			11.33			0		
AMX ^r <i>Klebsiella pneumoniae</i>	Juice	0			11.33			10.67			0		

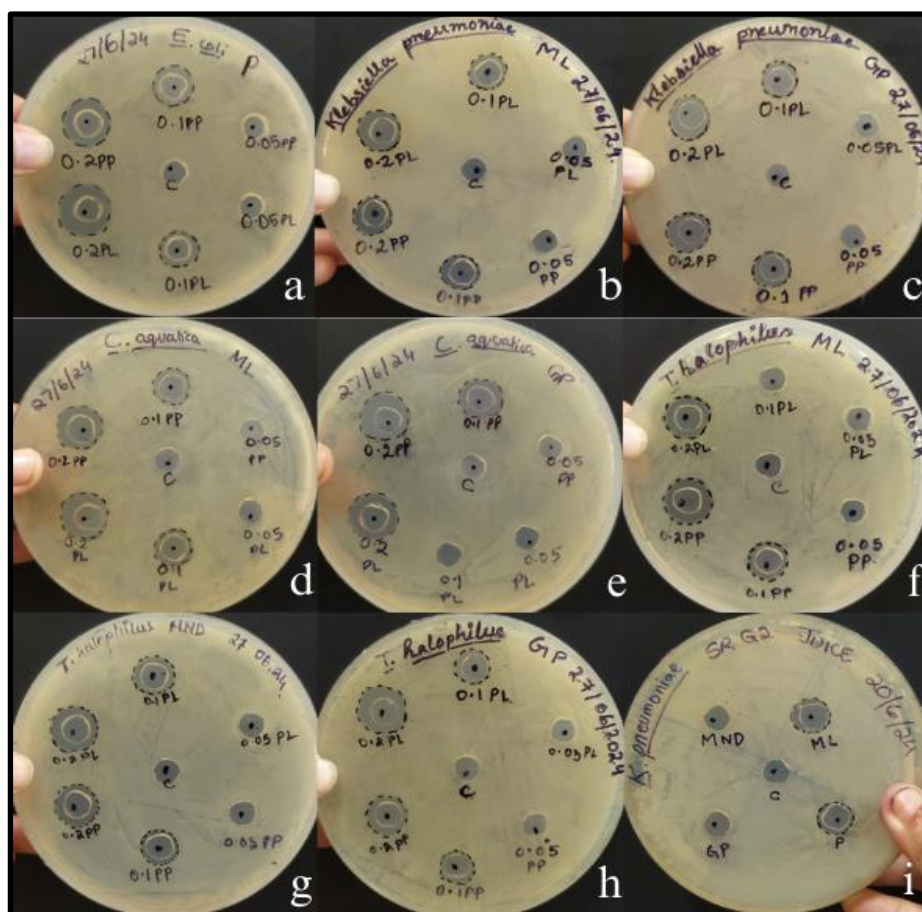


Fig.2. Plates showing zones of growth inhibition in different test bacterial strains of (a) VA^r AMX^r *E. coli*; (b, c, i) AMX^r *K. pneumoniae*; (d, e) Amp^r Met^r $Clind^r$ NA^r *C. aquatica*; and (f, g, h) Amp^r Ery^r

T. halophilus by peel (PL) and pulp (PP) extracts, and natural juices of Pomelo (P), Grapefruit (GP), Malta (ML) and Mandarin (MND).

4. Conclusion

This novel screening among the 4 non-conventional fruits revealed that because of the highest radical-scavenging (antioxidant) potencies of pomelo (*C. maxima*) juice owing to its highest content of vitamin C, flavonoids and phenolics, there is a great potential for the development of antioxidant formulations from pomelo in future. Also, antimicrobial activity shown by the peel and pulp extracts of all the fruits against all the test bacteria may be due to the presence of bioactive components in them, thus throwing light on possibilities of development of green pharmaceuticals from those in near future for fighting global health challenges. Besides peel and pulp extracts, DR-*K. pneumoniae* showed significant sensitivity to malta and pomelo juices also, thus opening up newer avenues for using these natural citrus juices in battling MDR-pathogenic infections, following exhaustive studies in future.

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Paper Title: Edible Hydrogel: A Modern Drug Carrier System in Bioactive Phytochemical Delivery.

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Abstract:

Polysaccharide-based hydrogels (e.g. chitosan, alginate, and κ -carrageenan) have maintained a high level of interest owing to their biocompatibility, biodegradability, and capability to improve the stability and bioavailability of bioactive compounds. These materials, alone or in hybrid configuration, effectively meet challenges associated with their delivery in pharmaceutical formulations, functional foods, and food packaging by facilitating targeted delivery, sustained release, or protective encapsulation of phytochemicals. Solvent casting, lyophilization, and cryogelation are among the techniques for hydrogel encapsulation, which may be adapted for applications like intelligent food packaging, nutraceuticals etc. The incorporation of phytochemicals like polyphenols into hydrogels enhances solubility, increases shelf life, and maintains bioactivity during food processing. Other applications include their use as pH indicators for tracking food freshness, further demonstrating their potential for smart packaging. However, despite these benefits some challenges like, hydrogel microspheres scalability, mechanical strength and complexity of the processes in their fabrication still remain leading to the requirement of a detailed investigation to improve the properties of hydrogel and broaden their applications. This research emphasizes that polysaccharides are an essential ingredient for developing high performance polymeric and functional delivery systems.

Keywords: Polysaccharides, Hydrogels, Encapsulation, Phytochemicals.

1. Introduction:

Hydrogels are three-dimensional, cross-linked polymeric networks that possess a remarkable ability to absorb and retain large amounts of water while maintaining their structural integrity. These unique properties arise from their hydrophilic functional groups and cross-linked structure, enabling them to hold water many times their dry weight without dissolving. Due to their biocompatibility, biodegradability, and tunable physicochemical properties, hydrogels have gained significant attention in various industries, including food preservation, drug delivery, wound healing, and nutraceuticals (1). In the food industry, hydrogels serve as effective carriers for bioactive compounds, enhancing their stability, bioavailability, and controlled release. Many bioactive compounds, such as polyphenols, probiotics, and essential vitamins, have limited stability in conventional food matrices due to degradation from temperature, pH, and enzymatic reactions. Hydrogels protect these sensitive compounds by forming a protective network that regulates their

diffusion and release, ultimately prolonging shelf life and improving functional properties (2). Furthermore, hydrogels have been explored in the development of sustainable food packaging, offering an alternative to conventional plastics. Their ability to incorporate antimicrobial agents, antioxidants, and functional additives provides enhanced food safety and extended preservation (3). Beyond food applications, hydrogels are widely used in biomedical and pharmaceutical fields, particularly in targeted drug delivery and wound healing. Their highwater content and porous structure facilitate cell adhesion, nutrient exchange, and controlled drug release, making them ideal for personalized medicine and regenerative therapies (4). Additionally, hydrogel-based nutraceutical formulations provide a sustained and efficient delivery of dietary supplements, ensuring better absorption and therapeutic efficacy. With continuous advancements in polymer science and nanotechnology, hydrogels are evolving into a multifunctional material with vast potential in food, medicine, and environmental sustainability. Their versatility in bioactive encapsulation, smart delivery systems, and eco-friendly applications positions them as a promising innovation for the future.

2. Methods

The preparation of Thankuni jelly involves the use of key ingredients, including Thankuni leaves (*Centella asiatica*), which can be either fresh or dried, serving as the primary source for bioactive extraction. RO water is utilized for both the extraction process and the jelly formulation. Honey functions as a natural sweetener, enhancing the taste while also contributing to the jelly's preservative properties. Pectin is incorporated as a gelling agent to achieve the desired consistency and texture of the jelly. For the polyphenol content analysis, several essential materials and equipment are required, including distilled water, the Thankuni jelly sample, and various laboratory tools such as test tubes, cuvettes, pipettes, and volumetric flasks. A spectrophotometer set at 765 nm absorbance is employed to measure the total polyphenol content, ensuring an accurate assessment of the jelly's bioactive compound concentration. The spoilage test of the Thankuni jelly sample involves a microbial and physical spoilage assessment, which is conducted using sterile Petri dishes for sample observation and analysis. This process helps evaluate the shelf life and overall microbial stability of the formulated jelly. Additionally, an entrapment test is performed to examine the microstructural properties of the jelly. This test requires the use of a microscope for detailed analysis, enabling the observation of bioactive compound distribution and entrapment efficiency within the jelly matrix. These assessments are crucial in determining the stability, quality, and functional properties of the formulated Thankuni jelly.

2.1. Preparation of Thankuni Jelly:

Fresh Thankuni leaves (*Centella asiatica*) were thoroughly washed with RO water to remove dirt and impurities. The cleaned leaves were blended with 1.5 cups of RO water until smooth, and the mixture was strained using a fine sieve or cheesecloth to obtain a concentrated extract. The extract was then heated to a gentle simmer over low-medium heat to enhance the concentration of active compounds and remove excess moisture. In a separate bowl, pectin was dissolved in $\frac{1}{2}$ cup of cold RO water and stirred thoroughly to prevent lump formation. The pectin solution was then gradually added to the heated extract with continuous stirring to ensure uniform dispersion. Honey was

incorporated into the mixture as a natural sweetener and texturizing agent. The jelly mixture was cooked over medium heat with constant stirring until thickened. Consistency was assessed using the cold plate method. Once the desired gel formation was achieved, the jelly was poured into molds, allowed to cool at room temperature for 20-30 minutes, and refrigerated for a minimum of four hours to ensure proper setting.

2.2. Physiochemical Analysis:

2.2.1 Determination of Polyphenol Content in Thankuni Jelly

For the polyphenol content analysis of Thankuni jelly, a sample preparation process was carried out by dissolving 1 g of Thankuni jelly in 10 mL of ethanol, followed by continuous stirring for 30 minutes to facilitate polyphenol extraction. The extract was then filtered to obtain a clear supernatant for further analysis. In the standard solution preparation, gallic acid standard solutions of varying concentrations (0.01, 0.02, 0.05, and 0.1 mg/mL) were prepared, with 1 mL of each transferred into separate test tubes. The reaction setup involved the addition of 0.5 mL of Folin-Ciocalteu reagent to each test tube, followed by 2 mL of 20% sodium carbonate solution(4). The reaction mixtures were then incubated in the dark at room temperature for 30 minutes to ensure proper development of the colorimetric response. The absorbance measurement was performed at 765 nm using a spectrophotometer, with a blank sample containing only reagents included as a reference. For data analysis, a calibration curve was constructed using the absorbance values of the standard solutions, and the polyphenol content of Thankuni jelly was determined by interpolation. The final results were expressed as mg gallic acid equivalents per gram of jelly, providing a quantitative assessment of the jelly's polyphenolic composition.(5)

2.2.2. Method for Entrapment Test of Thankuni Jelly:

The entrapment test was conducted to evaluate the encapsulation of Thankuni leaf (*Centella asiatica*) extract within the jelly matrix. A small section of the prepared jelly was carefully placed on a clean glass slide and covered with a coverslip. Microscopic analysis was performed using a compound microscope to examine the distribution and retention of the extract within the gel structure. The observations focused on the uniformity of entrapment and the structural integrity of the jelly matrix, ensuring the potential for bioactive compound retention.

2.2.3. Method for Spoilage Test of Thankuni Jelly:

To evaluate the stability and shelf-life of Thankuni jelly under open environmental conditions, a spoilage assessment was conducted over a period of two weeks at room temperature. The jelly samples were aseptically transferred into sterile Petri dishes and exposed to ambient air to simulate real-world storage conditions. Daily monitoring was performed to record any visible signs of deterioration, including microbial contamination, changes in texture, color variations, and the development of off-odors. Microbial growth was assessed based on the appearance of surface colonies or fungal mycelium, while textural changes were evaluated in terms of firmness, syneresis, and overall structural integrity. Any deviations in color were documented to determine oxidative or enzymatic browning, and olfactory analysis was conducted to detect the presence of any unpleasant

or rancid odors indicative of spoilage. All observations were systematically recorded to analyze the stability of the jelly and to assess the effectiveness of its preservation under ambient storage conditions. The findings from this study provide insights into the susceptibility of Thankuni jelly to spoilage factors and inform potential strategies for extending its shelf-life through improved formulation or packaging interventions.

3. Result and Discussions

3.1. Jelly Structure Formation:

The modeling of jelly structure development has identified essential characteristics for an ideal gel, including proper gelation, uniform consistency, structural integrity, clarity, and resistance to syneresis (liquid separation). A key outcome of this model is its precise representation of the complex interactions among pectin concentration, sugar content, acidity, and temperature, which collectively determine the gel's firmness, elasticity, and stability.

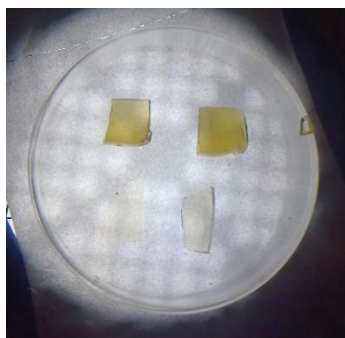


Fig.1. Jelly Structure Formation

The model effectively captures the thermodynamic and rheological mechanisms governing gel formation, highlighting the importance of precise formulation and processing conditions. Proper gelation arises from controlled molecular interactions, forming a stable three-dimensional network that ensures mechanical strength and desirable texture. Additionally, the model underscores acidity's role in optimizing pectin-sugar interactions, preventing premature breakdown or excessive rigidity. These insights enhance the understanding of gelation kinetics, contributing to advancements in jelly formulation and processing, ultimately improving the sensory and functional attributes of the final product.

3.2. Phytochemical Entrapment Test:

The entrapment test confirmed the successful encapsulation of **Thankuni leaf (Centella asiatica) extract** within the jelly matrix, effectively retaining its bioactive compounds and ensuring long-term stability. This encapsulation minimizes **oxidation and degradation**, enhancing the **shelf life and therapeutic efficacy** of the extract. The jelly matrix serves as an **efficient delivery system** for medicinal and nutritional applications, preserving the extract's **antioxidant and anti-inflammatory**

properties. These findings highlight **Thankuni jelly's potential as a functional food**, offering a natural and convenient way to deliver bioactive compounds while ensuring consumer acceptability.

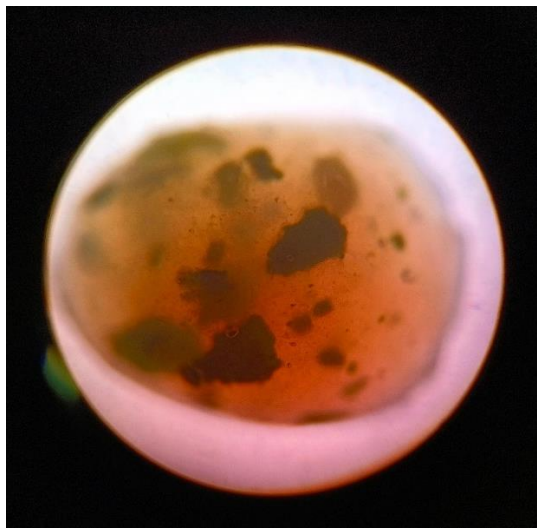


Fig.2. Entrapped Extract inside beads under microscope.

3.3. Polyphenol Test:

The polyphenol content in Thankuni jelly was determined using the Folin-Ciocalteu method. Based on the calibration curve, the polyphenol concentration was found to be 197 mg gallic acid equivalents (GAE) per gram of jelly.

Calculation:

At 68% entrapment, 197mgGAE of polyphenol was found. So, at 100% entrapment, the amount of polyphenol was found to be:

$$X = \frac{197}{68} \times 100 = 290mgGAE$$

Hence, Encapsulation Efficiency:

$$\text{Encapsulation Efficiency (EE) \%} = \frac{R}{L} \times 100 \quad (6)$$

Here, R denotes the final Polyphenol content of the product, L denotes the initial Polyphenol Content of the extract.

$$EE = \frac{197}{290} \times 100 = 94\%$$

Hence the Encapsulation Efficiency is 94%.

3.4. Spoilage Test:

After two weeks of exposure to open environmental conditions at room temperature, visible signs of spoilage were observed in the Thankuni jelly. These included microbial growth, changes in texture, color alterations, and the presence of off-odors, indicating the instability of the jelly under unprotected storage conditions.



Fig.3. Spoilage Test

4. Conclusion

This study underscores the significant potential of biocompatible hydrogels in functional food, nutraceuticals, and therapeutic applications. Their unique three-dimensional, cross-linked polymeric structure allows them to absorb and retain large amounts of water while maintaining mechanical stability, making them highly effective in various industrial and biomedical fields. One of the most critical advantages of hydrogels is their ability to enhance the bioavailability, stability, and targeted delivery of bioactive compounds, such as phytochemicals, probiotics, and essential nutrients, which are often susceptible to degradation due to environmental factors like pH, temperature, and enzymatic activity. By encapsulating these compounds, hydrogels ensure their controlled release, prolonged functionality, and improved therapeutic efficacy. Beyond food applications, hydrogels play a vital role in wound healing, drug delivery, and sustainable food packaging. Their biodegradable and antimicrobial properties make them a promising alternative to conventional packaging materials, contributing to eco-friendly and sustainable solutions. In the medical field, hydrogel-based dressings provide moisture retention, cellular adhesion, and gradual drug release, accelerating the healing process and improving patient outcomes. Their use in nutraceuticals and functional foods further demonstrates their multifunctionality and adaptability across diverse sectors. Future research should focus on optimizing hydrogel formulations for enhanced efficiency, scalability, and cost-effectiveness, particularly for commercial applications in food and healthcare industries. Emphasizing sustainability, advanced polymer modifications, and integration with

nanotechnology will further expand the potential of hydrogels, paving the way for next-generation biomaterials that cater to evolving consumer and industrial needs.

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Development of Betalain-Enriched Millet-Semolina Pasta: Extraction, Incorporation, and Future Directions

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Abstract:

This study explores the development of a nutritionally enriched pasta by incorporating betalain, a natural pigment from beetroot, into a millet flour and semolina blend (60:40). Betalain is known for its antioxidant, anti-inflammatory, and antimicrobial properties, along with its vibrant color. Microwave-assisted extraction was the most efficient method for isolating betalains, with stability maintained by adding citric acid to beet paste at a controlled pH of 4–6. Millet flour, valued for being gluten-free and rich in minerals and polyphenols, was combined with semolina to ensure elasticity and structural integrity. This formulation preserved betalain stability against heat and pH variations, producing a high-quality pasta. Nutritional analysis confirmed superior mineral and polyphenol content, while antioxidant capacity significantly increased. Sensory evaluations indicated favorable texture, taste, and overall acceptability, making it suitable for health-conscious and gluten-sensitive consumers. This research highlights the potential of betalain-enriched millet-semolina pasta in addressing consumer demand for plant-based, functional foods.

Keywords:

Betalain; Millet flour; Semolina; Microwave extraction; Nutritional properties; Shelf life; Stabilizers; Functional food.

Introduction:

Native to Asia and Europe, beetroot (*Beta vulgaris* L.) is a popular root vegetable of the Chenopodiaceae family ^[1]. Because of its high amount of nitrate (NO_3^-), a substance that may have cardiovascular advantages by encouraging the body to produce more nitric oxide (NO), beetroot (*Beta vulgaris* L.) has attracted a lot of scientific attention ^[2]. Furthermore, the fact that beetroot contains a variety of vitamins (such as vitamin C, thiamin, vitamin B6, β -carotene, vitamin A, vitamin K, and vitamin E), minerals (such as calcium, iron, magnesium, potassium, selenium, and zinc), phenolics, carotenoids, ascorbic acid, and betalains makes it a functional food ^[3]. Beetroot juice is a useful functional component since it is high in nitrates and antioxidants, both of which have major health advantages. Because of its main ingredient, inorganic nitrate, it is frequently promoted as a sports drink. Beetroot juice's nitrate content improves blood vessel function and increases oxygen transport to skeletal muscles, which improves exercise performance ^[4]. Beetroot's use in a

variety of food products not only benefits human health but also makes it easier to create functional foods ^[3]. Beetroot must be processed to increase its shelf life and guarantee availability even in the off-season ^[5]. Bioactive chemicals, particularly betalains, are abundant in red beetroot ^[6]. The two primary components of betalains, which are nitrogen-containing, water-soluble pigments, are yellow-orange betaxanthins, which absorb maximally at 480 nm, and red-violet betacyanins, which are nitrogen-containing water-soluble pigments. 5–25% of betalains are betaxanthins, while 75–95% are betacyanins ^[7]. The most prevalent betacyanin, bethanin, which gives beetroot its distinctive red color, is found in 300–600 mg/kg of beetroot juice [8]. Betacyanins, namely betanin and its isomer isobetanin, make up around 80% of beet pigments ^[9]. These compounds' phenolic and cyclic amine groups provide them exceptional electron-donating capabilities. On the other hand, betalamic acid and amino acids condense to form betaxanthins ^[10]. The overall color of beetroot is determined by the betacyanin-to-betaxanthin ratio, which is normally between 1 and 3. The chemical structure, pH, temperature, water activity, exposure to light, and interactions with metal ions are some of the variables that affect betalains' stability. Pasta, a widely consumed staple food, is traditionally made from refined wheat flour due to its favorable textural and sensory attributes. However, with increasing awareness of health and nutrition, there is a rising demand for pasta fortified with functional ingredients and alternative grains. Millet is gaining recognition for its role in combating climate change due to its resilience. It has a short growth cycle of approximately 100 days, requires minimal nutrients, and thrives in high temperatures with limited water availability. Since the early 2000s, Switzerland has conducted extensive research on developing new millet varieties ^[11]. From a nutritional standpoint, millet contains a protein content (11.5–13.5%) comparable to that of wheat and corn, yet it is naturally gluten-free. Its dietary fiber content (14.2%) exceeds that of wheat (12.9%) and is significantly greater than that of white rice (5.2%), making it an excellent choice for producing gluten-free pasta with high fiber content. Millet is also abundant in micronutrients and minerals, including niacin, vitamin B6, and folic acid, along with potassium, iron, and manganese. Furthermore, it provides notable amounts of magnesium and silicic acid ^[12,13,14].

This study on millet-based pasta enriched with betalains reveals a promising combination of ancient grains and potent antioxidants, delivering both nutritional advantages and a visually striking appearance. By incorporating betalains, this innovative pasta not only improves its health benefits but also introduces a naturally appealing hue to the dish, seamlessly blending tradition with modern wellness.

Materials and Methods:

Fresh beetroots (*Beta vulgaris* L.) were washed, peeled, and blended into a smooth paste for betalain extraction using solvent extraction and microwave-assisted extraction. For solvent extraction, four solvents—distilled water, acetone, ethanol, and methanol—were selected based on their polarity and efficiency in extracting betalains ^[15]. Test tubes containing 5 mL of each solvent were prepared, and 5 g of beetroot paste was submerged in each. The samples were left at room temperature for 1 hour, then filtered. The absorbance of the extracted betalains was measured at 530 nm using a UV-visible double beam spectrophotometer ^[16]. For microwave-assisted extraction, beetroot paste mixed with distilled water was heated in a microwave for 5, 10, 15, and 30 minutes to determine optimal

extraction time. The mixture was then filtered, and betalain absorption was measured at 530 nm using a UV-visible spectrophotometer^[17].

For pasta preparation, a beetroot paste was filtered, and 14 mL of betalain-rich extract was mixed with 60 g of proso millet (*Panicum miliaceum*) flour, 40 g of semolina, an egg, 2 tablespoons of rice-bran oil, and salt. The dough was kneaded for 30 minutes, rested for another 30 minutes, then rolled out and cut into pasta strips. The pasta was stored in aluminum foil in a refrigerator for further stability analysis^[15].



Fig.1 Betalain-Enriched Millet-Semolina Pasta

Testing Procedures of Pasta Sample:

1. Ash Content Estimation

Ash content was determined using a gravimetric method^[18]. A clean, dry silica crucible was weighed, and a known amount of pasta sample was added. The sample underwent alcohol charring using ethanol, followed by ignition. The crucible was placed in a muffle furnace at 550°C for 4 hours. After cooling in a desiccator, the final weight of the crucible with ash was recorded, and ash content was calculated as a percentage of the initial sample weight.

2. Moisture Content Estimation

Moisture content was measured using the hot air oven method^[18]. A pre-weighed Petri dish containing a known amount of pasta sample was dried at 105°C for 4 hours. The sample was then cooled in a desiccator and reweighed. Moisture content was calculated using:

$$\text{Wet basis (\%)} = (\text{Initial weight} - \text{Final weight}) / \text{Initial weight} \times 100$$

$$\text{Dry basis (\%)} = (\text{Initial weight} - \text{Final weight}) / \text{Final weight} \times 100$$

3. Polyphenol Estimation

Total polyphenol content was determined using the Folin-Ciocalteu method^[19]. A sodium carbonate solution (4 mL) and Folin-Ciocalteu reagent (5 mL) were mixed with 0.5 mL of pasta extract and

incubated in the dark for 15–20 minutes. Absorbance was recorded at 765 nm using a spectrophotometer. A standard curve using gallic acid was prepared, and total polyphenols were expressed as mg gallic acid equivalent (GAE) per 100 g of pasta, using the regression equation:

$y = 0.0028x - 0.2026$, where y is absorbance and x are concentration.

4. Total Sugar Estimation

Total sugar content was determined using Fehling's titration method ^[20]. The pasta extract was filtered and hydrolyzed using 12N HCl, followed by gentle heating for 5–10 minutes. The solution was neutralized with NaOH to pH ~7. It was titrated with Fehling's A and B solutions using methylene blue as an indicator. A 1% dextrose solution was used for standardization, and total sugar was expressed as g sucrose per 100 g of pasta.

5. Fat Estimation

Fat content was estimated using the Soxhlet extraction method ^[18]. A 10 g pasta sample was placed in a thimble inside the Soxhlet apparatus. Petroleum benzene was used as a solvent, and repeated extraction cycles were carried out at 60–70°C. After 8–9 cycles, the solvent was evaporated, and the final weight of the flask was recorded. Fat content was calculated gravimetrically.

Results and Discussion:

Table-1: The result of solvent extraction of betalain are as follows-

Name of the solvent	Absorbance	Mean Absorbance
Water	1.170	1.171
	1.176	
	1.168	
Methanol	0.382	0.382
	0.377	
	0.386	
Ethanol	0.144	0.144
	0.149	
	0.139	

Acetone	0.155	0.155
	0.158	
	0.151	

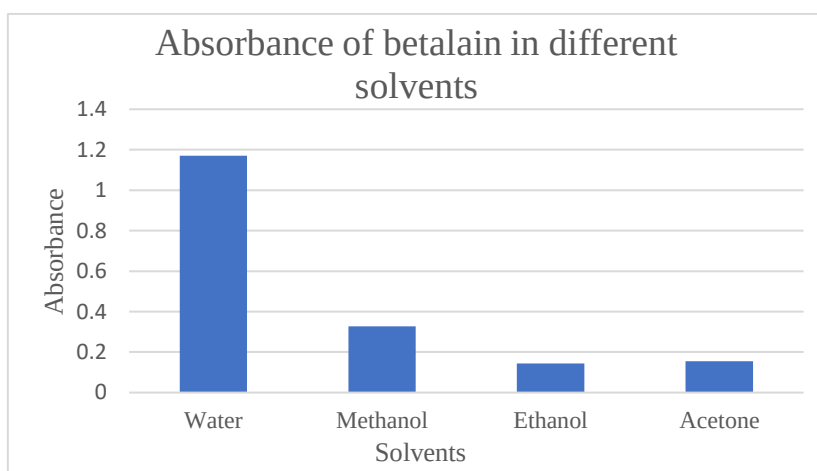


Fig.2

The solubility of betalains was evaluated in water, methanol, ethanol, and acetone. Betalains showed the highest solubility in water due to their strong polarity and ability to form hydrogen bonds. Acidified water further enhanced stability. Methanol and ethanol exhibited moderate solubility but may cause some degradation. Acetone, being less polar, failed to dissolve betalains effectively, likely due to insufficient hydrogen bonding. These findings confirm that betalains are best solubilized in polar, aqueous environments, with acidified water being the most suitable solvent for maintaining both solubility and stability.



Fig.3 Results of microwave extraction of betalain

Table-2: The result of microwave extraction of betalain are as follows-

Time for keeping the paste of beet in micro-oven (mins)	Absorbance	Mean absorbance
5 (for crude sample)	0.767	0.767
	0.760	
	0.775	
9 (for crude sample)	0.823	0.823
	0.821	
	0.826	
15 (for 100 times diluted sample)	0.121	0.123
	0.125	
	0.124	
30 (for 100 times diluted sample)	0.131	0.133
	0.133	
	0.136	

As microwave exposure time increases, the extraction yield of betalain also increases, making it an effective non-conventional extraction method. In contrast, conventional extraction techniques such as boiling lead to significant degradation of betalain. This degradation occurs because boiling involves direct heat application, which adversely affects the stability of natural pigments. On the other hand, microwave-assisted extraction (MAE) utilizes electromagnetic energy, which is converted into thermal energy, allowing for a more controlled and efficient extraction process. Therefore, non-conventional techniques like MAE are more effective than traditional methods in preserving and enhancing betalain extraction.

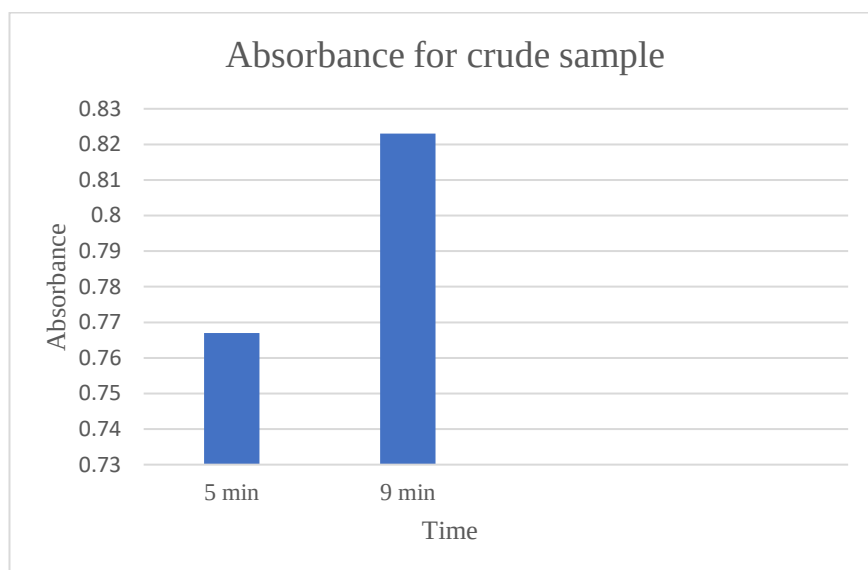


Fig.4

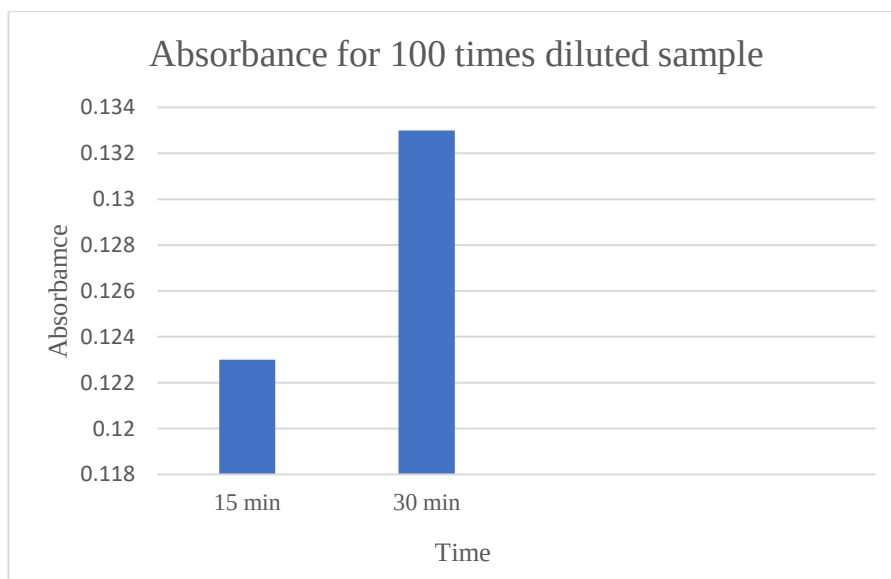


Fig.5

Table-3: Testing results of the pasta sample (contains millet and wheat flour both):

Chemical composition (g/100 g)	
Moisture	13.6% [in wet basis] 17.4% [in dry basis]
Ash	0.72%
Crude fat	5.62%
Total sugar	7.99 gm of sucrose equivalent
Polyphenol	66.75 mg GAE

The moisture content of the pasta was found to be 13.6% (wet basis) and 17.4% (dry basis). Moisture content is a critical factor influencing the shelf life and texture of pasta products. Previous studies suggest that pasta with a moisture content above 12% is more susceptible to microbial spoilage ^[21]. However, high moisture content also contributes to the softness and palatability of fresh pasta ^[22].

The ash content was 0.72%, indicating the presence of essential minerals in the pasta. This is consistent with findings by Manthey et al. (2004) ^[23], who reported similar ash content in whole-grain pasta formulations. The crude fat content was 5.62%, which is relatively higher than conventional wheat-based pasta, possibly due to the inclusion of millet. Millets are known for their higher lipid content compared to wheat, contributing to improved energy density and sensory properties ^[24]. The total sugar content, expressed as sucrose equivalent, was 7.99 g/100 g. This value is within the range reported for composite pasta formulations containing cereals with moderate starch hydrolysis ^[25]. The sugar content influences the Maillard reaction during cooking, which can enhance the color and flavor profile of the pasta. The polyphenol content was recorded as 66.75 mg GAE (Gallic Acid Equivalent), highlighting the presence of bioactive compounds. Polyphenols are beneficial antioxidants that contribute to the nutritional quality of millet-based products. Studies have shown that polyphenol-rich diets can help reduce oxidative stress and improve metabolic health ^[26]. The presence of millet in the pasta formulation is likely responsible for this enhanced polyphenol content, making it a functional food product.

Conclusion:

This study showcases the successful extraction of betalains from beetroot using solvent extraction and microwave-assisted extraction (MAE), with distilled water proving to be the most effective solvent. MAE emerged as a superior technique, preserving pigment stability, and minimizing thermal degradation. Incorporating betalain-rich beetroot extract into millet-based pasta enhanced both its nutritional and functional properties. The pasta's balanced moisture content ensured a desirable

texture, while its rich polyphenol content (66.75 mg GAE/100 g) highlighted its antioxidant potential. Millet contributed to its energy density, mineral content, and unique flavor, making it a wholesome alternative to conventional pasta. This research underscores the potential of innovative extraction techniques and nutrient-rich formulations in developing functional foods. By blending tradition with modern technology, this beetroot-millet pasta not only offers a vibrant hue and enhanced flavor but also delivers significant health benefits. Future studies should refine storage conditions and sensory appeal to maximize consumer acceptance and product longevity.

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Utilisation of Lactobacillus Strains for Prebiotic Food Materials

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Abstract:

Different oil seed meals like sesame, soybean and linseed have been identified as excellent prebiotic material which may be used for the preparation of various food products with medicinal importance. These fibre rich meals are also high in protein and loaded with polyphenols. In the present study, three *Lactobacillus* Strains e.g. *Lactobacillus bulgaricus* NCIM 2056, *Lactobacillus acidophilus* NCIM 2285, *Lactobacillus brevis* MTCC 4460 have been exploited for their growth on these seed meals as *Lactobacillus* bacteria plays an important role in improving human gut health. Based on prebiotic activity score, sesame and soybean seed meals have been identified as better prebiotic food material compared to linseed oil meals. Biscuits nowadays are most popularly used for fortification and recognised as an efficient vehicle for nutrient incorporation. Moreover, high consumer acceptance has led them to receive more attention for formulating functional foods or nutraceuticals. Use of these seed meals for making prebiotics biscuits will serve as a cheap source of prebiotics along with will open up a new dimension of revenue earning for the oil industries.

Keywords: lactobacillus; seed meals; prebiotics; soybean; sesame

1. INTRODUCTION

Use of probiotics and prebiotics in the treatment of various gut disorders has open up a new dimension in the field of alternative medicines. The WHO defines probiotics as live microorganisms which, when administered in adequate amounts, confer a health benefit on the host. Common probiotics are bacteria belonging to the genera *Bifidobacterium* and *Lactobacillus*. On the other hand selective compounds promoting growth of probiotic bacteria in host's intestine are called prebiotics. The concept of prebiotics was first introduced in 1995, and they have gained attention in industry and academia due to their potential health benefits. Basically prebiotics are nondigestible food ingredients, which remains undigested in the upper gastrointestinal tract and preferentially promotes the growth of probiotic microorganisms in the large intestine. To date, the greatest scientific interest was focused on the nutritional and health benefits of oligofructose and inulin as prebiotics. Bacterial growth data showed that inulin and oligofructose exerts stimulatory effect on *Bifidobacterium* and *Lactobacillus*, whilst maintaining populations of potential pathogens (*Escherichia coli*, *Clostridium*) at

relatively low levels. A symbiotic is a combination of probiotics and prebiotics, which has not been extensively studied. Some authors suggest that their individual advantages might be additive or even synergistic.

Though oligofructose and inulin are established prebiotics, still there exists a vast scope of utilizing several other compounds of plant and microbial origin as prebiotic food. The part of the edible seed remains after extraction of oil is known as the seed meals. The seed meal with low carbohydrate content but rich in fibre can serve as potential prebiotic material.

The study aimed at finding the prebiotic activity score of different seed meal with an objective of producing protein-probiotic food for human consumption. The objective behind the present study is to use the sesame meal for different food preparations like biscuits, bread, laxative powder etc. enriched with prebiotics.

2. Methods

2.1. Microorganisms: Lactobacillus strains: one isolated from curd (Indian Dahi) purchased from local market, one isolated from commercial probiotic available in market. Other three lactobacillus strains i.e. Lactobacillus plantrum, Lactobacillus brevis, Lactobacillus plantrum were purchased from IMTECH, Chandigarh.

2.2. Oil Seed Meals: Oil seed meals i.e. Sesame used for the study were collected from G.M. Oil Mills, Mallarhat.

2.3. Culture media: MRS agar, MRS agar was prepared by adding 1.5% agar agar in MRS broth and sterilized.

2.4. Prebiotic Screening: The ability of the lactobacillus to utilize the substrates i.e. seed meals were examined in MRS basal medium without Dextrose, peptone, beef extract along with 2% of the oil seed meals.

1ml culture of each strain grown on MRS broth for 24 hours was added to 100 ml of

- i. MRS broth (control)
- ii. MRS broth without glucose and nitrogen source supplemented with 2% of oil seed meals.

After 24 hours of shaking 0.1ml from each flask was diluted and spread onto the MRS agar plates to give approximately 30-300 colonies. The plates were incubated for 24 hours at 37°C-40°C.

2.5. Determination of prebiotic activity score: By definition, substrate with a high prebiotic activity score support good growth of the probiotic bacteria, with cell densities (cfu/ml) comparable with that when grown on glucose (Sangwan et al. 2014).

Prebiotic activity score (Huebner et al. 2007) =

$$\frac{[\text{probiotic } \log_{\frac{\text{cfu}}{\text{ml}}} \text{ on the prebiotic at 24 hr} - \text{probiotic } \log_{\frac{\text{cfu}}{\text{ml}}} \text{ on the prebiotic at 0 hr}]}{[\text{probiotic } \log_{\frac{\text{cfu}}{\text{ml}}} \text{ on glucose at 24 hr} - \text{probiotic } \log_{\frac{\text{cfu}}{\text{ml}}} \text{ on glucose at 0 hr}]} -$$

$$\frac{[\text{enteric } \log_{\frac{\text{cfu}}{\text{ml}}} \text{ on the prebiotic at 24 hr} - \text{enteric } \log_{\frac{\text{cfu}}{\text{ml}}} \text{ on the prebiotic at 0 hr}]}{[\text{enteric } \log_{\frac{\text{cfu}}{\text{ml}}} \text{ on glucose at 24 hr} - \text{enteric } \log_{\frac{\text{cfu}}{\text{ml}}} \text{ on glucose at 0 hr}]}$$

3. Result and Discussions

Growth of prebiotic bacteria i.e. *Lactobacillus bulgaricus*, *Lactobacillus acidophilus* and *Lactobacillus brevis* were examined on sesame, soybean and linseed oil seed meal for 24 hrs and comparative study of their growth is shown in Table 2. It has been observed that *Lactobacillus bulgaricus* and *Lactobacillus acidophilus* showed higher growth (cfu/ml) in soybean and linseed seed meal whereas *Lactobacillus brevis* showed comparatively poor growth in all the three seed meals. Their growth was also compared where glucose was used as the carbon source and in all the cases, growth in seed meals were higher than their respective growth in glucose medium.

Table 1: Comparative analysis of growth of probiotic bacteria on seed meals after 24 hours

Probiotic bacteria	Glucose (cfu/ml)	Soybean (cfu/ml)	Sesame (cfu/ml)	Linseed (cfu/ml)
<i>Lactobacillus bulgaricus</i>	220 × 10 ⁵	255 × 10 ⁵	235 × 10 ⁵	255 × 10 ⁵
<i>Lactobacillus acidophilus</i>	187 × 10 ⁵	234 × 10 ⁵	204 × 10 ⁵	260 × 10 ⁵
<i>Lactobacillus brevis</i>	178 × 10 ⁵	200 × 10 ⁵	205 × 10 ⁵	205 × 10 ⁵

cfu/ml: Colony forming units/ml of growth medium

Prebiotic Score

It has been observed that prebiotic activity score for sesame and soybean seed meal is higher than linseed seed meals and almost at par with the popular prebiotic Inulin.

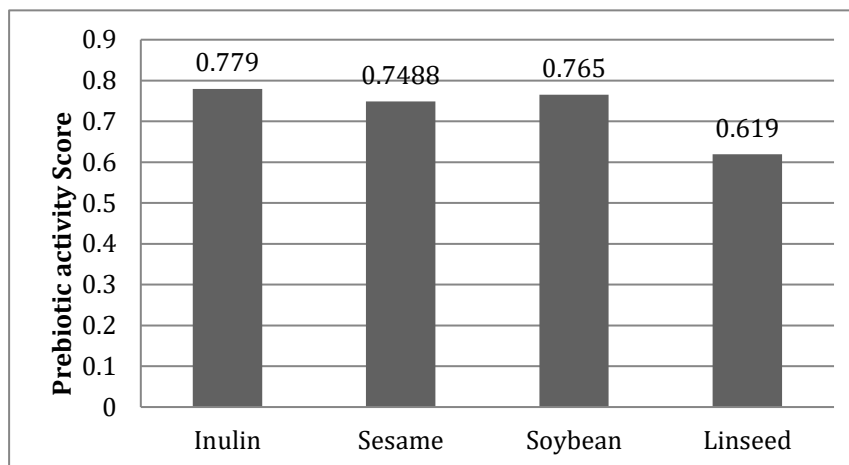


Fig. 1: Prebiotic activity score for seed meals

CONCLUSION

India being one of largest producer of oil seeds supports a large number of edible oil industries which in turn produces a huge amount of seed meal after extraction of oil. Use of these seed meals for making prebiotics foods like biscuits will serve as a cheap source of prebiotics along with will open up a new dimension of revenue earning for the oil industries. These products will serve as a super food as they are protein and fiber rich and loaded with antioxidants. Future scope remains for development of synbiotic biscuits or synbiotic food products; which contains both prebiotics and probiotics.

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Impact of Climate Change on Fisheries and Traditional Cuisines across West Bengal: A Review

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Introduction:

“*Macher bhat bangali*” is a self explanatory phrase to explain the significance of fish in the preparation of traditional food dishes and ethnic culture of Bengal. Previous literatures and records show that due to various political and landmass division, a huge number of people were rehabilitated and moved from Bangladesh to West Bengal and vice-versa which results in an intermixing of culture, traditions and food habits across Bengal during the past decades. Various rivers and water bodies of West Bengal play an important role for the availability of different varieties of fish like Rohu, Katla, Bhetki, Promphret, Magur, Jiol fish, Prawns, Pabda and others which have been used for the preparation of various types of traditional cuisines like Paturi, Bhapa, Malaikari, Doi katla etc across different districts of Bengal. Recently Bengalis have become very fond of continental dishes like Chinese, Thai etc that has significantly impacted the previous traditional fish dishes and their availabilities across Bengal. This marked change in the Bengali tradition and culture is explained in terms of two major factors: one is the adaptation of western culture due to the foreign intervention and the other being the unavailability of various fish for the preparation of traditional Bengali dishes. It has been observed that most of the fish like Chela, Noina, Kalbush, Ganga, Magur, Singhi etc. have become rarely available or very costly when available in the fish markets. In addition to this, few other reasons such as climate change due to global warming, loss of water bodies due to urbanization, water pollution etc also have profound impacts on the availability of the traditional Bengal cuisines based on fish items.

This paper aims to highlight how the climate pattern change has impacted the availability of various traditional fish [1] and different fish-dishes [2] across West Bengal. It mainly focuses on the anthropogenic activities [3] that result in significant environmental hazards like global warming [4], which in turn, influence the diverse climatic pattern among the districts of West Bengal. Our attempt is to find out possible solutions that may potentially minimize these effects and offer suitable approach to save the diverse aquatic species and manage our traditional food resources.

Change in weather patterns and its impact on fish diversity

The burning of fossil fuels and deforestation are increasing the concentration of carbon dioxide and other greenhouse gases in the atmosphere which is playing a pivotal role in the ever increasing global warming and climate change across the globe. On the other hand, climate pattern and its variations significantly bring in a large-scale change in the biosphere.

Like every other animals in the biosphere, fish also have their own specific breeding seasons. Nowadays, the shifting of wind and precipitation patterns resulting from extreme change in climate across Bengal has severely impacted the reproduction and ease of availability of traditional fish in commercial fish markets [5, 6, 7]. Moreover, the urbanization and uncontrolled population growth along with a short rainfall issue [8,9] have completely changed the present agriculture as well as the fishery in a significant way across Bengal. To fulfil the demand of ever increasing population and overcome the various challenges faced by the farmers, modern technology has been implemented in the field of pisciculture [9] to boost up the fish production, like *Chingri project* at Sandesh Khali in West Bengal although the quality of the fish is seen to be reduced. Moreover, this technology is limited to a few hybrid species [9].

On the other hand, the advent of various types of nitrogenous chemicals like Di-ammonium Phosphate (DAP), Urea, super phosphate and other types of pesticides and insecticides in the agricultural land consequently results in prolonged eutrophication and water body[10] degradation. The enhanced BOD (biological oxygen demand) thus also affects the production of organic Rohu, Katla [10], Charapona etc and that is why artificial production in the fish hatcheries has given emphasized [10]. In addition to these, as per the reports published by IMD Kolkata, number of floods has increased over past few years due to global warming and melting of the polar ice caps [11] and tropical cyclones like Amphan, Phani, Ramil etc. have caused the submergence of various ponds, saltwater bodies, as well as estuaries [12] in the southern part of Bengal like Sundarbans and the southern part of Bangladesh. Many salt water fishes like hilsha, promphret, koi bhola etc. generally come to the fresh water bodies during breeding season to reproduce and lay eggs but due to the cyclones [13] and floods, they are not able to reproduce, which in turn results in a significant diversity losses and species extinction[13] across Bengal.

Due to the development of cities in the outskirts of Kolkata like North and South 24 Parganas , Joka, small ponds and lakes are getting transformed into the ideal place of construction where various wastes are disposed [14]. As a result, the pond or lake ecosystems are getting destroyed and consequently the production of small fresh water fishes like Koi, Singhi, Magur, Bhetki [16,17] etc. are severely getting hampered.

Government initiatives and preventive measures:

In order to facilitate and foster the fish production minimizing pollution and several environmental hazards, the government also has adopted several plans and attempted to execute those for the benefit of the country since last few decades. The government of India approved Ganga and Yamuna action plan in 1986 to prevent water pollution [18] across India. ICAR-Central Institute of Brackish water Aquaculture (CIBA) at Kakdwip [19] West Bengal is working on captive breeding of hilsa. In addition to this, CIBA is also attempting to standardize captive breeding in freshwaters, develop formulated feed for hilsa and set up experimental farms rearing of hilsa in brackish [20, 21, 22] water ponds. Besides constructing several sanctuaries and reserved water bodies to conserve endangered aquatic species, aquaponic agriculture [23] also has been adopted to balance the lost land resources and rejuvenate the growth of various traditional fish to conserve the biodiversity.

What types of cuisine are lost from our traditional culture:

There were various types of dishes [23-33] cooked since the time of our ancestors but now they are extinct from the market. People have almost forgotten the recipes of them as well today. Some of the famous recipes which were made earlier such as: -

“Noina macher jhal” (it is a spicy cuisine where lots of spices are used for cooking)

“Tangra macher Tok” (a type of Bengali cuisine where tamarind is used for cooking food.

“Singhi macher bati chochori” (very famous for its simplicity and high healing power for gastric ulcer patients)

“Chingrir macher tobga” (it is a very delicious recipe where the prawns are cooked along with pulses like MOONG OR MASUR)

“Chanda macher Tok” (here also tamarind is used for making the cuisine with fish)

Many of these forms of dishes are still served in pure Bengali families but the number is too low now.

CONCLUSION

The local food practice of a particular area depends on the type of climatic condition prevailed there. West Bengal has tropical monsoon type of climate, where the level of humidity is too high in comparison to the other parts of India. Rice is consumed as a staple diet. Fish comprises of a huge quantity of protein and protein is a major contributor in the BMR of body.

In all the Bengali cuisine culture and traditions is affected due to the extinction of various types of freshwaters as well as salty fishes including hilsha fishes which are imported from Bangladesh during monsoons. This is mainly due to climatic changes influenced by huge rainfall and sometimes due to seasonal storms (like, kal Baisakhi) along with the tropical cyclones and drought in places of Purulia and Bankura. The huge variation in temperature (varies from extremely hot during summers, 40-45°C to very low as 6°-7°C during winters) can also affect the fish production.

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Enhancement of Shelf Life and Quality of Food Products with Bio-edible Films Incorporating Sesame Protein and Fenugreek Seed Mucilage

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Abstract:

Growing demand for sustainable alternatives to conventional packaging has prompted great interest in biodegradable edible films. This study describes the formulation of an innovative edible film based on sesame protein isolate (SPI), fenugreek seed mucilage (FSM), and glycerol as a plasticizer, as well as its properties. The goal is to evaluate its mechanical strength, barrier effectiveness, thermal stability, and structural characteristics for potential use in food packaging. Sesame protein isolate, derived from sesame seeds, provides strong film-forming capabilities due to its high protein content. Fenugreek seed mucilage, a natural polysaccharide, enhances the film's integrity with its emulsifying and thickening properties. Glycerol is used as a plasticizer to lend flexibility and prevent brittle nature. The SPI and FSM were dissolved in water in different ratios and mixed well with glycerol to form film-forming solutions. The mixed solutions were cast onto the flat surface for drying to obtain uniform films. Testing revealed that adding FSM improved the film's strength and flexibility. Increasing glycerol concentration reduced tensile strength but enhanced elongation at break, making the film more pliable. The films also exhibited low water vapor permeability, enhancing moisture resistance, while maintaining moderate solubility, supporting biodegradability. Thermal analysis showed good stability, making them suitable for food storage. Overall, this study highlights the potential of SPI-FSM-based edible films as an eco-friendly alternative to synthetic packaging, offering durability, flexibility, and sustainability for food preservation.

Keywords:

Sesame Protein Isolate (SPI); Fenugreek Seed Mucilage (FSM); Biodegradable; Flexibility

1. Introduction:

Edible films are biodegradable, lightweight coatings made of food ingredients to enhance the shelf life of food, safety, and sustainable packaging. In recent informative years, there has been a gradually gaining interest in making edible films from agricultural by-products, particularly with the use of hydrocolloids-the gel-solubilizing proteins or polysaccharides. Such compounds reinforce the structural strength of food surfaces, offer resistance to cracking, and generally present their hydrophobicity [1]. Among the natural hydrocolloids, mucilage is the most widely used edible coating. This man-made polysaccharide and protein compound forms a dense, cohesive network that makes mucilage suitable for film formation [2]. In water, mucilage causes a thick, viscous solution

which gives it excellent film-forming properties. Mucilage-based emulsions are new approaches to replace synthetic plastic packaging and have the added bonus of biodegradability and growing demand worldwide for solutions for sustainable food preservation.

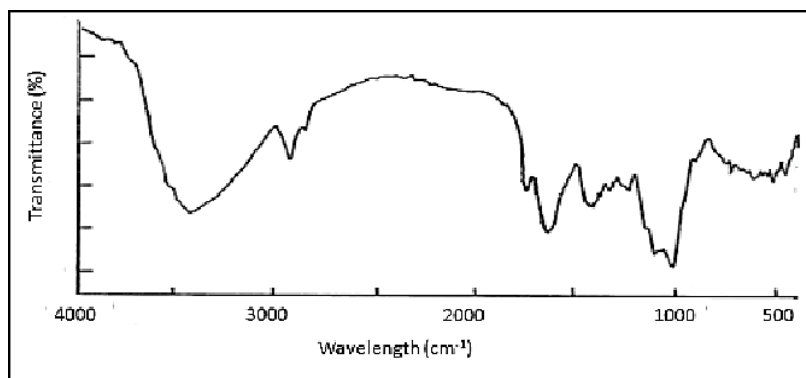


Fig.1: FTIR Spectra of Isolated Mucilage from Fenugreek (*Trigonella foenum-graecum* L.) seeds [2]

A valuable source of a mucilage is fenugreek (*Trigonella foenum-graecum* L.), a herbaceous legume indigenous to Western Asia. Over time, the cultivation of fenugreek has spread to Europe, Western Asia, Southeast Asia, and the Mediterranean among other regions [3]. For centuries, fenugreek has been used both as a food ingredient and as a medicinal substance. Fenugreek seeds were actually first recognized for their new preservative qualities, increasing their documented use in pickles, chutneys, and other preserved foods. Rich in bioactive compounds, fenugreek seeds have been widely used in traditional Indian and Chinese medicine [4]. They are known for their treatment of digestive problems, chronic cough, diabetes, and inflammation. Further, fenugreek is famous for its ability to increase the lactation of women after giving birth. The mucilage in fenugreek further helps in digestion by promoting peristalsis, thus Najarian nutrition and health.

Another oilseed crop important for extensive applications is sesame (*Sesamum indicum* L.). Sesame is probably indigenous to ancient Pakistan and is among the oldest cultivated oil crops [5]. Due to its climatic adaptability, the countries which produce it in considerable quantity include India, Sudan, Myanmar, and China. Sesame seeds are known for their rich nutty flavor and excellent nutritional value [6]. They are a major source of healthy oils, protein, and minerals. Sesame protein is a complete protein since it contains an optimal balance of essential amino acids and hence is a nutritious ingredient in food preparations [7]. Given the diversified applications, sesame remains a critical crop in global food production and nutrition.

2. Techniques applied for extraction of Protein from Sesame Seed and Production of Edible film

2.1) Extraction of sesame protein

Sesame seeds are oil rich and protein rich. In sesame oil industry, oil is extracted using organic solvents or mechanical pressing and sesame meal is left as by-product. This meal can be whole, dehulled, defatted or both dehulled and defatted. Dehulling increases protein content and digestibility by reducing fiber and oxalic acid. Various methods like alkaline or salt extraction and isoelectric precipitation are used to isolate sesame proteins [8]. Defatted sesame flour gives protein concentrates up to 95% protein and is a valuable ingredient in food industry. Aqueous extraction process (AEP) has been considered as a good option for simultaneous extraction of oil and protein [9]. Since AEP avoids damage to the oil and proteins of the seed and allows production of food-grade instead of feed-grade protein products

2.2) Retrieval of fenugreek seeds mucilage

Fenugreek seed mucilage is extracted by first washing and soaking the seeds in distilled water for several hours to ensure complete swelling. The swollen seeds are then boiled to release mucilage into the water [10]. After cooling, the slurry is filtered to separate the liquid extract from seed residues. The clear filtrate is concentrated by gentle heating, and acetone is gradually added with constant stirring to precipitate the mucilage [10]. The resulting precipitate is collected by filtration, washed with acetone to remove impurities, and dried at a controlled temperature.

2.3) Formulation of the composite edible film

Edible films from biopolymers such as protein and mucilage can be produced using two main methods: casting (wet method) and extrusion (dry method). The casting method hinges on how well protein–mucilage and additives dissolve, while the extrusion method banks on thermo-plasticity, gelatinization, and phase changes[11]. Due to its lower cost, the casting method, also called solvent casting, is widely preferred. This process involves three key steps: (i) dissolving starch–mucilage in a suitable solvent, (ii) pouring the solution into molds to form a film, and (iii) drying the casted solution. The synthesis of starch–mucilage films follows this structured approach [12].

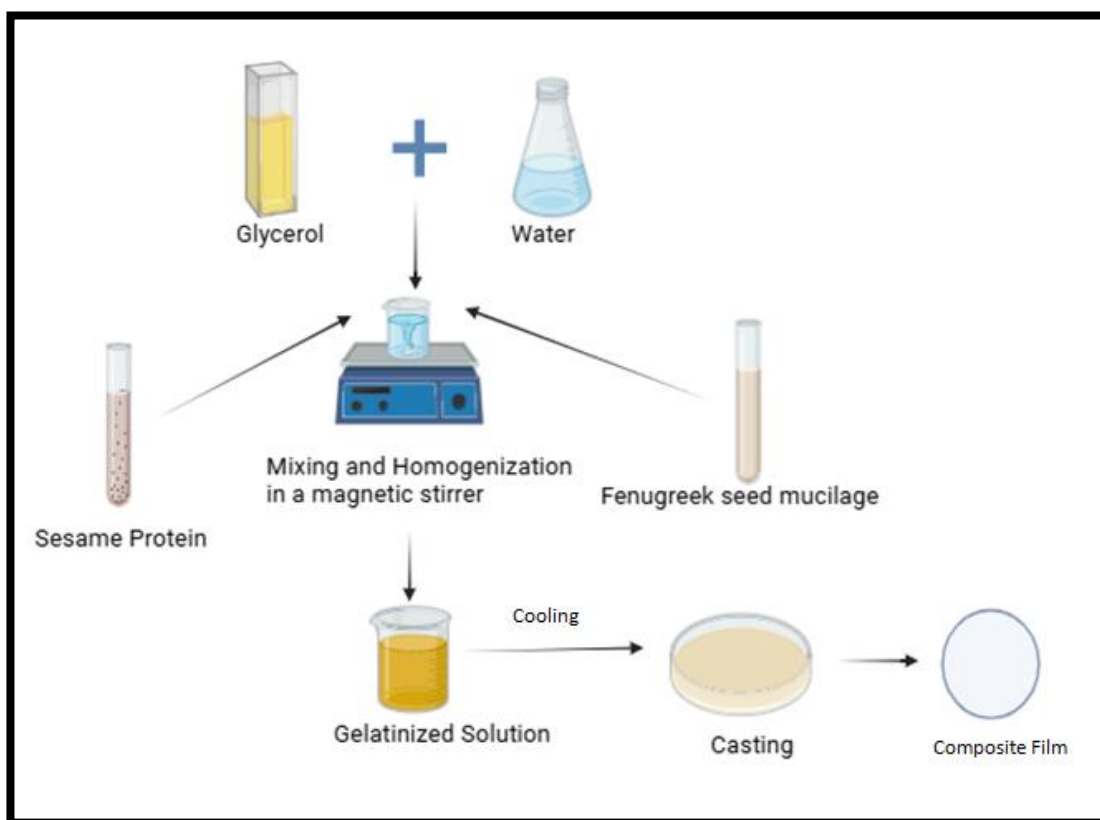


Fig.2: Process flowchart depicting the formation of the composite edible film

3. Evaluation of Physico-Chemical Properties of Edible Film

3.1) Tensile strength

Tensile strength plays a key role in the mechanical properties of protein–mucilage films. This makes the casting method the top pick to get high mechanical performance. Strong tensile strength with little stretching ensures better structural integrity for food packaging during storage and shipping [13]. Adding sesame protein to mucilage lowers tensile strength. Yet, research hints that mixing proteins with mucilage often boosts film strength. Adding sesame protein and fenugreek seed mucilage improved the tensile properties. It increased strength from 7.35 to 8.70 MPa at different levels. This boost comes from hydrogen bonding. It strengthens the polymer network while cutting down on elasticity [14].

3.2) Water vapour permeability

WVTR and water solubility are some of the key parameters used in film evaluation to determine how the film reacts to moisture [15]. The WVTR tester is an instrument used for determining water solubility. Results have indicated that sesame protein and mucilage films are very soluble in water, having solubility in the range of 41.11-62.74%. Thus, such films may be applied as edible coatings or films. The incorporation of proteins into biopolymer blends enhanced the physicochemical and

mechanical properties of films. For example, the addition of sesame protein to fenugreek mucilage significantly increased the viscosity of the latter, enhancing the structure of the film and its functionality in food packaging [16].

3.3) Transparency and thickness of the film

Transparency is an important characteristic of packaging materials, especially when the visibility of a product is a determining factor in consumer purchasing [17]. It is the amount of light that can pass through a material, which affects its appearance. The addition of mucilage to protein changes the transparency of films drastically. Transparency levels are reported to be $42.6 \pm 0.57 \mu\text{m}$ for mucilage-based films and $45.6 \pm 0.57 \mu\text{m}$ for the control. The film thickness also decreases with increasing protein concentration in fenugreek seed mucilage, but higher concentrations do not significantly change the overall thickness [18]. This shows that the structure of the film is well-integrated, thereby pointing to strong composite formation between protein and mucilage for efficient packaging solutions.

3.4) Antimicrobial Activity and Bio-Degradation of Film

The base materials used are natural gums such as mucilage. These materials are inherently environmentally friendly and biocompatible, but they have limited industrial use due to lower water solubility and distinct flavors. Composite technology helps increase their solubility and stability [19]. The antimicrobial effectiveness of binary films depends on the type of agents used; natural agents are safer and easier to access than synthetic agents. Essential oils have been added to protein–mucilage films to enhance their antimicrobial properties [20]. The films resist both Gram-positive and Gram-negative bacteria effectively, which helps to preserve food. They also provide superior mechanical properties that include moisture and oxygen barriers, stiffness, flexibility, and have high tensile strength, which enhances the overall safety of food.

4. Conclusion

In recent years, the environmental impact of plastic waste has endangered the human environment, thus necessitating searching for sustainable alternatives to petroleum-based plastics. One of such alternatives with the most potential is the use of plant-derived biopolymers, which saw a renaissance in eco-friendliness spiraled along functionality in packaging applications. Such trends bring attention to an increasing demand for biodegradable, non-toxic, biocompatible polymer films as the awareness of plastic pollution and adverse effects on human health rises now more than ever. Of particular importance is mucilage known for its biodegradability, and abundance, with interest for this reason for food packing. Besides, one of the challenges of using mucilage alone is its weak barrier properties, hence food cannot be properly protected from moisture and gases. Further, researchers have been addressing these issues by attempting to enhance the properties of edible films by altering the balance between hydrophilic and hydrophobic bio-molecules. While chemical modifications may improve starch functionality, they often introduce chemical residues that may raise safety concerns when they direct contact food. Alternatively, the combination of different plant-based polymers has shown promise in the mechanical strength and barrier properties of biodegradable packaging films. Sometimes these polymeric blends may highly protect food and simultaneously pursue sustainability.

One of the most important emerging areas of work is that of plant-derived mucilage, which has not yet received extensive industrial development but holds a great potential for biodegradable packing materials. Because of the peculiar nature of mucilage, it can form a stable polymeric network for protein. The developed network enhances the mechanical strength and durability of the packing film. Mucilage based materials could become the key for developing more efficient and eco-friendly food packaging solutions. Despite advancements made in these fields, biodegradable packaging materials have yet to make any significant inroads in terms of technology owing to certain challenges. Biodegradable packaging materials are suffering for their economic feasibility, being incapable of reaching large enough production scales to effect policy changes, and being therefore less relevant to industry, one hears from various stakeholders on different media. Traditional plastic packaging flourishes as it is cheap and well-understood with respect to its production processes. However, while opinions have begun to change and tighter plastic-waste regulations are developed, new cost-effective high-performance biodegradable materials that guarantee that plastic-substitute production maintains its availability into current supply chains must be developed. New biopolymer formulations, aimed at improved mechanical strength, greater flexibility and modified barrier functions where product safety is not challenged, represent the next step of innovation that scientists and manufacturers will have to pursue. Public awareness and supportive policies are other factors that can influence the transition of the business and consumer towards adopting more sustainable alternative packaging solutions.

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Breast Cancer and PCOD: Breaking Down the Complex Relationship

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Abstract

Polycystic Ovary Syndrome (PCOD) is a common endocrine disorder affecting 6-10% of women of reproductive age, characterized by hyperandrogenism, irregular menstruation, and ovarian cysts. These symptoms, especially in adolescents, can impact mental health and self-esteem. PCOD is associated with hormonal imbalances, including elevated androgen and luteinizing hormone levels, which disrupt ovulation and fertility. The potential association between PCOD and breast cancer has been a subject of growing interest due to overlapping risk factors, such as hyperandrogenism, hyperinsulinemia, obesity, and prolonged estrogen exposure. However, evidence regarding this relationship remains inconclusive and conflicting. This review highlights conflicting findings regarding PCOD and breast cancer, emphasizing limitations in study designs, small sample sizes, and methodological inconsistencies. Interventions like weight management, physical activity, and insulin-sensitizing medications may mitigate future risks of cancer and cardiovascular disease. Further research is essential to elucidate the molecular mechanisms linking PCOD to hormone-dependent cancers and to refine therapeutic strategies aimed at reducing long-term health risks for individuals with PCOD.

Keywords: Polycystic Ovarian Syndrome, Breast cancer, Hormone imbalance, Irregular menstruation, Obesity

Introduction

PCOD

PCOD, also known as Polycystic Ovary Syndrome (PCOD) when symptoms persist beyond adolescence, is an endocrine disorder that affects 6-10% of women of reproductive age globally (Goodarzi et al., 2011). Characterized by hyperandrogenism (high levels of male hormones), irregular menstrual cycles, and the presence of multiple ovarian cysts, PCOD can lead to various symptoms, including acne, hirsutism, and infertility. In adolescents, these symptoms can be particularly distressing and can impact self-esteem and mental health (Rosenfield & Ehrmann, 2016).

While the exact cause of PCOD is unknown, it is believed to involve a complex interplay between genetic, hormonal, and environmental factors. Obesity is a well-established contributor to PCOD, as excess adipose tissue exacerbates insulin resistance and hormonal imbalance, both of which are central to PCOD pathology.

Polycystic ovary syndrome (PCOS) affects 5%–8% of women of reproductive age (Shobeiri F et al., 2016). PCOS was thought to represent a reproductive dysfunction but is now recognized as part of a metabolic disorder, associated with type 2 diabetes mellitus, insulin resistance and metabolic syndrome, all recognized as risk factors for cardiovascular disease (Barry JA et al., 2014 & Gottschau Met al., 2015). The metabolic and hormonal environment changes among these women and may increase the risk of some types of cancers (M. Gottschau *et al.*, 2015). The response of breast tissue to androgens is controversial, as some reports make it clear that androgens promote the risk of breast cancer, while others display that they have a protective role for hormone-dependent breast carcinomas [16]. Fibrocystic breast changes are frequently observed in women between the ages of 20 and 50 (Kunicki M et al., 2021 & Chen Y-Y et al., 2018). Symptoms like nipple pain and discharge can negatively impact the quality of life of premenopausal women. Thyroid disorders are among the most common endocrine conditions and are more prevalent in women than in men. While the exact cause of benign breast disorders, particularly fibrocystic changes, remains unclear, studies have shown a link between these changes and endocrine disorders involving reduced thyroid function. Numerous studies have been conducted worldwide to explore the relationship between PCOS, thyroid disorders, and fibrocystic breast changes in women.

The Role of Hormonal Imbalance in PCOD

A key feature of PCOD is hyperandrogenism, or elevated levels of male hormones such as testosterone, which disrupts the normal menstrual cycle and ovulatory process. In adolescence, these hormonal imbalances can cause anovulation (lack of ovulation), making conception difficult when the individual eventually tries to become pregnant (Rosenfield et al., 2016). In addition, women with PCOD often have elevated levels of luteinizing hormone (LH) relative to follicle-stimulating hormone (FSH), leading to abnormal follicular development in the ovaries. This hormonal imbalance has long-term implications on reproductive health, as it impairs the ability of the ovaries to produce healthy eggs (Goodarzi et al., 2011).

Impact of Adolescent PCOD on Fertility and Pregnancy

Adolescent PCOD has been linked to a higher risk of infertility and pregnancy complications. The anovulatory cycles and hormonal imbalances characteristic of PCOD frequently result in difficulties with conception, making assisted reproductive techniques (ART) such as in vitro fertilization (IVF) more commonly required for women with PCOD (Palomba et al., 2015). Furthermore, research has shown that women with PCOD who become pregnant are more susceptible to complications such as miscarriage, gestational diabetes, preeclampsia, and preterm birth (Boomsma et al., 2006).

Breast cancer

In the case of correlation between breast cancer and PCOS proofs are also not convincing, and research results even show reverse correlation (Gammon MD et al., 1991 & Anderson KE et al., 1997). The basic problem underlying these studies was the fact that in the second study PCOS women accounted just for 0.94% of the study control and for 0.49% of breast cancer group, while in the first study for 1.35% of the overall study group. Another drawback of these studies was that patients reported PCOS by themselves. It seems one cannot talk of correlation between breast cancer as PCOS, just as in the case of ovarian cancer. Problems with proper evaluation of correlation between PCOS and respective factors are present in a paper showing higher mortality of PCOS patients from breast cancer compared to healthy population (Pierpoint T et al., 1998). This paper traces back medical records of patients diagnosed with PCOS in their lifetime in order to determine standardized mortality ratio (SMR). It was proved that SMR for breast cancer was 1.48 in this group, while mortality was not higher from circulation diseases at the same time. However, as soon as 2 years later the same study group released study results that did not show correlation between deaths from breast cancer and PCOS despite the same patient group. Different conclusions resulted from modified methodology of the study (Wild S et al., 2000).

Based on available literature one may draw a conclusion that correlation between adenocarcinoma of endometrium and PCOS is likely to exist. This results both from clinical trials and papers on changes of endometrium in PCOS patients. However, despite single papers that report on the link, correlation between ovarian or breast cancer and PCOS is doubtful.

Ovulation-induction medications

Clomiphene citrate can reduce oestrogen receptor activity in some tissues (Harris HR et al., 2016). A direct pro- apoptotic effect was described in breast cancer cell lines, suggesting a potential anticancer effect (Elloumi-Mseddi J et al., 2015). This may explain why some studies demonstrated a reduction in breast cancer in women who had taken clomiphene (Rossing MA et al., 1996 & Terry KL., 2006). Ovulation-induction drugs are used in PCOS for anovulatory infertility (Harris HR et al., 2016), increasing oestradiol levels, which is a mechanism associated with breast cancer risk. However, their effect on breast cancer remains uncertain. A cohort study that enrolled 12,193 women with infertility proved that clomiphene does not influence breast cancer risk. However, the authors found a non-significant increased risk in women treated with more than 12 cycles (M. Gottschau *et al.*, 2015).

In some cases, controlled ovarian hyperstimulation may be needed for in vitro fertilization (IVF), leading to temporarily elevated oestradiol levels that might affect breast cancer risk. Several studies observed conflicting results, mainly due to short follow-up periods. In a recent historical cohort study that included 19,158 women submitted to IVF treatments between 1983 and 1995, the long-term risk of breast cancer, with a median follow up of 21 years, was found not to be significantly different from that in the general population, standardized incidence ratios: 1.01 95% CI 0.93-1.09 and from the risk of a comparison group of 5950 women that started non-IVF treatments between 1980 and 1995, hazard ratios (HR): 1.01 95% CI 0.86-1.19 (van den Belt-Dusebout AW et al., 2016).

Letrozole is an aromatase inhibitor, used in PCOS anovulatory infertility. It is well tolerated, being associated with fewer side effects compared to clomiphene. In hormone-receptor-positive postmenopausal breast cancer women, letrozole is used as an adjuvant treatment, so a reduced hormonal-dependent cancer risk can be hypothesized (Harris HR et al., 2016). Considering that hyper-oestrogenism has been shown to affect breast cancer risk in BRCA 1/2 mutation carriers, a national study evaluated the risk among 2514 BRCA 1/2 germline carriers who underwent controlled ovarian hyperstimulation of IVF. This study showed no evidence of an increased breast cancer risk even among this high-risk population with ovarian stimulation, HR: 0.79 95% CI 0.46-1.36 (Derks-Smeets IAP et al., 2018). Also, controlled ovarian hyperstimulation with letrozole co-administration is a safe fertility preservation option for women with breast cancer (Rodgers RJ et al., 2017).

Epidemiologic evidence of the link between polycystic ovary syndrome and breast cancer

Based on its reproductive and metabolic repercussions, PCOS is expected to affect the risk of endometrial cancer and other oestrogen-dependent gynaecological tumours, for example breast and ovarian cancer (Fanta M et al., 2013). In addition, hyperandrogenaemia and hyperinsulinemia are independent risk factors for breast cancer and may have the main mediators of the obesity-breast cancer relationship (Gunter MJ et al., 2009). The plausible association between PCOS and breast cancer has been investigated in the last two decades due to overlap between clinical manifestations of PCOS and risk factors for breast cancer (Anderson KE et al., 1997). Examples of the mentioned previously are age at first pregnancy at older age and nulliparity. Also, obesity is a major risk factor for breast cancer not only in post-menopause but also in premenopause and is often linked with PCOS (Harris HR et al., 2016). Recently, a large prospective study reported the positive association between circulating anti-müllerian hormone (AMH) and breast cancer risk, statistically significant for hormone-dependent breast cancer (Ge Wet et al., 2018). However, it is likely that this association results from the higher prevalence of PCOS in the group with high AMH levels.

Understanding how PCOS is related to breast cancer development is very important for further clarification of hormonal aetiology among both conditions. Also, regarding the high prevalence of PCOS, the recognition of this association can lead to the development of a screening program for patients with increased breast cancer risk and to the establishment of primary interventions in order to decrease their risk.

Conclusion

Fundamental problem in estimating correlation between PCOS and tumor formation exists primarily in a limited number of reports on this problem. If research does exist, there has been either too small patient group or it has not been properly conducted from the very beginning (e.g. no control group).

This review focused on PCOS controversial association with breast cancer risk in several aspects, from epidemiological to molecular mechanisms and the influence of PCOS therapeutic approaches in breast cancer incidence. A clinical association between PCOS and breast cancer risk was reported in several studies which had several limitations and consequently did not establish a clear association. Androgen influence in breast tissue seems to be mainly due to conversion to oestrogens,

but the molecular mechanisms involving AR and PCOS need to be clarified. Up to this point, basic research suggests an influence of androgens in hormone-receptor-positive breast cancer. However, clinical research considering PCOS has already emphasized an overlapping gene with breast cancer. Further research on this area should involve large prospective studies focusing on the epidemiological risk and intervention protocols allowing conclusions about the influence of PCOS medical treatment on breast cancer pathogenesis.

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Physicochemical and Sensory Characterization of ω 3 Enriched Mayonnaise Formulated with Flax Seed Oil and Chia Seed Oil

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Abstract:

Consuming omega-3 (ω 3) fatty acids can reduce the risk of cardiovascular diseases, but their unsaturation makes them heat sensitive. Mayonnaise, an oil-in-water emulsion, is typically not heat-treated during preparation. In this study, control mayonnaise (MC) was prepared with rice bran oil (RBO), and two ω 3-rich oils, flaxseed oil (FO), and chia seed oil (CSO), were blended with RBO at a 20% (w/w) level to create mayonnaise samples designated as MFO and MCSO, respectively. The study evaluated the mayonnaise samples' physico-chemical, and sensory properties, as well as shelf-life analysis. During the 90-day storage period, the pH of all mayonnaise samples decreased, but the pH of MCSO remained satisfactory, ranging from 3.41 to 3.19. All mayonnaise samples exhibited a pseudo-plastic nature, as desired. Sensory evaluation on a 9-point hedonic scale showed acceptable results for all mayonnaise samples, with MCSO receiving the highest overall acceptance score of 8.73. The omega-6: omega-3 ratio of MFO, and MCSO was in the required range of 1-5. The extracted oil from all mayonnaises exhibited acid values <1 , which was found satisfactory. Overall, the study concluded that MCSO exhibited better physicochemical properties, and had a longer shelf life than MFO and MC.

Keywords:

Omega-3 rich mayonnaise; physicochemical properties; sensory analysis; shelf-life

INTRODUCTION

Mayonnaise, an oil-in-water (O/W) emulsion, is a popular seasoning known for its creamy texture and distinctive flavor. Typically containing 65–80% lipids [1], [2], it is made by emulsifying egg yolk and edible oil with vinegar, salt, and other seasonings. Common oils used in traditional mayonnaise include soybean, sunflower, and corn oils. The oil type significantly influences mayonnaise's texture, flavor, appearance, and shelf life. However, due to its high unsaturated fatty acid content, lipid oxidation occurs at the oil-aqueous interface during storage, affecting sensory and nutritional qualities through discoloration and toxic by-products [3].

Studies have explored oil phase modifications in mayonnaise to improve its health benefits, functionality, and oxidative stability. Rice bran oil (RBO), rich in monounsaturated fatty acids (MUFA) and antioxidants like oryzanol, tocopherol, and phytosterols [4], [5] was used in this study

to prepare control mayonnaise (MC). Additionally, flaxseed oil (FO) and chia seed oil (CSO), abundant in omega-3 ($\omega 3$) and omega-6 ($\omega 6$) fatty acids, were incorporated for their nutritional and therapeutic properties, such as anti-inflammatory and cardioprotective effects [6]. However, these oils are prone to oxidation due to their high unsaturation levels.

Unlike cooking oils, mayonnaise is not heat-treated, preventing thermal oxidation of unsaturated fatty acids. This study aimed to enhance mayonnaise by blending FO and CSO with RBO, achieving improved nutritional value and oxidative stability. Over 90 days, pH changes, rheological, sensory, and chemical properties, fatty acid profiling, and oxidative stability were evaluated.

MATERIALS AND METHODS

Preparation of Mayonnaise:

RBO, FO, CSO, eggs, vinegar, salt, and sugar were sourced from Kolkata. With modifications, mayonnaise was prepared following El-Waseif et al. (2022) [7]. Vinegar, egg yolk, sugar, salt, and RBO were used for control mayonnaise (MC) preparation. Mayonnaise was prepared using a mechanical homogenizer at $30 \pm 2^\circ\text{C}$. For omega-3 enriched mayonnaise 20% FO and 20% CSO was added to RBO for preparing MFO, and MCSO respectively.

Rheological analysis:

The rheological study of the mayonnaise samples was done using a rheometer (Brookfield DV2T), at $30 \pm 2^\circ\text{C}$ [8]. The rheological data were then fitted to Newton's and Power law models to identify the different rheological properties of the mayonnaise samples [9]. The mathematical equations of Newton's model and the Power law model are presented in equations 1 and 2 respectively.

$$\tau = \mu\gamma \quad (1)$$

$$\tau = m\gamma^n \quad (2)$$

Here, τ is shear stress (D/cm^2), γ is shear rate (1/ sec), μ is dynamic viscosity (Cp), and m and n represent flow consistency index, and flow behavior index respectively.

Analysis of pH:

The pH values of the mayonnaise samples were measured using a digital pH meter. For shelf-life analysis, the samples were stored at $30 \pm 2^\circ\text{C}$. Measurements were taken at 15-day intervals over 90 days to monitor changes in pH.

Sensory analysis:

Ten trained panelists from the Department of Food Technology at Guru Nanak Institute of Technology conducted sensory evaluations of the prepared mayonnaise samples. Using a 9-point

hedonic scale, appearance, color, flavor, texture, spreadability, mouthfeel, and overall acceptability were analyzed. On the scale, a score of 1 indicated extreme dislike, while 9 represented extreme like [10].

Extraction of lipids from mayonnaise:

The mayonnaise samples were first frozen overnight to disintegrate the emulsion. Then, they were thawed for roughly two hours at $30\pm 2^{\circ}\text{C}$. The mayonnaise was then centrifuged to separate and extract the lipid phase [11].

Fatty acid analysis:

By using gas chromatography (Agilent 6890N GC) coupled with a flame ionization detector (FID), fatty acid analysis of the oil samples used and the lipid extracted from the mayonnaise samples was performed by using the method of American Oil Chemists' Society (AOCS) Ce2-66 [12]. The fatty acid compositions of the oil extracted from mayonnaise samples were evaluated using the Agilent Technologies Chemstation series software.

Analysis of chemical and oxidative properties:

The chemical and oxidative properties of all oil samples were evaluated. The Acid Value (AV), Peroxide Value (PV), Para-Anisidine Value (p-AV), TOTOX value, and Comparison of Oxidative Stability (COX) were analyzed. AV was determined by titration [13], and the PV was determined by the iodometric titration method [14]. p-AV was analyzed by spectrophotometer [15]. The TOTOX value was determined using the oil samples' PV and p-AV [16]. Wij's method was used to calculate the IV by following the AOCS method: Cd 1c-85 [17]. COX values were calculated from C18 fatty acid [18].

RESULTS AND DISCUSSIONS

Rheological analysis:

The graphical representation of changes in shear stress and viscosity with the shear rate of the mayonnaise samples is presented in Fig 1. Table 1 presents m, and n values.

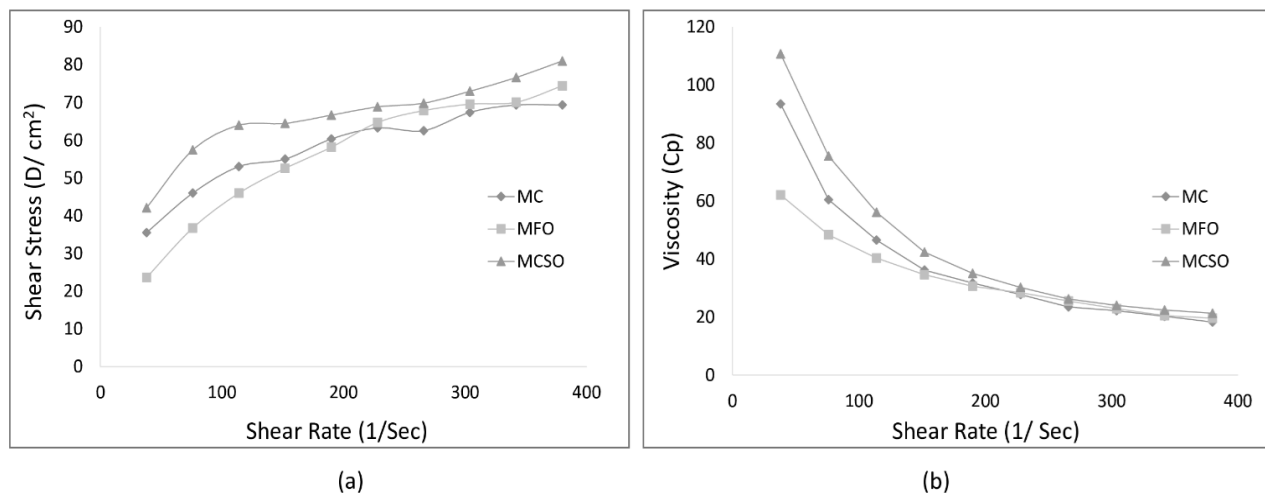


Fig 1: (a) Shear stress vs. shear rate (b) Viscosity vs. shear rate of the mayonnaise samples

Table 1: n and m values of the mayonnaise samples

Samples	Flow behavior index (n)	Consistency index (m)
MC	0.29	2.57
MFO	0.49	1.46
MCSO	0.24	2.89

Figure 1(a) illustrates the shear stress vs. shear rate curves for the mayonnaise samples, which conform to Newton's model and exhibit overall linear regression. Figure 1(b) shows that the viscosity of MCSO was higher than MC across various shear rates, while MFO exhibited smaller viscosity changes compared to MC. The Power Law model (Equation 2) was used to calculate the n and m values shown in Table 1. For all samples $n < 1$, indicating pseudoplastic behavior [9]. The consistency index of MCSO was 2.89, the highest among the samples, signifying superior structural consistency.

pH analysis:

The pH changes of the mayonnaise samples during a 90-day storage period at $30 \pm 2^\circ\text{C}$ were monitored. As storage time increased, the pH values of the samples decreased. The pH significantly impacts the stability and consistency of mayonnaise, with an acidic pH preventing microbial growth, maintaining structure, and improving stability [19]. When the pH approaches the egg yolk's isoelectric point, proteins have the least charge, providing optimal viscoelasticity and stability. Additionally, pH affects the distribution of volatile compounds (secondary oxidation products) with pro-oxidant properties [20]. MCSO's initial pH was closest to this optimal range. It was observed that MCSO had a better shelf life than the other two mayonnaises.

Sensory analysis:

Different parameters of sensory analysis, viz. appearance, color, flavor, texture, spreadability, mouthfeelness, and overall acceptability of the mayonnaise samples at a 9-point hedonic scale is shown in Fig 2.

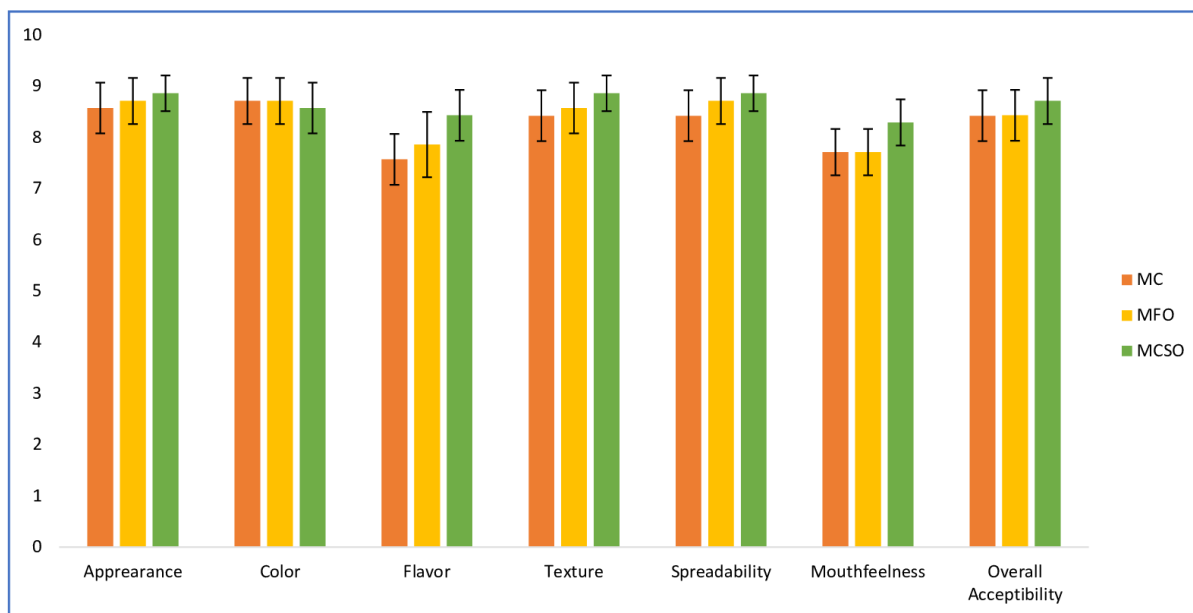


Fig 2: Sensory analysis of mayonnaise samples

It was observed in Fig 2 that the significance levels of the sensory parameters between all three mayonnaise samples were at 95%. In the 9-point hedonic scale except for the color attributes of mayonnaise samples other sensory properties of MCSO were higher than, MC and MFO. The overall acceptability of MCSO was found highest among the all prepared mayonnaise sample.

Fatty acid compositions:

The fatty acid compositions of RBO, RFO, RCSO, RBOM, RFOM, and RCSOM are presented in Table 2. The ratio of saturated fatty acid (SFA), MUFA, polyunsaturated fatty acid (PUFA), and ω_6 : ω_3 of the oil samples are also presented in Fig. 3.

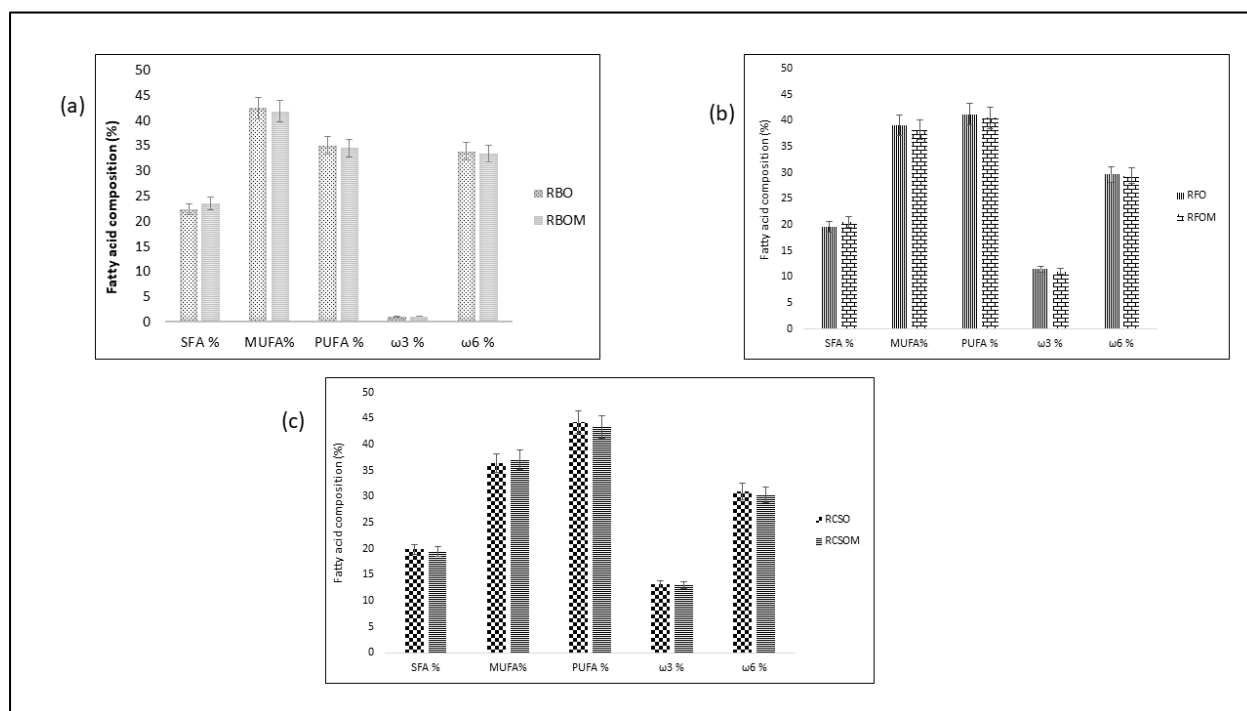


Fig. 3 (a) RBO, and RBOM, (b) RFO, and RFOM, (c) RCSO, and RCSOM

No significant difference was observed in the fatty acid compositions of each oil sample before and after extraction from the mayonnaises. RBO was rich in MUFA and ω6 fatty acids but contained less amount of ω3 which are important for their health benefits[13]. By blending FO and CSO, both rich in ω3 fatty acids, at a 20% level with RBO, the ω3 content in RFO and RCSO increased. After incorporating RFO and RCSO in mayonnaise, the ω3 percentages also increased. No significant differences in ω3 levels were found between RFO and RFOM, or RCSO and RCSOM. Diets with higher ω6:ω3 ratios promote the production of lipid mediators from ω6 fatty acids, which contribute to thrombus and atheroma formation, inflammatory diseases, cell proliferation, and excessive endocannabinoid activity [21]. Chaves et al. (2019) [22] recommended an ω6:ω3 ratio between 1 and 5 for optimal health. In this study, the ω6:ω3 ratio in RFO, RFOM, RCSO, and RCSOM fell within this healthy range, indicating that mayonnaises made from FO and CSO blended with RBO were healthier than the control.

Chemical and oxidative properties:

Fig. 4 indicates the oxidative and chemical characteristics of the oil samples before and after extraction from mayonnaise. After the oils were extracted from the mayonnaise, it was found that the AV, PV, p-AV, and TOTOX of the oils had increased, but the changes were not significant. The AV values of the extracted oils were within 1, which was considered desirable for edible oil.

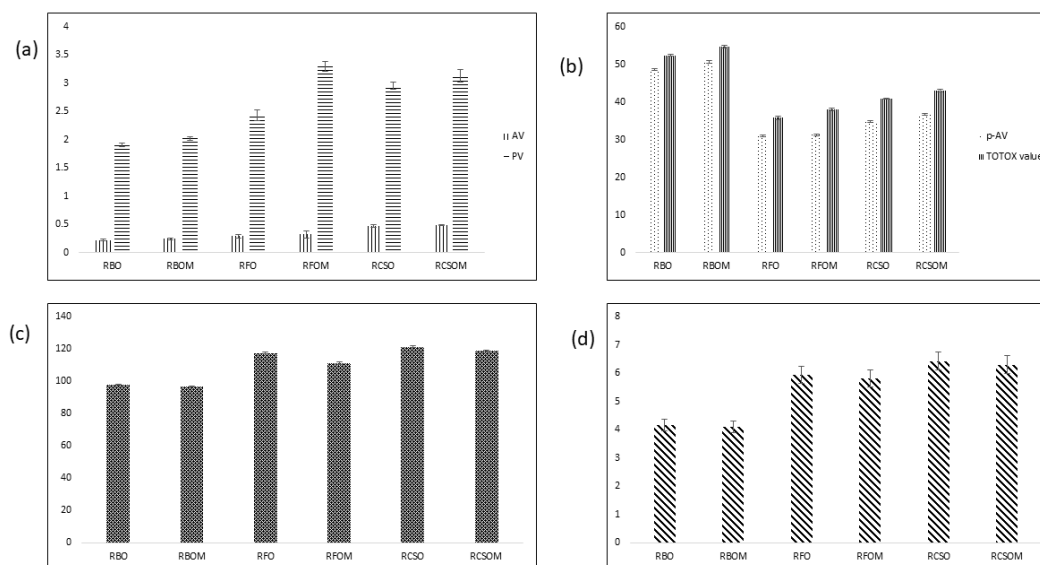


Fig. 4 (a) AV, PV, (b) p-AV, TOTOX value, (c) IV, (d) COX values of the oil samples before and after extraction from mayonnaise

CONCLUSION

CSO and FO are excellent sources of $\omega 3$ fatty acids. By replacing 20% of RBO with FO and CSO in mayonnaise production, a healthier mayonnaise with a higher nutritional value can be achieved. All mayonnaise samples were found to be pseudoplastic in nature, with MCSO having the highest flow consistency index. The 90-day shelf-life study showed satisfactory results, with the lowest pH change observed in MCSO. The $\omega 3$ fatty acid content was highest in mayonnaise made from the RBO-CSO blend compared to the other samples. The $\omega 6:\omega 3$ ratio for both MFO and MCSO fell within the optimal 1-5 range. Chemical, physical, and sensory analyses yielded positive results, with MCSO showing the highest overall acceptability. In conclusion, MCSO demonstrated superior rheological, nutritional, and sensory properties, as well as a longer shelf life compared to MFO and MC.

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Study of Extraction of Polyphenols from Food Wastes

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Abstract :

This research investigates the potential utilization of food wastes viz. potato, pointed gourd, cucumber peels etc. as a sustainable source of polyphenolic compounds. Polyphenols are a diverse group of naturally occurring compounds with multiple phenol units in their structure and can be broadly classified into four major categories which includes Flavonoids, Phenolic acids, Stilbenes and Lignans. It offers unique health benefits including antioxidative and anti-inflammatory effects to improved cardiovascular and cognitive health. This study explores the extraction of polyphenol using four solvents i.e., water, methanol, ethanol and acetone. The study focuses on evaluating the effectiveness of the solvents for various food waste and quantifying the polyphenolic content, which was represented as mg GAE (Galic Acid Equivalent) per gram of sample. The findings showed notable differences in polyphenol yields, showcasing the consequences of both the type of food waste and choice of extraction medium. This study not only underscores the importance of waste valorization but also reveals its future applications that includes significant potential to reduce the environmental waste, sustaining the bioactive potential of polyphenols and fortifying polyphenols and antioxidants in various food products to enhance their nutritional quality.

Keywords:

Polyphenols ; phenolic compounds ; antioxidants ; food waste

1. Introduction :

Food waste has emerged as a significant global concern, with Europe generating approximately 89 million tons of food waste annually and projections indicating potential increases. In India, the situation is equally alarming, with the Food and Agriculture Organization (FAO) reporting that nearly 40% of total food production goes to waste [1,2]. The Food Corporation of India has documented a decline in total food production by 10-15%, while the Ministry of Food Processing Industries (MFPI) estimates substantial losses—12 million tons of fruits and 21 million tons of vegetables—resulting in economic losses approximating USD 4.4 billion, with the total economic impact reaching around USD 10.6 billion [1].

The concept of fruit and vegetable waste encompasses the non-edible components discarded throughout the agricultural and food processing lifecycle [3]. This waste occurs across multiple stages, from pre-harvest agricultural activities to post-consumer disposal, representing a significant loss of potentially valuable agricultural resources. Interestingly, FVW is rich in bioactive

components, including phenolic compounds, dietary fibers, and phytochemicals, which have captured scientific attention for their potential extraction and utilization [4,5,6].

Emerging research highlights the nutritional density of fruit and vegetable byproducts, particularly fruit peels. Studies reveal that inedible components like peels often contain higher concentrations of beneficial compounds compared to edible portions. It has been observed that the polyphenol content can be increased upto about 2.7 times in case of cucumber peel fortified soups [6,7] .

The potential of FVW extends beyond mere waste management. By implementing sustainable strategies for processing and utilizing these agricultural byproducts, researchers and industries can simultaneously address environmental challenges, reduce economic losses, and develop innovative, nutrient-enriched products. This approach represents a promising avenue for converting agricultural waste into valuable resources that contribute to both economic sustainability and human health [8] .

Plants synthesize a diverse array of secondary metabolites that serve multiple critical biological functions. These compounds play essential roles in plant survival, including providing defense mechanisms against microbial invasions and pest attacks, enabling adaptation to challenging environmental conditions, and developing resilience against various biotic and abiotic stresses.

Among the vast spectrum of plant-derived natural metabolites, phenolic compounds have recently emerged as a focal point of scientific research. Their remarkable significance stems from their multifaceted biological activities, which encompass a broad range of potential health benefits. These compounds demonstrate notable physiological properties, including anticlotting capabilities, antimutagenic effects, anti-inflammatory actions, antidiabetic potential, and potent antioxidant characteristics. Particularly compelling is their potential to mitigate cancer development risks and reduce the likelihood of cardiovascular disease progression, making them a subject of intense scientific interest and medical investigation[9-11].

Potato peels (*Solanum tuberosum* L.), a byproduct of potato processing, are rich in polyphenols and dietary fiber. Studies reveal that nearly 50% of potato phenolics are concentrated in the peel, with chlorogenic acid and caffeic acid contributing significantly to antioxidant activity. These antioxidant activity helps reduce and stabilize oil oxidation through minimizing peroxide , totox and p-anisidine indices [12] . Oil oxidation is a free radical change process which leads to the deterioration of oils and lipids . These reactions can cause rancidity , loss of nutritional value (vitamin A, D &E) and essential fatty acids . Oxidation reaction must involve highly reactive molecules called free radicals . These are the molecules that have lost an electron replace it by breaking down of the substances which may impose a severe threat of cancer to our bodies . However addition of some suitable antioxidant in fats and oils can reduce the oxidation process [13] .In food systems, potato peel extracts have demonstrated inhibition values of 84-94% in preventing oxidation.



Fig : 1 Potato Peels

Pointed gourd (*Trichosanthes dioica* Roxb.) , also known as ‘ Parwal ‘ or ‘ Patal ‘ , is a promising source of natural antioxidant especially its peel which is often discarded as waste . Research has indicated that the peel is rich in bio active compounds such as phenolic acids flavonoids and vitamin C which have their scavenging ability to inhibit lipid peroxidation and neutralize free radicals [14] .

Cucumber peel (*Cucumis sativus* L.) is recognized as an affordable source of flavonoids and holds potential as an antioxidant for industrial applications (Agarwal et al., 2012) [15]. A study by Zeyeda et al. (2008) examined the phenolic content in various vegetable wastes and ranked them as follows: olive leaves > tomato peel > cucumber peel > watermelon peel > potato peel [16]. The primary phenolic compounds in cucumber peel were identified as chlorophyll, pheophytin, phellandrene, and caryophyllene, with concentrations ranging from 1.21 to 3.46 mg/g. Both cucumber and watermelon peels had the highest levels of chlorophyll and pheophytin. Additionally, while cucumber peel powder exhibited antioxidant activity at higher concentrations (800 ppm), it showed lower effectiveness compared to 200 ppm of TBHQ (Tertiary Butyl Hydroquinone).



Fig. 2 Cucumber peels

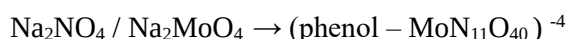
2. Methods :

2.1 Materials :

- Food wastes / peels (cucumber , potato , Pointed gourd)
- Glass apparatus (petri dishes , test tubes)
- Hot air oven
- Desiccator
- UV-vis spectrophotometer

2.2 Reagents :

- **0.1 (N) Na₂CO₃**
- **FC reagent :** Folin – Ciocalteu Reagent is used in determination of polyphenols which is a mixture of phosphomolybdate and phosphotungstate . It is used for the calorimetric in vitro assay of phenolic and polyphenolic antioxidants , also called the Galic Acid Equivalent (GAE) method . The intensity of Blue-colored Tungsten – molybdenum complexes with polyphenol is measured spectrophotometrically at the wavelength of 765 nm .



$\text{Mo (VI) (Yellow)} + e^- \rightarrow \text{Mo (V) (Blue)}$

2.3 Procedure :

- *Removal of Free Moisture of the samples :*
 - At first , the initial weight of the samples were measured in a weighing balance machine .
 - Then the sample was kept on hot air oven for about four hours for moisture removal.
 - Again it was taken out and kept inside the desiccator for 15 minutes and its weight was checked for several times until there's no change in the two consecutive readings . This indicates , the free moisture has been removed completely .
 - Thus after complete removal of moisture the final weight of the sample was taken.
Moisture content (dry basis) % = (Initial wt. – Final wt.) / Final wt. * 100
- *Dry weight calculation :*
 - In three test tubes , 15 ml of each of the solvents (Ethanol , Methanol, Water) were taken .
 - Each of samples were soaked overnight in those solvents .
 - Before that , initially the weight of samples were measured with weighing balance machine .
 - Dry weight is determined by reducing the moisture content (dry basis) from the initial weight measured before soaking .
Dry wt. = Initial wt. of sample – Moisture content

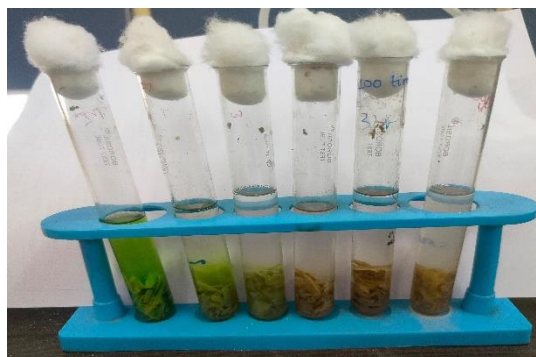


Fig. 3 Samples soaked in solvents

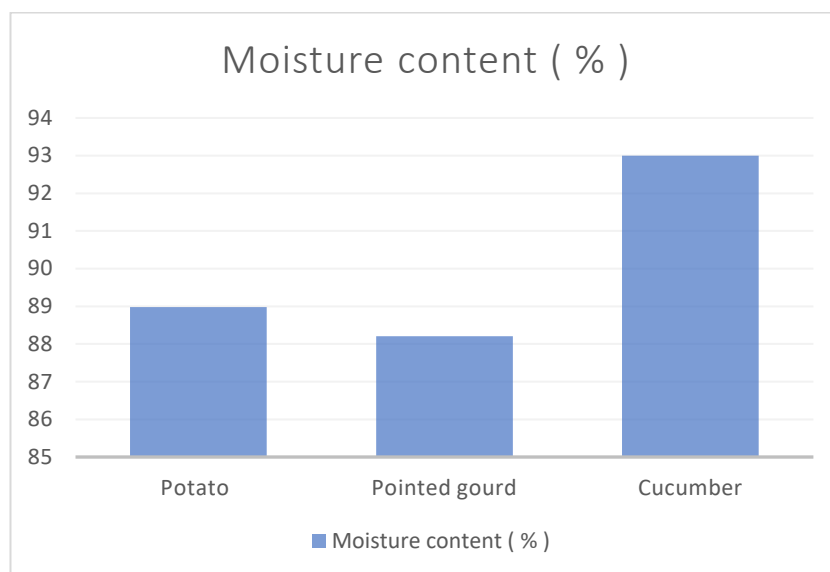


Table : 1 Dry weights of the vegetable peels (in gm) soaked in the solvents

Solvents	Dry weight		
	Potato	Pointed Gourd	Cucumber
Ethanol	0.161	0.177	0.108
Methanol	0.171	0.2	0.125
Water	0.171	0.188	0.122

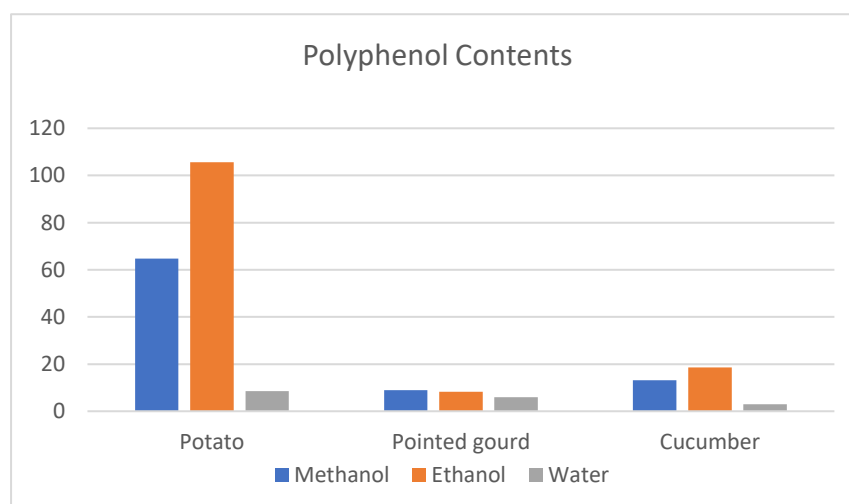
• **Polyphenols estimation :**

- Na_2CO_3 Solution was prepared in a volumetric flask by adding 10.6 g Na_2CO_3 was dissolved in 100 ml distilled water .
- FC reagent was prepared in a beaker by mixing FC reagent (4 ml) with distilled water (40 ml) in a ratio of 1:10 .
- In a test tube , blank sample was prepared by adding Na_2CO_3 solution (4 ml) and FC reagent (5 ml) followed by 0.5 ml (methanol,ethanol or distilled water for the respective medium) .
- Then in another test tube Na_2CO_3 solution (4 ml) to FC reagent (5 ml) was taken and 1 ml crude sample was pipetted out from the respective medium(methanol ,ethanol,,water) and added in a test tube and a slightly blue color was observed in the solution .
- Next , the blank solution was taken as to set autozero in the spectrophotometer . Then , respective samples were observed at the wavelength of 765 nm and the absorbance was noted down .

3. Results and discussions :

Table : 2 Polyphenol content (mg GAE / g) of the peels

Solvents	Polyphenol content (mg GAE / g)		
	Potato	Pointed gourd	Cucumber
Ethanol	105.65	8.220	18.611
Methanol	64.74	8.992	13.140
Water	8.596	5.904	9.467



4. CONCLUSION :

The present study highlights the potential of vegetable peels such as potato, pointed gourd, and cucumber as valuable sources of polyphenols, which are known for their strong antioxidant properties. The findings suggest that these commonly discarded by-products can be utilized effectively in the development of functional foods, nutraceuticals, and other health-promoting applications. Among the studied peels, the polyphenol content varied, reflecting the influence of the vegetable type and its inherent composition.

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ETBFT-24-038

**QUALITY EVALUATION OF TRADITIONALLY PREPARED LANGCHA OF
SAKTIGARH CITY IN WEST BENGAL**

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Abstract:

Langcha is an Indian Sweet dish prepared in West Bengal, Jharkhand, Orissa, Tripura and throughout Bangladesh. The present study was carried out to evaluate the quality of langcha in Saktigarh city, Burdwan district of West Bengal. The samples were collected from different shops in Saktigarh (The Langcha Hub of West Bengal) and the quality attributes were recorded and documented. The Langcha Sweet was examined for sensory analysis (flavor, texture, color and appearance) and chemical parameters (moisture, fat, protein, lactose, sucrose, ash, acidity, free fatty acids, water activity, HMF and total solid contents). The results revealed that the chemical parameters of the market samples were lied in the range of 31.69-46.00, 3.25-6.55, 4.07-6.56, 5.88-9.94, 28.36-37.48, 0.29-0.69, 0.38-0.48, 0.29-0.52, 0.85-0.92, 40.26-45.21, 54.00-68.31%, respectively. A few textural attributes (hardness, cohesiveness, springiness, chewiness, and adhesiveness) of langcha samples were evaluated. Microbial analysis (SPC, Coliform, YMC) of market samples of langcha were also performed for checking the microbial quality of the sweet meat. The results showed that the SPC, Coliform, YMC varies in the range of (5.76-6.00, 3.00-3.25, 3.29-3.6) log cfu/g respectively.

Keywords:

Langcha; Shaktigarh city; sensory evaluation; physico-chemical attributes; microbial quality analysis.

1. Introduction:

Milk and milk products occupy a very prominent place in the Food sector and the economy of India. In India, about 50-55 per cent of the total milk product is converted into a variety of traditional milk products by the unorganized sector employing various unit operations such as coagulation, desiccation and fermentation [1].

India has emerged as the largest milk producer in the world with a record production of 239.3 Million Tonnes in the year 2023-24 and per capita availability of milk in India during the year 2023-2024 is about 471gms/day [2].

Products like Pinni from Punjab, Sharbhaja and Sharpuria from Krishnagar, Jalbhara Sandesh of Chandannagar City, Channabara from Berhampur City, and Langcha from Saktigarh City are types of region-specific dairy products in India. Indian dairying sustained an annual growth rate of over 5.29 % over the previous year, which brought about considerable socio-economic upliftment in rural people's lifestyles. Processing dairy products also produces a variety of physicochemical changes

that may occur in proteins, carbohydrates, and fat [3].

Langcha, Lyangcha, or Lemcha, is an Indian sweet dish prepared in West Bengal, Jharkhand, Odisha, Bihar, Assam, Tripura, and also throughout Bangladesh. It is made from flour and milk powder by frying it and dipping it into sugar syrup for a long time. Though very similar to pantua in color and appearance, Langcha differs essentially in ingredients used in the manufacture. The origin of the sweet is in Bardhaman, West Bengal, India [4].

The flour and milk powder is mixed thoroughly with soda and water and made into a dough. Ghee added during making the dough at constant intervals. Mixed well and the dough is kept untouched for few hours and the pieces are soft and juicy and ready to serve in nature. These pieces are then deep-fried in oil until a brown crust is formed around and they turn stiff and hard. The fried cylindrical pieces are then boiled into the sugar syrup. Once done, they are brought back to a tub containing cold rose-flavored or elaichi flavored sugar syrup. Kept for few hours untouched, these hard pieces become soft and juicy, ready to be served [5].

2. MATERIALS AND METHODS

2.1 Collection of samples

All the langcha samples were collected from different shops from Saktigarh city in a sterile, airtight container and transported in ambient conditions to determine the physicochemical characteristics, microbial, textural and sensory quality of langcha.

2.2. Sensory quality analysis of Langcha

Langcha samples were evaluated by using 9-point Hedonic scale with 1 = disliked extremely while 9 = liked extremely. [6]. The samples were judged independently by a panel of judges and evaluated in respect of colour and appearances, flavour, body texture and overall acceptability.

2.3. Physico-chemical analysis of Langcha

Proximate composition of protein of langcha samples were determined by the methods described by AOAC [7].

To measure the water activity of the langcha, a digital water activity meter (Aqua Lab water-activity meter 4TE, USA) was used [8].

Fat content of the samples was estimated using Mojonnier method [9].

Sucrose content was determined as per Lane-Eynon method given by AOAC [10].

The titratable acidity of langcha samples were determined by following the standard technique [11].

The moisture content in samples was estimated by the gravimetric method [12].

The free fatty acid content was determined according to the procedure [13] with some modifications.

2.4. Textural Profile Analysis (TPA)

The textural quality of langcha was evaluated following the standard method [14] for textural attributes. The textural attributes like hardness, cohesiveness, springiness, chewiness, and adhesiveness were measured using a Texture Analyzer (TA-XT plus, Stable Micro Systems, England) fitted with a 5 Kg load cell.

2.5. Microbiological analysis of Langcha

Total plate count, coliform count and, yeast and mould count in the langcha samples were determined following the standard protocol [15].

2.6. Statistical Analysis:

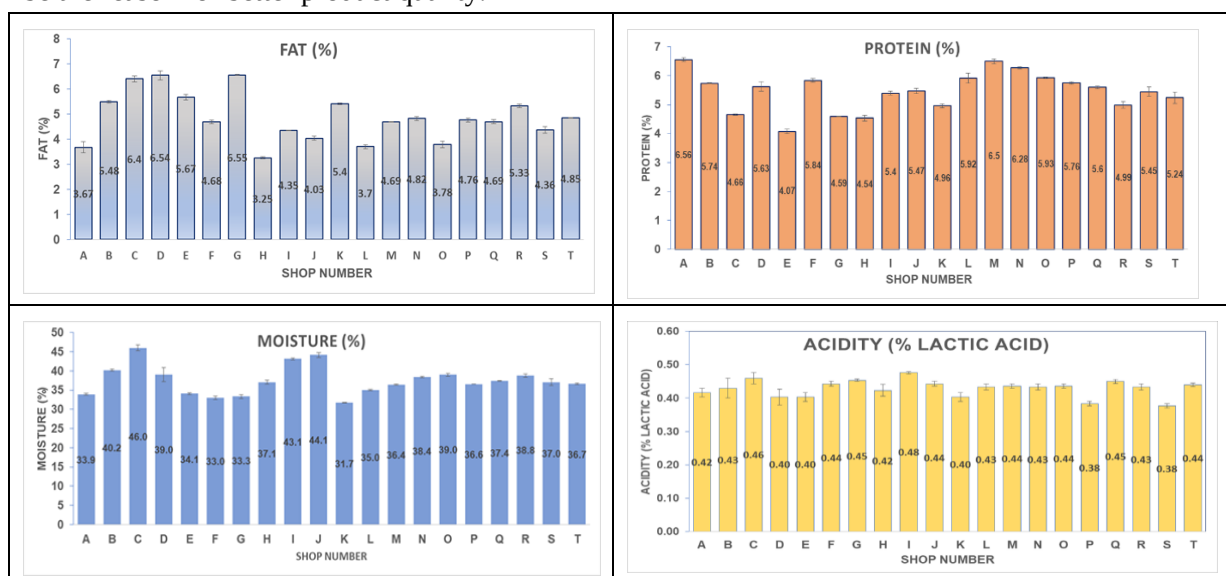
The statistical analysis of the data obtained during the investigation was done for meaningful interpretation of the results. Statistical software IBM SPSS Statistics 20 was used for statistical analysis of the results. The findings were presented as mean ($n = 5$) $\pm$ standard error. Each treatment with 5 replicated ($n = 5$) was compared with the control independently and with each other treatment using one way ANOVA and Duncan's multiple range test. The level of significance at ($p < 0.05$) was used to determine significant differences between means from all the treatments [16]

3. Results and Discussion

3.1. Physico Chemical properties of the langcha

3.1.1 Fat Content

The physico-chemical composition like Fat (%), Protein (%), Moisture (%), acidity (%), Sucrose (%) and free fatty acid (%) content of langcha samples of different shops of Saktigarh city is presented in Fig.1. Fat content of market sample langcha showed significant differences ($p < 0.05$) from samples of different shops. The fat content of langcha samples of different shops of Saktigarh were in the range of 3.25 ± 0.04 to 6.55 ± 0.02 with the lowest percentage found in shop number H ($3.25 \pm 0.04\%$) and the highest percentage found in the shop number G ($6.55 \pm 0.02\%$) with an average value of 4.96% . Similar findings were recorded by others [17] and they reported that fat is responsible for mellow texture and pleasant flavour. Higher fat content may lead to greasy texture while lower fat content may result in gritty or hard texture of the product. Optimum fat content (9.97%) in the product may be the reason for better product quality.



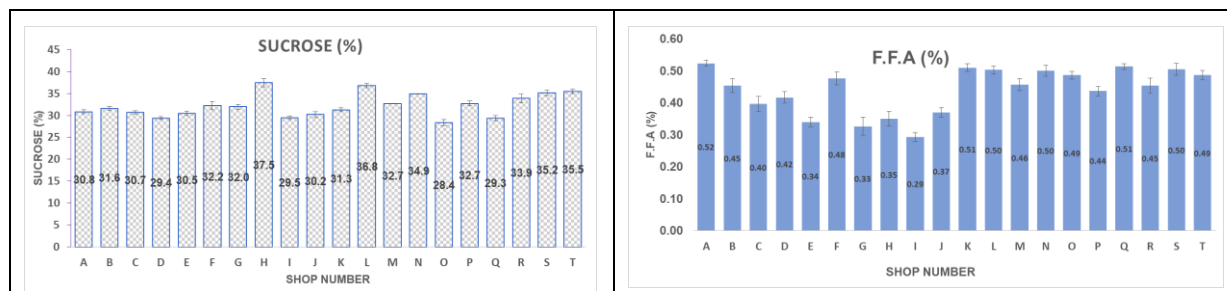


Fig.1. Physico Chemical properties of the langcha samples collected from Saktigarh city

3.1.2 Acidity content

It was observed by the researcher that the titratable acidity (expressed as per cent lactic acid) [18] is an important deteriorative chemical change which can occur in Thirattupal like in any other milk sweet. The level of acidity produced may also be an indicator to the extent of microbial fermentation. The range for acidity of Langcha samples varied between 0.37 and 0.44 % (LA).

3.1.3 Protein Content

The protein content of langcha samples of different shops was seen in the range of $4.07 \pm 0.08\%$ to $6.56 \pm 0.06\%$ with the lowest percentage found in shop number E ($4.07 \pm 0.08\%$) and the highest percentage found in shop number A ($6.56 \pm 0.06\%$) with an average value of 5.32%. The protein content in langcha is one of the most important constituents which exert direct as well as indirect influence on textural or rheological properties of Langcha. The present findings are similar to those recorded by other workers.

3.1.4 Sucrose content

The sucrose percentage of langcha samples of different shops of Saktigarh were found to be in the range of $28.36 \pm 0.70\%$ to 36.82% with the lowest percentage was found in shop number O ($28.36 \pm 0.70\%$) and the highest percentage was found in the shop number H ($37.48 \pm 0.94\%$) with an average value of 32.92%. Significant variation ($p < 0.05$) has been observed among the samples of langcha. Difference in sucrose content might be due to the difference in milk composition, different amount of sugar added for enhancement of flavour and improvement of textural property, different cooking methods employed, concentration of sugar syrup they used to dip the cooked langcha [18].

3.1.5 Free Fatty Acid (% of Oleic acid) content

The Free Fatty Acid (FFA) content (% of Oleic acid) of langcha samples of different shops were in the range of 0.29 ± 0.01 to 0.53 ± 0.01 with the lowest F.F.A found in the shop number I (0.29 ± 0.01) % and the highest F.F.A found in the shop number A (0.52 ± 0.01) % with an average value of 0.41%. The average value of free fatty acid content differs significantly ($p < 0.01$) among the langcha samples. The determination of F.F.A content in langcha is done mainly to check the hydrolytic rancidity of the langcha. The variation of F.F.A may be due to frying condition, temperature of cooking, temperature of storage [19].

3.1.6 Moisture content

The moisture percentage of langcha samples of different shops were in the range of 31.69 ± 0.08 to 46.00 ± 0.73 with the lowest percentage found in the shop number K ($31.69 \pm 0.08\%$) and the highest percentage found in the shop number C ($46.00 \pm 0.73\%$) with an average value of 37.92% . The average value of moisture content differs significantly ($p < 0.01$) among the langcha samples. The variation of moisture content mainly due to boiling temperature, time of cooking and storage condition [20].

3.2. Sensory analysis of langcha

The colour and appearance of langcha samples of different shops of Saktigarh were in the range of 6.36 ± 0.45 to 8.71 ± 0.15 with the lowest score found in shop number B (6.36 ± 0.45) which implies that the colour and appearance is below average in that shop whereas the highest score found in the shop number Q (8.71 ± 0.15) that means the judges like its colour and appearance with an average value of 7.54 [21].

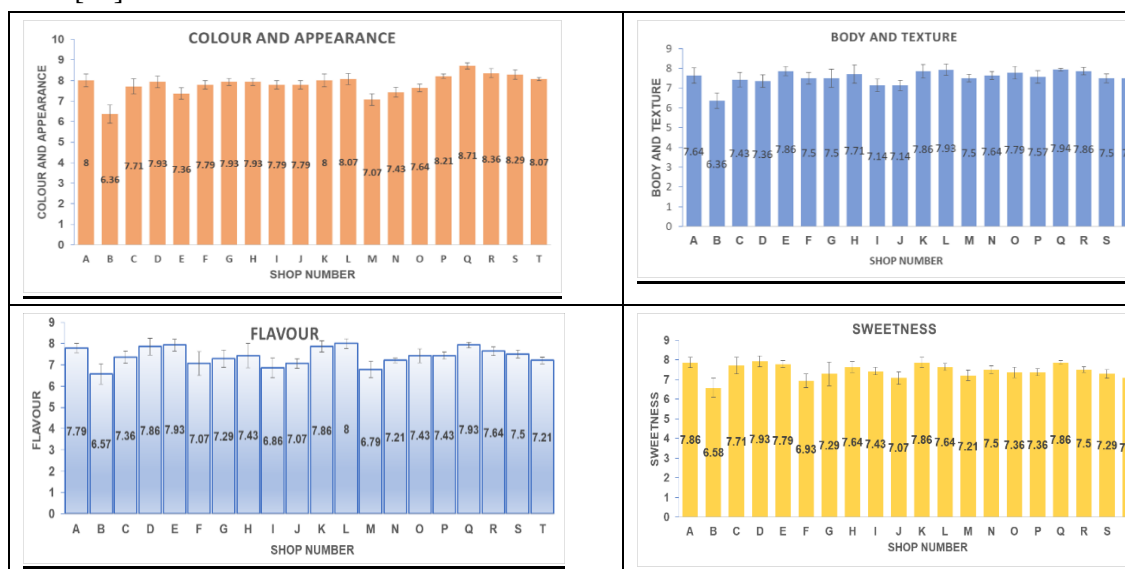


Fig. 2. Sensory analysis of langcha samples available in different shops of Saktigarh city

Microbial quality of Langcha samples

The standard plate count (SPC) of Langcha samples of different shops of Saktigarh were in the range of (5.76 ± 0.01) to (6.00 ± 0.00) log cfu/g with the lowest SPC count was found in shop number J ((5.76 ± 0.01) log cfu/g) and the highest SPC count was found in the shop number N ((6.00 ± 0.00) log cfu/g) with an average value of 5.88 log cfu/g. Similar findings have been reported by several authors [21].

The coliform count of Langcha samples of different shops were in the range of (3.00 ± 0.02) to (3.25 ± 0.01) log cfu/g with the lowest coliform count was found in the shop number F ((3.00 ± 0.02) log cfu/g) and the highest coliform count was found in the shop number I ((3.25 ± 0.01) log cfu/g) with an average value of 3.12 log cfu/g. It was observed that the coliform count in Langcha samples ranged from 0.25×10^2 to 2.5×10^2 MPN/g. Total coliform found in samples R₁, R₂, R₃ and R₄ were 2.50×10^2 , 2.32×10^2 , 0.25×10^2 and 2.50×10^2 MPN/g respectively [22].

The Yeast & Mold Count (YMC) of langcha samples of different shops were in the range of $(3.29 \pm 0.02$ to $3.60 \pm 0.01)$ log cfu/g with the lowest yeast and mold count was found in the shop number A (3.29 ± 0.02) log cfu/g and the highest yeast and mold count was found in the shop number I (3.60 ± 0.00) and J (3.60 ± 0.01) log cfu/g with an average value of $3.43 \log \text{cfu/g}$. YMC count of Gulabjamun blended with coconut and wheat bran goes on increasing. The highest YMC count for treatment (24.22 CFU/g) due to increase level of coconut in gulabjamun. The lowest count found in (13.44 CFU/g) on 4th day [23].

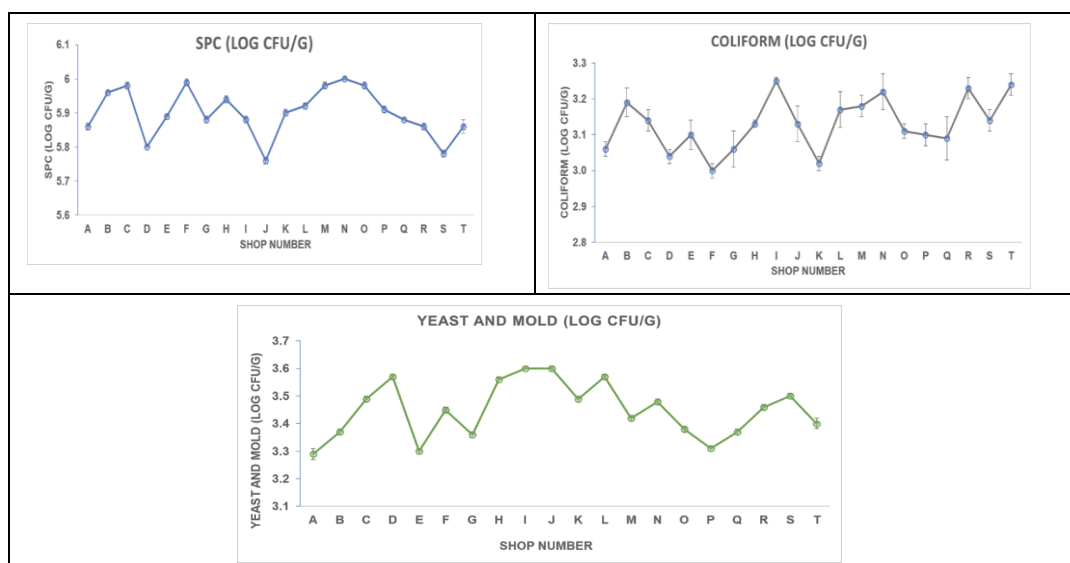


Fig. 3. Microbial Characteristics of langcha samples available in different shops of Saktigarh city

4. Conclusion

This study is useful from the point of view of the need to undertake concerted efforts in characterizing and standardising procedure for preparation of langcha for appealing the consumers throughout the country. The results suggest that the on the basis of the sensory evaluation of langcha among the Judges, shop number Q is liked by most of the panelist followed by shop number K, A and shop number B having the least like among all the shops.

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Studies on Characterization and Functional Properties of Akashmoni Seed Oil and its De-oiled Meal

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Abstract:

Akashmoni (*Acacia auriculiformis*) belongs to the second-largest genus within the Leguminosae family, Fabaceae, specifically in the Mimosoideae subfamily of legumes. Akashmoni seeds are low in fat and glycemic index yet high in complex carbohydrates, protein, and fibre. Akashmoni seeds of different cultivars were assessed for their physico-chemical and functional properties. Protein and fat content of seed kernels varies from 58.54-61.44% and 5.06-5.78% respectively. Akashmoni seed oil shows desired physico-chemical characteristics as per FSSAI norms with saponification value of 205.63-208.98 and moderate iodine value of 128.69-130.46. Linoleic acid (71.72-72.56%) and palmitic Acid (9.6-9.8%) are the major fatty acids present in akashmoni seed oil. Deoiled akashmoni seed meal (DOSM) contains 61.48-64.55% protein and minerals like magnesium, potassium, zinc and calcium. Solvent retention capacity of DOSM ranges from 60.56-102.36% (Water), 82.36-124.66% (5% Sodium Carbonate Solution), 92.36-114.565% (5% lactic acid Solution) and 84.65-142.62% (50% sucrose solution). Water holding capacity(WHC) and Oil absorption capacity(OAC) range from 1.23-2.34 g/g and 1.85-2.17 g/g respectively. Solubility of DOSM varies from 25-32% in alkaline pH (8.5). The study on characterization of Deoiled akashmoni seed meal and its oil concluded that akashmoni seed being an unconventional source of Protein and PUFA rich oil providing a sustainable, environmentally friendly and plant-based dietary source to cater malnutrition globally.

Keywords:

Akashmoni Seed, Protein, Oil, Glycemic index, Physico-chemical Properties

1. Introduction

The increasing demand for food is directly linked to global population growth. In many developing nations, large segments of the population experience protein malnutrition, hunger, famine, and related diseases. Addressing these nutritional challenges, particularly in the context of a growing population, necessitates research into alternative food sources [1]. Consequently, there has been a growing interest in underutilized plants as potential food sources for humans and feed for animals.

The *Acacia* genus comprises a diverse range of woody species, including shrubs belonging to the Fabaceae family. *Acacia* plants have traditionally been used in medicine for treating fever, diarrhea,

leukorrhea, hemoptysis, and throat infections. Additionally, the seeds of certain *Acacia* species are recognized as a valuable food source due to their high protein and soluble carbohydrate content [2]. For example, the seeds of *Acacia nilotica* and *Acacia leucophloea* are consumed by tribal communities in India.

The *Acacia auriculiformis* (Akashmoni in local parlance) often referred to as “poor man’s teak” owing to its impressive grains, relatively low cost, faster growth, less rotation age, edaphic and climatic versatility. Hence it became one of the economically important “naturalized exotic” species in the West Bengal State. It has been widely adopted in the forest fringe plantations of South West Bengal as a quick growing species (QGS) and in North Bengal as strip plantation along the road sides, being a non-grazing species [3]. Now, the tree became immensely popular among general public. This plant thrives in environments with temperatures ranging from 0 to 50°C and annual rainfall between 100 and 1000 mm (3.9–39.4 inches). Its seeds are traditionally used as animal feed. However, there is limited research on the chemical composition, physical properties, and nutritional value of *Acacia auriculiformis* seeds [4]. Therefore, this study aims to physicochemical and functional properties of akashmoni seed oil and its deoiled meal. The results will assist in evaluating its suitability for human consumption.

2. Materials and Methods

2.1. Raw Materials

Akashmoni seed is naturally distributed across various soil types in the South West Bengal. In September 2024, approximately 5 kg of ripe pods were harvested from the region’s natural forests in southwest Bengal. the seeds were carefully separated from the pod by hand, thoroughly washed with sterile water, and then dried at 25°C. Following the drying process, the seeds were stored at 4°C until further processing for oil extraction.

2.2. Proximate Analysis

The composition of akashmoni seeds, especially deoiled seed meal was evaluated for moisture, ash, fat, crude protein, and crude fiber content using standard AOAC methods (950.46, 938.08, 948.22, 981.10, and 978.10) as outlined in AOAC (2005). The crude protein content was quantified using the Kjeldahl method, employing a conversion factor of 6.25 to estimate crude protein from total nitrogen. The carbohydrate content was determined by the difference method [4].

2.3. Extraction of akashmoni seed oil

The dried seeds were finely ground using a milling process and subjected to extraction with n-hexane at a solvent-to-meal ratio of 10:1 (v/w). This extraction was carried out with soxhlet extractor for 6 hours. The hexane extract was then filtered under vacuum using a Buchner funnel and standard filter paper. Finally, the oil was separated from the hexane using a rotary evaporator (Buchi Labortechnik AG, Flawil, Switzerland) [5].

2.4. Physico-chemical characterization of akashmoni seed oil

The extracted akashmoni seed oil was evaluated for its physicochemical properties, including specific gravity (920.212), acid value (ISO 660:1996), refractive index (921.08), iodine value (920.159), saponification value (920.160), and peroxide value (965.33), following the standard methods outlined by AOAC (2000) [6].

2.5. Fatty acid profile of akashmoni seed oil

The fatty acid profile of akashmoni seed oil was analyzed by converting the oil into fatty acid methyl esters (FAME) following the IUPAC (1987) protocol. Gas Chromatography (GC) (Agilent Technologies Inc., Santa Clara, U.S.) was utilized for the analysis, equipped with a hydrogen flame ionization detector (FID) and an SP2560 column (100 m × 0.25 mm, 0.20 µm film thickness). The injector and detector were initially set at 100°C for 4 minutes, followed by a temperature increase of 3°C per minute until reaching a final temperature of 240°C, which was maintained for 15 minutes. Helium was used as the carrier gas, operating at a flow rate of 18 cm/s with a split ratio of 200:1. A 2 µl FAME sample was injected into the GC system and analyzed based on standard fragmentation patterns [6].

2.6. Preparation of deoiled akashmoni seed meal

After solvent extraction, the seed cake was oven-dried at 40°C for six hours to eliminate any residual hexane. The dried seed cake was then ground and sieved using a 0.5 mm mesh. The resulting deoiled seed meal (DOSM) was stored in polyethylene bags at -20°C until further use.

2.7. Analysis of Mineral Profile

Mineral composition analysis of DOSM was conducted following the AOAC (2006) protocol (999.11–2005). A 0.5 g sample was subjected to digestion using 0.2 ml of hydrochloric acid (HCl), 1 ml of hydrogen peroxide (H₂O₂), and 2 ml of nitric acid (HNO₃) for 30 minutes in a microwave digestion system (Anton Paar GmbH, Graz, Austria). The mineral content was then quantified using inductively coupled plasma spectrometry (ICP) (Agilent Technologies Inc., Santa Clara, U.S.) and expressed in mg/g [7].

2.8. Analysis of Functional Properties

2.8.1. Water Holding Capacity and Oil Absorption Capacity

The water-holding and oil-absorption capacities were assessed using a modified approach based on the method. In this procedure, 250 mg of deoiled meal was mixed with 15 mL of distilled water using a vortex mixer and left to rest at room temperature for one hour. The mixture was then centrifuged at 850×g (3000 rpm) at 25°C for 20 minutes, after which the supernatant was carefully removed. The remaining residue was weighed to calculate the water-holding capacity, expressed as grams of water per gram of sample. For oil-holding capacity, the same procedure was followed, substituting distilled water with sunflower oil, and the results were recorded as grams of oil retained per gram of sample [8].

$$\text{Water holding capacity (g / g)} = \frac{\text{Final weight of the tube after water decanted off}-\text{Initial weight of the tube}}{\text{Weight of sample}}$$

$$\text{Oil absorption capacity (g / g)} = \frac{\text{Final weight of the tube after oil decanted off}-\text{Initial weight of the tube}}{\text{Weight of sample}}$$

2.9. Solvent Retention Capacity

Solvent retention capacity (SRC) is a key parameter for evaluating the functional properties and potential applications of wheat flour. In this study, SRC for DOSM was determined following the methodology outlined by with slight modifications. Four different solvents were prepared: distilled water, 5% sodium carbonate, 5% lactic acid, and 50% sucrose solutions. A 1 g sample of DOSM was mixed with 5 ml of each solvent in centrifuge tubes and thoroughly shaken. The samples were then incubated at room temperature at 150 rpm for 20 minutes. Following incubation, centrifugation was

performed at 3214 g for 15 minutes. The supernatant was carefully decanted, and the tubes were placed in an inverted position to ensure complete drainage [8]. The final weight of the drained tubes was recorded, and the SRC values were calculated using the specified equation.

$$\text{SRC (\%)} = \left(\frac{\text{Wt. of pellet (g)}}{\text{Initial wt. of flour (g)}} - 1 \right) \times \left(\frac{86}{100 - \text{moisture content of flour (\%)}} \times 100 \right)$$

2.10. Protein solubility

A mixture of 250 mg of DOSM and 25 mL of deionised water was agitated for two hours to test for solubility at alkaline pH of 8.5. The assay method was used to measure the soluble content of the mixture's supernatant, which was obtained by centrifuging it for 10 minutes at 6000 rpm. Equation 4 was used to determine the solubility [9].

$$\text{Solubility (\%)} = \frac{\text{Soluble content of supernatant (\%)}}{\text{Initial soluble content of suspension (\%)}} \times 100$$

3. Result and Discussions

3.1. Proximate composition of akashmoni seeds

According to the results in Figure 1, akashmoni seeds have a low moisture content (5.30%), which indicates that they store well. This outcome was comparable to that which was documented for *A. leucophloea*. Akashmoni seeds had an ash level of 3.99%, which was comparable to that of *A. leucophloea*. The fat output (6.19%) was within the range recorded for *A. colei* and *A. tumida*, but it was higher than that reported for *A. leucophloea* [10]. Akashmoni seed would make a suitable source of energy due to its comparatively high crude fat content.

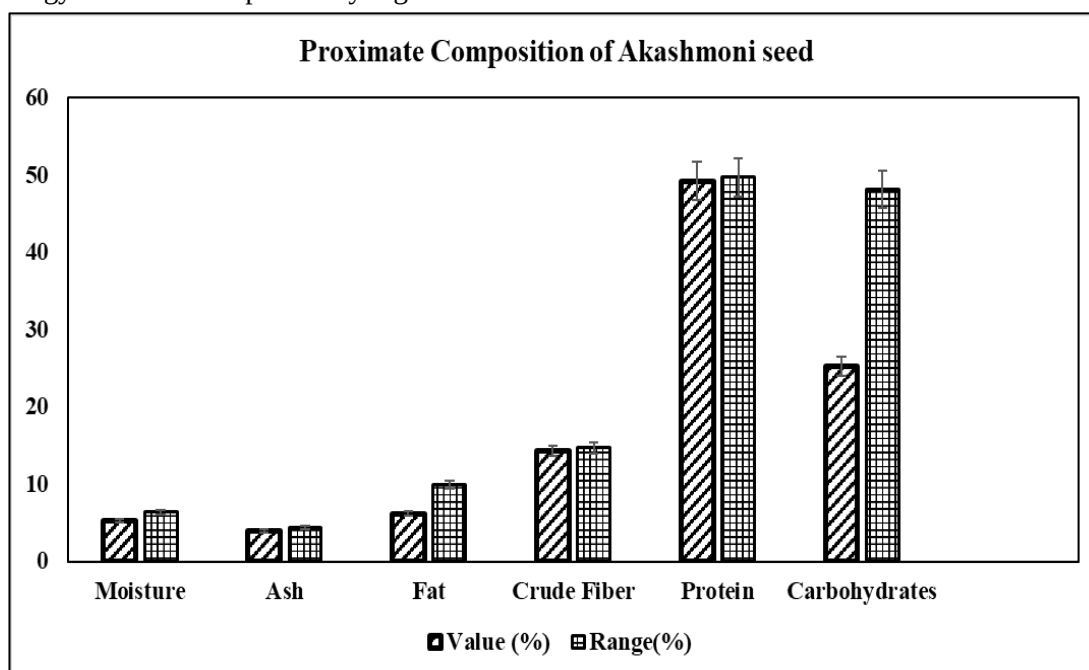


Figure 1: Proximate Composition of Akashmoni Seed

Crude fibre content (14.31%) was comparable to that reported for *A. nilotica* but higher than that for *A. leucophloea*. Acacia seeds are therefore regarded as a good source of dietary fibre [12]. Dietary

fibre actually plays a significant role in human nutrition since it keeps the gastrointestinal tract healthy. However, too much fibre can bind trace minerals, resulting in iron and zinc deficits.

The findings indicate that the high protein content of akashmoni seeds (49.21%) was higher than that found for *A. colei* and *A. tumida*, but it was comparable to that reported for *A. leucophloea* [13]. These findings suggest that acacia seeds can be used as a protein source in food compositions. The seeds of akashmoni had a carbohydrate content of 25.30%. Because of the increased amounts of crude protein, crude fat, and fibre in the seed, this level of carbohydrates was lower than that recorded for *A. leucophloea* and *A. tumida* [14]. Consequently, it was found that the chemical constituents of akashmoni seeds was nutrient-dense, and incorporating this seed to human meals will enhance nutritional status.

3.2. Physicochemical analysis

The oil yields from akashmoni seeds were 6.05 ± 0.1 (v/w%). The refractive index and density of the seed oils were 1.4691 and 0.92 g/ml at 25°C, respectively, according to the physicochemical study. These values are comparable to those of sunflower oil, which has a density of 0.92 and a refractive index of 1.468. Hunterlab found that the oil had a green to yellowish colour and had the following coordinates: a (0.7 ± 1.1), b (4.4 ± 1.2), and L (25.5 ± 1.3). Akashmoni seed oil had an acid value (2.3 ± 0.7 mg KOH/g), which was as per the suggested F.A.O/W.H.O standard value of 4.0 mg KOH/g [15]. Before it could be used as edible oil, it would need to be refined. Furthermore, because of its high acidity, akashmoni seed oil may undergo some hydrolytic reactions during extraction.

The iodine value of native oils, which represents their level of unsaturation, is a crucial property. This statistic indicates the presence of unsaturated fatty acids in triacylglycerol. This value indicates how susceptible oil is to oxidation by quantifying double bonds. The iodine value of the oil was 128.69-130.46, which is in good agreement with the unsaturated fatty acid content of sunflower oil [16].

3.3. Fatty Acid Profile of akashmoni oil

The fatty acid composition of akashmoni seed oil is presented in Table 1, with linoleic acid being the most abundant (66.57%), followed by palmitic acid (12.31%), stearic acid (11.88%), oleic acid (7.74%), and arachidic acid (1.50%). These findings align with the fatty acid profiles reported for seeds of three other Australian *Acacia* species (*A. alata*, *A. dealbata*, and *A. drummondii*). Similarly, research on four subspecies of *A. saligna* demonstrated that their seed oil contained high concentrations of linoleic acid, followed by oleic, palmitic, and stearic acids [17]. Furthermore, the linoleic acid content of akashmoni seed oil was comparable to that of sunflower oil. Given that linoleic acid-rich oils, including akashmoni oil, have been shown to contribute to lowering blood cholesterol levels when consumed regularly as part of a balanced diet, this suggests that the oil possesses significant nutritional value [18]. Additionally, akashmoni seed oil was found to contain 74.31% unsaturated fatty acids, a level of unsaturation similar to that of common vegetable oils. The high proportion of mono- and polyunsaturated fatty acids highlights the oil's potential health benefits for both humans and animal.

Table1: Fatty acid composition of akashmoni (*Acacia auriculiformis*) seed oil (% of total fatty acids).

Fatty Acid	Value (%)
Palmitic (C16:0)	12.31±0.83
Stearic (C18:0)	11.88 ±0.42
Oleic (C18:1)	7.74 ±0.3
Linoleic (C18:2)	66.57 ±0.36
Arachidic (C20:0)	1.5±0.12

3.4. Functional properties and mineral profile of deoiled akashmoni meal

Water absorption capacity refers to the ability of a food material to retain water against gravitational forces. A higher capacity is desirable as it helps to maintain key sensory attributes over an extended period. The water absorption capacity (WAC) of proteins is a key functional property in various culinary applications, such as soups, gravies, doughs, and baked products. WAC of DOSM varied from 1.23-2.34 g/g [18].

OAC is crucial because oil preserves flavor and gives food smooth texture in the mouth. OAC is also crucial for the development of rancidity and for storage stability. OAC is essentially the trapping of oil by various food ingredients, especially by proteins and carbohydrates. OAC of any protein depends on the percentage of its non-polar amino acids, its surface hydrophobicity, particle size and also processing conditions. OAC of DSM of selected cultivars varied non-significantly ($p \geq 0.05$) from 1.85-2.17 g/g [19,25].

Originally, SRC was developed to evaluate the suitability of wheat flours for baking applications. Due to its high protein and fat content, DOSM is widely used in the baking industry. However, research on the SRC analysis of muskmelon seed meal remains limited [20]. The SRC of DOSM was assessed using four different solvents: water (WSRC), sodium carbonate (SCSRC), sucrose (SUSRC), and lactic acid (LASRC). The WSRC values for DSM ranged from 60.56% to 102.36%, WSRC provides insights into the combined influence of protein and carbohydrate content on water absorption, reflecting the overall hydration behaviour of flour components such as gluten, starch, and pentosans [21].

The LASRC of DOSM ranged from 92.36-114.565%. This parameter simulates the acidic conditions created by lactic acid bacteria during fermentation and indicates the expansion of gluten fibrils, which contributes to dough strength [22]. SUSRC is associated with the characteristics of pentosans and gliadin, while SCSRC reflects starch hardness. The SUSRC values for DOSM varied between 84.65-142.62%.

DOSM was identified as a significant source of essential minerals, including potassium, phosphorus, magnesium, and calcium. The average mineral concentrations in DOSM were observed within the ranges of 2820–3205 mg/100 g for potassium, 186.05–235.02 mg/100 g for phosphorus, 165–192.06 mg/100 g for magnesium, and 168–175 mg/100 g for calcium. Comparatively, prior research has highlighted acacia seed flour as being rich in phosphorus (1507–1508 mg/100 g), magnesium (504 mg/100 g), and potassium (957 mg/100 g). Additionally, it has been reported that seeds contribute to 14% of the total phosphorus content in cantaloupe acacia fruit [23,24]. Potassium is particularly important for cardiac and nervous system functions and plays a crucial role in protein synthesis and

metabolic processes. Notably, heavy metals such as arsenic, cadmium, lead, and mercury were not detected in DOSM.

4. Conclusion

This study on the chemical composition and nutritional profile of akashmoni (*Acacia auriculiformis*) seeds indicates their potential as a novel food ingredient, particularly for enhancing protein, lipid, fiber, and mineral content. However, the presence of certain factors necessitates their reduction or removal prior to consumption. Additionally, the physicochemical and functional properties of the seed flour suggest its suitability for various food applications.

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Development and Characterization in Respect to Phytochemical Content and Antioxidant Properties of Dried Curry Leaves

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Abstract -

Curry leaf (*Murraya koenigii*), an aromatic ephemeral herb native to South Asia, a vital component of traditional cuisines and Ayurveda medicine, known for its phytochemical and therapeutic potential. Present study includes drying of curry leaves at different temperatures (40°C, 50°C, 60°C, 70°C) for 3 hours in hot air oven. After drying ash content of samples were measured by muffle furnace at the temperature of 550°C for 4 hours. Ash content was in the range from 9% to 11%. Moisture content was also measured by hot air oven at 105°C for 3 hours. Moisture content was in the range from 3% to 5%. pH of all the dried samples were in between 6 to 6.7. Phytochemical content of the dried powder samples was analyzed. Dried samples at 40°C showed highest phenolic and flavonoids content (97 mg GAE/100 gm and 9.56 mg CE/gm respectively) whereas dried samples of 70°C showed lowest phytochemical content (24 mg GAE/100 gm and 4.02 mg CE/gm respectively.) Antioxidant activity was evaluated based on DPPH, FRAP and ABTS assay. Antioxidant activity of the dried sample was higher at low temperature as compared to high temperature. Among oxidative stability acid value and peroxide value were performed. Acid value and peroxide value of all the dried samples were below 5 mg KOH/gm sample and 10 mill equivalents of peroxide per kg sample. That indicates these samples are safe for our consumption. Not only these can its high antioxidant and phytochemical content boost up our immune system.

Keywords:

Curry leaves; Phytochemical; antioxidant; Oxidative stability

Introduction

Curry leaves are included in the family of Rutaceae (1). It is the domestic plant of South Asia especially India, Bangladesh and Sri Lanka (2). *Murraya koenigii* is well known as flavouring agent (3). It is popular as most important ingredients in South Asian cookery for its aroma and fragrance. It is a popular spice in tropical countries due to maintaining its flavour and other parameters even after drying (4). The causative agents for generating flavour and aroma of curry leaves included caryophyllene, pinene, sabinene, cardinene and cardinol, (5). The plant is considered as tonic and visceral (6). It also contains several bioactive phytochemicals that includes essential oils, phenolic compounds, proteins alkaloids and minerals (7), terpenoids, β -carotene, tocopherol, and lutein (8). It is used as both fresh and dried powdered form in Indian cuisine. It is known as many names like Curry Leaf, Mitha Neem Karuveppilai and Surabhiniimba etc. (9). Herbal drugs are highly effective with minimum side effects and are to be used extensively in treating various diseases and they are relatively low cost. This review explains the different uses and potentials of curry leaf. *M. koenigii* has several medicinal uses. It has been reported that this leaves contain antifungal, antimicrobial, anti-inflammatory and antioxidative properties (10). It is also used as traditional medicine and home

remedies. The main aim of the present study is to evaluate the phytochemical content, antioxidant properties and oxidative stability of the dried curry leaves samples of different temperatures.

Materials and Method –

All materials are analytical grade and purchased from MERK, India.

Methods

Curry leaves powder preparation-

The curry leaves were cleaned and dried in hot air oven at different temperature – 40°C, 50°C, 60°C, 70°C for three hours. Then the dried leaves were placed in a mixer grinded to make powder form.

Moisture Content

Moisture content analysis of the dried powder samples was conducted according to the standard method of AACC, 2000 (11). The samples were placed in petri plates and kept in hot air oven at 105°C for 30 minutes. After that the samples were taken out and weighed and the procedure was continued until the weight of the sample became constant.

Ash Content –

Ash content of the dried curry leaves was analyzed according to the standard method of AACC, 2000 (11). Samples were placed in muffle furnace and kept in hot air oven at 550°C for 5 hours.

Ph measurement –

Dried powder samples were mixed with distilled water and pH was measured with the help of pH meter (12).

Phytochemical Content –

Total Phenolic Content –

The extract of sample was mixed with Folin Ciocalteu's reagent and incubated in room temperature for 5 minutes. Then 20% of sodium bicarbonate was added to the sample mixture and the absorbance was measured at 765 nm., against a blank solution (13).

Total Flavonoid Content -

The extract of sample was mixed with distilled water and 5% NaNO₂ solution and AlCl₃ solution was added to the previous solution after incubation of 5 minutes at room temperature. The solution mixture was added with 1 M NaOH. Then the whole solution was diluted to 10 ml distilled water and absorbance was measured at 510 nm against a blank (14).

Antioxidant Activity –

Antioxidant activity of the dried curry leaves samples was measured by the following methods:

DPPH Free radical scavenging activity assay –

The samples were assessed by using 1, 1-diphenyl 2-picryl hydrazyl (DPPH) radical scavenging assay (15). An aliquot of sample was added to 2.8 ml of DPPH solution and kept it in the dark place for 30 minutes. The absorbance was measured at 517 nm.

Ferric reducing antioxidant power (FRAP) –

The FRAP reagent mixture was added with the extracted samples and incubated at 37°C temperature for 4 minutes and the absorbance was measured at 593 nm (16).

ABTS Free radical scavenging activity –

ABTS diluted solution was mixed with sample extract and the reaction mixture was kept for 6 minutes and absorbance was measured at 350 nm (17).

Oxidative Stability test-

Acid Value -

This test has been conducted according to AOCS Ca 5a-40 official method (18).

Peroxide Value -

This test was conducted according to AOCS Cd 8-53 (19).

Statistical Analysis –

Results were expressed as mean value $\pm$ standard deviation of three replications. Statistical differences were analysed using one way ANOVA followed by post-hoc Tukey HSD (Honestly Significant Difference) at level $p \leq 0.05$.

Result and Discussion

Moisture Content

Moisture content of the sample dried at 70°C showed highest moisture (5%) whereas sample dried at 40°C contained lowest moisture (3%) showed in Table 1.

Table 1 Moisture Content of Dried Curry Leaves

Temperature	40°C	50°C	60°C	70°C
Moisture Content (%)	3 $\pm$ 0.11	3.50 $\pm$ 0.09	4.3 $\pm$ 0.32	5 $\pm$ 0.41

Correlation is significant at the $p \leq 0.05$ level.

Ash Content

Ash content reveals the mineral content of the sample which was mentioned in Table 2.

Ash content of the dried samples ranges from 9% -11%.

Table 2 Ash Content of Dried Curry Leaves

Dried Samples	Ash Content (%)
40°C	11 $\pm$ 0.48
50°C	10.78 $\pm$ 0.61
60°C	9.51 $\pm$ 0.17
70°C	9.46 $\pm$ 0.29

Correlation is significant at the $p \leq 0.05$ level.

Phytochemical Content

Dried samples of 40°C contained highest amount of phenolics and flavonoids content while dried samples of 70°C showed lowest phenolics and flavonoids content (Table 3). Phytochemical contents were decreasing with higher temperature.

Ph Measurement

Ph of the samples were is less than 7. Ph of dried samples of 40°C and 50°C was 6 and 6.05 respectively whereas ph of 60°C-70°C dried samples were 6.02 and 6.09 respectively.

Table 3 Phytochemical Content of dried samples

Dried Samples	Phenolic Content(mg GAE/100 gm)	Flavonoid Content (mg CE/gm)
40°C	97 $\pm$ 0.67	9.56 $\pm$ 0.83 ^a
50°C	83.76 $\pm$ 0.59	7.24 $\pm$ 0.91 ^b
60°C	67.56 $\pm$ 0.71	5.73 $\pm$ 0.67
70°C	24 $\pm$ 0.55	4.02 $\pm$ 0.39

The data are presented as mean value $\pm$ standard deviation of triplet analyses. Different letters in the same column indicate statistically significant values ($p \leq 0.05$)

Antioxidant Activity

Antioxidant activity was lower at high temperature as compared to low temperature dried samples (Table 4).

Table 4 Antioxidant Activity of Dried Curry Leaf

Dried Samples	DPPH (%)	FRAP ($\mu\text{mol/ml}$)	ABTS (%)
40°C	67.17 $\pm$ 0.51 ^a	11.09 $\pm$ 0.39	31.56 $\pm$ 0.11 ^b
50°C	60.59 $\pm$ 0.83	9.15 $\pm$ 0.43 ^b	29.89 $\pm$ 0.38
60°C	58.87 $\pm$ 0.33 ^c	8.64 $\pm$ 0.57	29.09 $\pm$ 0.92 ^c
70°C	53.12 $\pm$	6.01 $\pm$ 0.11 ^c	27.89 $\pm$

The data are presented as mean value $\pm$ standard deviation of triplet analyses. Different letters in the same column indicate statistically significant values ($p \leq 0.05$)

Oxidative Stability Test

Dried samples are oxidatively stable because their acid value and peroxide value are within range. Temperature did not affect the oxidative stability of the samples which was shown in Table 5.

Dried Samples	Acid Value	Peroxide Value
40°C	1.02 $\pm$ 0.31	3.56 $\pm$ 0.49 ^a
50°C	0.89 $\pm$ 0.14	3.81 $\pm$ 0.51
60°C	1.39 $\pm$ 0.19	2.98 $\pm$ 0.37 ^b
70°C	1.32 $\pm$ 0.79	3.17 $\pm$ 0.56

The data are presented as mean value $\pm$ standard deviation of triplet analyses. Different letters in the same column indicate statistically significant values ($p \leq 0.05$)

Conclusion

Curry leaves are rich in phytochemical contents. Their antioxidant properties are also high at low temperature as compared to high temperature of drying leaves. Not only these it is very clear from its ash content that they are rich in minerals content also. They are also oxidatively stable at room temperature after storage of one month.

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Mitigating Carbon Footprint in the Food Chain: Strategies and Policies Towards Sustainable Development

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Abstract

Global warming is a global concern with noticeable impacts on many systems and industries. According to the United Nations, it is a significant contributor to climate change. Increased global human populations are impacting the use of resources and contribute to global warming. The phenomenon can be attributed to various greenhouse gas (GHG) emissions, of which the food system accounts for more than one-third. Many factors associated with the production of food products determine their carbon footprint. Given their significant contribution to greenhouse gas emissions, this calls for the food manufacturing industry to establish emission objectives and validate their emissions. In order to reduce carbon emissions, they need to manage their internal emissions in addition to emissions of the whole value chain. Proper site selection, eco-friendly packaging, and waste management will help mitigate land use change effects. Climate dynamics are also influenced by consumption behaviour as well. Appropriate purchasing practices and low-carbon food alternatives can be adopted to reduce greenhouse gas emissions. Some policies like the European Green Deal and the Paris Agreement, which have come out to be promising. Switching to renewable energy source in agricultural systems, has been reported to reduce carbon footprints by up to 7%, while the promotion of plant-based diets and reduction in food waste could collectively mitigate carbon emissions by 5-10%. Sustainable development is increasingly becoming important in the agri-food sector and the global economy. Holistic mitigation strategies, government initiatives and cooperation between agricultural producers and food manufacturers are considered feasible routes to sustainability.

Keywords:

Agri-food, Carbon footprint, Greenhouse gas emissions, Mitigation, Sustainable development

1. Introduction

Carbon footprint refers to all greenhouse gas emission associated with an organisation, action or goods [1]. Carbon dioxide, nitrogen dioxide, sulphur dioxide are greenhouse gases that are believed to be prime causes of global climate change, a subject that is gaining enormous importance. Carbon dioxide is the most common of these gases, and researchers have thus looked into carbon reduction and mitigation measures [2]. The major force leading to climate change is man-made GHG emissions that work like greenhouse glass trapping infrared radiation from the sun and stopping the heat from escaping into space. The average temperature has been rising worldwide and the weather patterns are changing radically for an extended period because of excess GHG emissions [3]. There has been rapid increase in population worldwide during the last few decades and this pressure have been exerted on the availability, management and disposal of food [4]. Besides, the modernization

and industrialization of the food and agro-industrial sector has been accompanied with a significant increase in the productivity and marketing of the sector including food and agro-industrial products. Thus, it also increases significantly the amount of food waste. [5] According to the Environmental Protection Agency (EPA), just 4.1% of food (2.6 million tons, to be exact) was composted out of the 63.2 million tons of food that's discarded, in 2018. Second largest of all food wastage to agricultural production globally (33%). In about 54% it is the upstream process, the whole production, postharvest management and storage. About 46% is accounted for by the downstream process (processing, distribution and consumption). They are said to be indicative of some of these financial, ecological and social issues [6]. Tillage and fertilization are the predominant contributors of agriculture to 18% of global GHG emissions. It is fossil fuel intensive and, thus, increases CO₂ emissions from fossil fuel-based transport and cold chain, i.e. Logistics constitute for 13% of global emissions. Furthermore, food loss and food waste aggravate the environmental issues [7,8,9]. Reducing emission of GHG in the food chain is paramount for mitigating climate change, and sustainable agriculture practices such as soil carbon sequestration in agriculture and modifications in cattle's diet are core strategies [10]. While in manufacturing, energy decarbonization and process optimization improve efficiency. Both local production and food packaging also play a major role in making such emission reduction possible. As a whole, these actions, when combined, help reduce carbon footprint in sector of food industry [11]. There are many international organizations that setup existing frameworks like the Greenhouse Gas Protocol, ISO 14064, ISO 14067, PAS 2050, and PAS 2060 which provide standardization to be approached to conduct emission accounting and to become carbon neutral [12]. In addition, government's efforts such as the European Green Deal and Agriculture Innovation Mission for Climate (AIM4C), stand as important aspects for pushing sustainable agricultural practices [13]. Food waste and resource depletion further worsen the climate challenges, thus, we require Sustainable practices like SDGs 12 and 13 which focus on sustainable consumption, production, as well as climate action. All of these challenges will need to be addressed through the global cooperation, policy enforcement, technological developments to build such a sustainable and resilient food system [14, 15].

2. Carbon Footprint

2.1 Agriculture

The global climate change debate has grown over the past 50 years, with predictions of rising temperatures, population growth, and increased greenhouse gas emissions [16]. The agriculture industry now supports biodynamic farming methods, reducing N₂O emissions. Greenhouse gas emissions from agricultural practices such as tillage and inorganic fertilization and harvesting and pesticide application and manuring and waste management and composting and biochar addition and crop photosynthesis capabilities directly influence the CF in agriculture [7]. This is one of the biggest sources of GHG emissions, accounting for roughly 10–12% of the total global GHG emissions in 2005, but this value has increased to 13.5% by 2009 and to 18% by 2011. New solutions must be researched to advance sustainable agriculture tools that can overcome these issues [17].

2.2 Food process and Packaging

A complete food cycle requires activities starting from farming to harvesting followed by transfer, processing, packaging, distribution and disposal of faulty products. All these procedures need energy consumption while emitting anthropogenic greenhouse gases (GHGs) [18]. Food processing facilities

need large energy usage to run their heat systems as well as their cooling operations and machinery requirements. Often, this energy is obtained from fossil fuels, which results in CO₂ emissions [3]. Nitrous oxide emissions originate from food items made of different crops and the production of rice and animal-origin meat and dairy products produces methane emissions [1]. Packaging materials especially plastics and metals generate GHG emissions throughout their production cycle and waste management phase. The manufacturing processes require high amounts of energy while depending mostly on non-renewable resources [3]. Food production and its accompanying food preparation together with consumption operations accounts for more than 20% of all anthropogenic greenhouse gas emissions. Annually the food supply chain produces between 9800 million tonnes and 16,900 million tonnes of CO₂ which is expected to rise to 30 million tonnes by 2050. The Food and Agriculture Organization (FAO) of the United Nations states that meat emissions account for more than 20% of food waste carbon impacts [19].

2.3 Transportation and Logistics

The rise in carbon emissions generated from fossil fuels exceeded 90% since 1970 while combustion along with industrial activities created about 78% of worldwide carbon emissions [20]. The transportation sector uses vehicles that run on fossil fuels for material distribution from sources to processing plants and processed goods to markets thus creating CO₂ emissions. Refrigeration systems used in maintaining the cold chain of perishable goods consume significant amount of energy. In addition, some refrigerants used have high global warming potential if they leak into the atmosphere [3]. The International Energy Agency (IEA) confirms that transportation together with industrial emission and energy production remain as the fundamental sources of carbon emissions. The production of energy stands out as the biggest contributor for carbon emissions at 42% whereas transportation follows closely at 23% and industry contributes 19% [21].

The logistics sector generates 13% of global carbon emissions according to estimates from the World Economic Forum. As pioneers of global trade operations transportation and logistics functions play a key part in producing atmospheric carbon emissions [22]. Business cooperators want organizations to decrease environmental impacts stemming from broad-scale logistics network application because these operations depend on fossil fuels thus create substantial carbon pollution. The logical and transportation sector implements carbon-related management practices more often as a response to stakeholder pressure [23, 24]. The dual motive behind this practice exists as both an obligation to their stakeholders and an opportunity to enhance operational efficiency for financial benefits [25].

2.4 Retail and Consumption

Food loss and waste are a significant issue that negatively impacts social systems and environmental conditions [26]. These issues arise from inadequate harvesting timing, ineffective sorting, unfavorable weather conditions, insufficient processing facilities, and inefficient food storage. Economic value from these issues must align with social and environmental benefits. Food loss reduction requires collaboration between food producers, consumers, government agencies, media companies, waste management groups, environmental activists, and non-governmental organizations to balance financial value with environmental benefits [27]. For instance, cold chain development in sub-Saharan Africa could reduce postharvest food loss by 23%, but increased net food-related carbon footprints by 10% and 2% for North American and European configurations [28].

3. Mitigation Strategies for Reducing Carbon Footprint

In recent years, reducing GHG emissions has become a critical concern in the food chain. Many governments and organizations are making significant efforts to mitigate the negative impact of this phenomena. As the GHG emissions from the food chain, spanning from raw material harvesting to consumption is huge, so to reduce carbon footprint effectively sustainable agricultural practices is required and moderation in food processing techniques is necessary to achieve this [29]. In 2015, the food sector accounted for more than one-third of man-made GHG emissions. Carbon markets are a technique that persuades enterprises to cut their emission of greenhouse gas, to contribute to the global mitigation of the climate change [30]. These are used as a way of price carbon emissions. To address the carbon footprint of agricultural practices, cattlemen and women are encouraged to modify cattle nutrition, use a methane vaccine, and sequester carbon in the soil. Land carbon storage is more than 75% in soil, overestimating total contained carbon in the atmosphere and vegetation [31]. It is a critical approach to shorten the emissions path through soil carbon sequestration. The use of sustainable practices such as no till cultivation and maintaining vegetation cover can increase soil carbon sequestration rates. Compost made from vineyard waste can help sequester carbon in soil [10]. The cattle industry has long researched strategies to reduce ruminant methane emissions, and two viable methods are changes to diets and methane vaccine. The previous method of including nitrate and methane inhibitors into the diet, together with increasing dietary fat levels, has shown efficacy in substantially reducing intestinal methane emissions [32]. The latter technique involves methane vaccination, which has shown efficacy in lowering methane emissions by 5-20 percent via the suppression of methanogenic bacteria in the rumen.

Potential GHG emission reduction strategies for food manufacturers should include solving the direct emissions that an industry can control, indirect emissions generated by bought sources of energy, as well as a portion of passive emissions from sources throughout a company's value chain that it cannot directly control. These emissions are in accordance with the GHG protocol [29] and are known as Scope 1, Scope 2, and Scope 3. It is possible to reduce overall carbon footprint through effective energy management implementation in these regions. The first strategy entails looking into new and clean energy sources to achieve energy decarbonization [11]. COP 26 urges for the speedy termination of the usage of traditional fossil fuel that is no longer efficient, as well as for creating more renewable energy sources to accelerate the process of energy decarbonization [33]. This includes switching to renewable electricity or implementing on-site renewable energy solutions [34]. For example, to meet energy demand, procure renewable energy sources such as solar and wind energy, reduce truck trips annually by using electric trains to transport products, and develop a husk-coal blend to reduce coal consumption. The second technique aims to improve energy efficiency in processing and transportation [35]. Sixty to seventy percent of the total energy consumption occurs in food manufacturing operations in process heat [36]. To reduce power consumption, the industry uses process optimization techniques like adjusting production schedules, improving equipment controls, and adopting continuous processing methods. Pinch analysis can save 50% of thermal energy in milk powder production. Waste heat recovery involves recycling squandered heat through heat exchangers and storage containers. Waste heat recovery integrated with a conventional engine further reduces the power consumption and CO₂ emissions in the combined heat and power technology. Other techniques for improving the efficacy of the food processing with diminished use of energy include high pressure processing, ohmic heating, and microwave heating [3]. Carbon usage

during food processing can also help to reduce carbon emissions. It entails absorbing and repurposing CO₂ to produce useful new goods [37].

Food packing is crucial for reducing environmental impact. Factor like choice of material can impact greenhouse gas emissions [29]. For example, replacing glass with plastic for baby food packaging or metal cans with retorted cups for tuna. To reduce GHG emissions in transport and logistic, short food supply chain, focusing on localized production and dispersed manufacturing techniques, can improve energy efficiency in food distribution [38] This reduces transportation, storage, and refrigeration energy requirements [39,40].

4. Government Policies and Initiatives

Various Government policies are there that play an important role in measuring, monitoring and managing GHG emissions. These are given by various international organizations. ISO 14064, ISO 14067, PAS 2050, PAS 2060 and Greenhouse Gas Protocol are international standards for the measurement and control of greenhouse gas emissions [41,42,43,44]. These documents have unique aims and deals with various domains. The GHG Protocol is the first GHG accounting protocol, providing a framework for identifying direct and indirect emissions in the food industry's value chain, including Scope 1, Scope 2, and Scope 3 as discussed earlier [43]. The ISO 14064 is based on the GHG protocol. ISO 14067 is an addition to the ISO 14064 standard regarding the measurement and disclosure of carbon footprints of products. Although the Scope 1–3 classifications are not equivalent to the six groups of a company's emission sources as defined by ISO 14064, I used these. PAS 2050 is mostly focused on quantifying greenhouse gas emissions of product life cycles but PAS 2060 is more available to engage in greenhouse gas emissions to carbon neutrality for particular items or processes [45]. That is, the success of particular strategies depends upon the particular objectives, the resources available and the degree to which the food sector has decided to take strong action on emissions reduction and sustainability. The European Green Deal is the European Union's global plan to be climate free by 2050. This strategy also includes encouraging the adoption of sustainable forced systems through 'Farm to Fork' approach of the agroecological practices, reducing food loss and waste, and promoting healthier diets [46]. United Arab Emirates and the United States are jointly conducting the Agriculture Innovation Mission for Climate (AIM for Climate) [47]. It was launched in 2021 to influence changes in the climate change and global hunger paradigm, as it brings together participants to significantly raise investment in climate-smart agriculture and food systems innovation over five years (2021-2025). The initiative has been endorsed by over 800 partners, 56 countries, and has invested up to \$29.2 billion more through 2024 [48].

5. Alignment with Sustainable Development Goals

A global issue arises from the waste and loss of one-third of all human food production [49]. The global food waste amounted to 931 million tons during 2019 while household waste contributed about 570 million tons. Each year food waste production by the EU reaches 88 million tons while resulting costs total 143 million euros [50]. Three main types of costs stem from wasted food including financial losses alongside GHG emissions and resources depletion [51]. The United Nations created the 17 Sustainable Development Goals (SDGs) to describe sustainable development through numeric targets addressing its environmental and social and economic elements (UN, 2015). The present sustainable development goals framework does not feature food waste management as

an individual target. Several objectives and their associated targets include direct references to food waste even when dedicated SDGs about this issue are lacking. The main mission of SDG 12 "Ensure Sustainable Consumption and Production Patterns" is to reorganize consumer behaviour alongside production methods while reducing resource depletion for human and economic progress which could also imply reducing food waste [14].

The SDG number 13 targeting immediate climate change action stands out because most people consider climate change as a primary crisis of our era [52]. Agricultural practices remain among the main targets of climate change effects which are presently affecting existing food systems. Many adaptation and mitigation measures must be implemented for the food systems to achieve SDG 13. Food systems connect with multiple SDGs creating a substantial issue because these connections will most likely lead to competing priorities among the SDGs through specific food system activities [53]. Developing countries particularly face challenging trade-offs because climate vulnerability reaches its peak level in their nations. SDG 13 prioritizes two components by promoting resilience while integrating climate change solutions into national frameworks as well as monitoring financial climate action [15].

6. Conclusion

The food system requires lowering its carbon footprint in order to defend climate change and preserve sustainability. The food industry produces major greenhouse gas emissions throughout all stages of agriculture together with processing and packaging and distribution. The reduction of emissions becomes possible through improved production methods with low carbon technologies and food waste elimination. Sustainable food systems are a matter of government policy, international standards and consumer choices. Given these challenges, integration of technological change, regulatory change and behavioural change can enable meaningful progress. To create a low carbon, resilient, environmentally sustainable food chain there has to be another collective work from all stakeholders in this chain.

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Preparation of orange peel blende Nutri-Cereal Burfi and consequent analysis of antioxidant, nutrient, moisture, ash, pH, sensory, and cost

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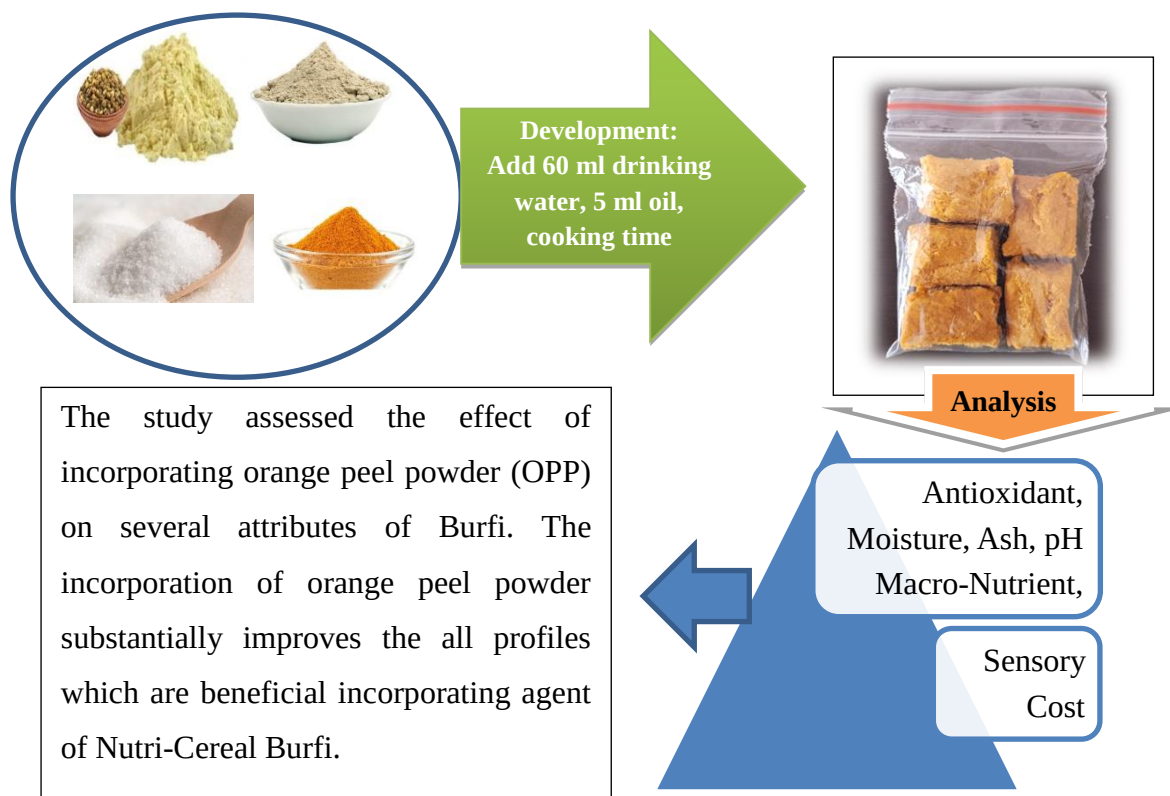
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Abstract

Nutri-Cereal Burfi (NCB) is an innovative product that is a healthy option for satisfying the sweet cravings of the general population. The study assessed the effect of incorporating orange peel powder (OPP) on several attributes of Burfi. Sample B, C, D, E, and F contain 0.5g, 1.0g, 1.5g, 2.0g, and 2.5g of orange peel powder, respectively. Increased ash content in Samples B, C, D, E, and F, as well as control, were 0.64, 0.69, 0.75, 0.86, 0.89, and 0.59, respectively, indicating that adding OPP greatly increased the mineral content. The acidity and moisture content showed only slight changes, staying largely constant throughout all samples, suggesting that OPP has little effect on these variables. Sample F, which contains the highest concentration of orange peel powder, exhibited the most notable improvements with a TPC value of 78.22 mg/g, TFC of 42.54 µg/g, DPPH of 36.41 % and ABTS of 41.67 % than the other samples. Sample F contains a high amount of carbohydrates (89.82g per 100 g). The sensory test indicated that the addition of OPP adversely affected the product's taste and aroma but not on price (14.95 INR per piece). In conclusion, the incorporation of orange peel powder substantially improves all profiles which are beneficial for incorporating the agent of Nutri-Cereal Burfi.

Keywords: Burfi, Antioxidants, Nutrient, Sensory, Cost.

Graphical Abstract:



1. Introduction

Burfi is one of the most famous traditional desserts in India. It is enjoyed by a considerable portion of the Indian population and is consumed by all age groups (Bhat et al. 2023). Manufacturing of burfi was limited to the domestic level only, but due to its unique taste, flavor, and texture, its popularity has increased internationally (Ganesan et al. 2022). Different ingredients like cashews, almonds, coconut, mango, orange, bottle gourd, potato, gram flour, and fig are used to prepare burfi. Indian heritage's social, cultural, and economic prospects have been significantly impacted by the traditional sweet and pastry items. Additionally, they positively impact people's nutritional health and are gaining popularity on a global scale. Burfi is the most popular sweet and is cherished by all because of its rich flavor and taste. There are numerous varieties of burfi available in the market, each having a unique composition and method of production (Balasubramanian and Shukla 2020). Since the sweet item is made on a small scale, regional variations in quality and recipe can be found, depending on consumer demand and cultural preferences. A major focus is on making bajra burfi with a high amount of bioactive compounds that help to maintain our good health (Balkrishna et al. 2024; Firdous Samreen and Anil B 2024). There are fewer studies on the production of value-added products using bajra. Therefore, a need was felt to utilize the bajra to make a variety of sweetmeats keeping in consideration various health benefits and nutritional aspects (Balkrishna et al. 2024). Phenolic compounds present in orange peel act as antioxidants (by either donation of protons or electrons) and protect cells against free radical damage as well as help in reducing the risk of many chronic diseases. Therefore, peels from citrus fruits can be used as sources of functional compounds

and preservatives for the development of new food products that are not only safe but also have health-promoting activities (Hegazy and Ibrahim 2012; Hazra et al. 2024; Chen et al. 2017). Therefore, the present study was formulated to (i) develop phytonutrient-rich rich Nutri-cereal burfi with extended shelf life and enhanced functionality and ii) evaluate the nutritional quality, and sensory profile.

2. Materials and methods

2.1 Raw materials and other equipment

All ingredients were purchased from the open-air local market at Haringhata (Lat Long 22°56'43.7" N 88° 32'38.7" E), Nadia in West Bengal.

2.2 Chemicals

All chemicals are analytical grade and purchased from SRL, and Mark, chemical suppliers which are registered suppliers in Maulana Abul Kalam Azad University of Technology, West Bengal, India.

2.3 Burfi preparation

At first, peels of orange were dried in a microwave oven at 450W for 3min because this microwave power level reach a high amount of bioactive compound (Nahar et al. 2022; Nahar, and Adhikari 2022; Kumari et al. 2023). After the peels were dried it was grounded in mortar and pestle to make powder. To make a sample of Burfi by using 12.5 g millet powder, 37.5g Bengal gram powder was stirred in the hot pan. Then 60 ml of drinking water and 60g of sugar were added to it and stirred continuously for 20 mins. Then 5 ml of hot refined oil was added and cooked until it properly separated from the pan. The procedure was repeated five more times by fortifying dried orange peel powder in the mixture with different quantities as 0.5g, 1g, 1.5g, 2g, and 2.5g and marking the sample as B, C, D, E, and F respectively. Control sample marked as A. Now the samples of Burfi were placed in a zipper bag and stored for further studies.

2.4 Nutritional analysis

The carbohydrate, protein, fat, moisture, pH, and ash content were analyzed following the procedure described by Nahar et al.(2024)

2.5 Antioxidant content

The extraction process was done by sonicating 1 g of the sample in 20 mL of 80% methanol for 30 minutes in a lab sonicator (Trans-O-Sonic/D150-IM, Mumbai). The solution was centrifuged for 10 minutes at 4°C at 8900 rpm in a high-speed centrifuge (Supra 22K, Hanil, Korea). After that, the Tarson tube will be used to collect the supernatant for additional analysis. Extracts' antioxidant content and antioxidant activity were assessed using the method outlined by Nahar et al. (2022); Saha et al. (2023); and Kumari et al. (2023).

2.6 Sensory evaluation

Prepared products were used as a subject for analysis of sensory parameters based on appearance, smell, taste, mouthfeel, color, and overall opinion. 9 (Nine) - A point hedonic scale was used where 1 (one) point is denoted as extremely dislike 9 (nine) points represented extremely like and 50-panel members were selected for sensory scoring (Nahar et al. 2023).

2.7 The selling price of the product

The food product cost was estimated based on food ingredients, labor, energy consumption, processing utensils, and transportation. 20% production cost added to the product allows for margin profit of vendor and producer (Nahar et al. 2023).

2.8 Statistical analysis

MINITAB 19.0 (Minitab, Inc., Pennsylvania, PA) was used for data analysis. All data was analysed the three times.

3. Results and Discussions

3.1 Nutritional profile

From this study, it was observed that orange peel improved the carbohydrate, protein and fat content of all Burfi. Moisture content of all Burfi samples were 2.63 ± 0.169 . High amount of ash (0.89 %), carbohydrate (91.17 g), protein (10.24 g) and fat content (7.74 g) present in sample F. Orange peel helps to increase the acidity of Burfi. The results of moisture, ash, pH, carbohydrate, protein and fat content were mentioned in Table 1.

Table 1: Analysis of nutritional profile and pH of Burfi.

Sample Name	Moisture (%)	Ash (%)	pH	CHO (g)	Pro (g)	Fat (g)
A	2.54 ± 0.002	0.59 ± 0.001	7.12 ± 0.004	89.82 ± 0.022	9.96 ± 0.011	7.58 ± 0.031
B	2.67 ± 0.002	0.64 ± 0.002	6.8 ± 0.002	90.09 ± 0.042	10.02 ± 0.013	7.61 ± 0.025
C	2.71 ± 0.002	0.69 ± 0.002	6.71 ± 0.002	90.36 ± 0.027	10.07 ± 0.009	7.64 ± 0.019
D	2.67 ± 0.002	0.75 ± 0.001	6.62 ± 0.005	90.64 ± 0.019	10.13 ± 0.015	7.67 ± 0.027
E	2.85 ± 0.002	0.86 ± 0.001	6.5 ± 0.003	90.9 ± 0.034	10.18 ± 0.017	7.71 ± 0.024
F	2.35 ± 0.002	0.89 ± 0.002	6.1 ± 0.004	91.17 ± 0.029	10.24 ± 0.012	7.74 ± 0.022

3.2 Antioxidant content and antioxidant activity

Antioxidants include vitamins C and E, total flavonoids, and total phenolic compounds. Total phenolic compounds are one of the most important groups of compounds occurring in plants which are interrelated with the antioxidant activity of the sample (Kaur and Kapoor 2002). ABTS and DPPH were a stable free radical compound and is widely used to test the free radical scavenging ability of various antioxidants (Saha et al. 2019). Incorporated orange peel help to enhance the antioxidant content and antioxidant activity of Burfi increases gradually with concentration (Table 2). From this study, it was observed that Burfi, total phenolic content range was 40.37 to 78.22 mg/g, flavonoid content range was 18.24 to 42.54 $\mu\text{g/g}$, and antioxidant activity like DPPH, and ABTS range were 14.76 to 36.41 % and 20.00 to 41.67%. Sample F have high amount of antioxidant content and antioxidant activity than the other samples. The antioxidant activity of total phenolic content might be due to their redox properties, which allow them to act as reducing agents, hydrogen donors, and singlet oxygen quenchers (Khan et al. 2022).

Table 2: Analysis of antioxidant content and antioxidant activity of Burfi.

Sample Name	DPPH (%)	ABTS (%)	TPC (mg/g)	TFC (Mg/g)
A	14.76±1.071	20.00±1.989	40.37±0.391	18.24±0.412
B	20.38±1.054	23.21±2.124	46.20±0.221	22.31±0.294
C	24.83±1.089	28.65±2.015	55.59±0.312	27.84±0.315
D	28.33±1.026	32.10±3.001	58.13±0.231	31.42±0.229
E	33.31±1.078	37.65±2.058	65.93±0.215	37.14±0.215
F	36.41±1.025	41.67±1.254	78.22±0.114	42.54±0.321

3.3 Sensory profile

The Burfi sensory profile was evaluated based on appearance, smell or aroma, taste, color, and overall opinion. The sensory acceptance level is measured at ≥ 8.0 on a nine-point hedonic scale. Overall acceptability rate high in sample F, Sample D, and E score is 8 out of 9 based on overall acceptability, i.e. less than sample F but greater than the others sample.

3.4 Cost analysis

The total production cost was approximately 14.95 INR per 50 g of Burfi, and the selling price of Burfi was 20 INR, so the profit was 5.05 INR of Burfi. The estimated production prices for the developed product were lower than the market product. By evaluating the result of the present study, it can be said that the Burfi fulfilled the nutrient recommendations of different age groups and also enriched with phytochemicals. Burfi made with locally available and affordable ingredients is used to replenish nutrient deficiencies of low socio-economic individuals.

4. Conclusion

The Burfi was formulated for different age groups from local food ingredients consisting of cereals, pulses, waste rich source of phytochemicals like orange peel. Those who cannot afford to buy some expensive delicious products available in the market can eat this food due to its advanced quality of nutrition. Burfi was prepared in this study can be easily developed at the village level at a low cost and that also can be a business opportunity for small-scale entrepreneurs. Further research is required for clinical trials.

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Impact of Nutrient Management and Varietal Choices on Productivity in Buckwheat-Green Gram Systems for Food Security

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Abstract:

Today, one of the biggest challenges currently humanity is facing is the decline of agricultural land and the growing population, leading to stagnant or decreasing productivity. This trend poses a potential threat to food and nutritional security of millions of people. To address these challenges, an experiment was conducted to study a resilient low input cropping system of buckwheat and green gram under different integrated nutrient management schedules. We studied the impact of three buckwheat varieties and four nutrient management schedules on the yields of buckwheat and the succeeding green gram grown on residual fertility. Our findings suggest that 50% organic substitution resulted in the highest buckwheat yield, while the highest yield of green gram was achieved with 100% and 50% organic nutrient substitution. The Shimla B-1 variety of buckwheat showed the highest yield, while the low-yielding VL Ugal-7 variety resulted in the highest yield of succeeding green gram. Despite the poor green gram yield obtained after the highest-yielding buckwheat variety, the Shimla B-1 variety resulted in the highest system yield which was 24.6% higher than the VL Ugal-7 due to higher income obtained from buckwheat. It was also found that integrating Vermicompost and Azotobacter as a source of organic nutrients with inorganic schedules can maintain a positive nutrient balance in the system. Overall, this study underscores the potential of a resilient buckwheat-green gram cropping system for low-input rainfed farming, offering valuable insights for promoting sustainable agriculture and such resource-limited management practices can add more pennies to the farm income and provide resilience to the farm under environmentally stressed conditions.

Keywords: Residual fertility; buckwheat; green gram; sustainability; food security.

Introduction:

In recent years, there has been a growing interest in alternative cereal sources for various reasons, including their nutritional benefits, adaptability to harsh environments, and potential for sustainable agriculture. Across the globe, there is an increasing awareness of healthy eating options and their incorporation into daily diets. One such underutilized crop with significant potential is buckwheat. Traditionally overlooked, buckwheat is highly valued for its rich nutritional composition and ability to thrive in harsh climatic conditions. Buckwheat grains are an excellent source of essential minerals, proteins, and amino acids (Dogra & Awasthi, 2009). The flour derived from buckwheat is particularly

rich in potassium, magnesium, calcium, phosphate, zinc, and iron (Gopalan et al., 1989). To maximize the benefits of buckwheat cultivation, appropriate cropping systems should be developed based on climate, soil type, and water availability. Such systems should aim to optimize the efficient use of natural resources while ensuring sufficient food supply for families, fodder for livestock, and income generation for farmers. Buckwheat's nutritional value is remarkable, as it contains a balanced combination of proteins, lipids, dietary fiber, and essential minerals. Compared to other cereal grains, its amino acid composition is superior, making it a valuable dietary component. Additionally, the health-promoting properties of buckwheat contribute to the prevention of several chronic diseases, including high cholesterol, hypertension, atherosclerosis, and diabetes (Yilmaz et al., 2020). Given its high nutritional value and adaptability, buckwheat presents a promising alternative to conventional cereal crops. Promoting its cultivation and consumption could play a crucial role in improving global nutrition and ensuring food security in challenging environments.

Materials and Methods:

A field experiment was conducted during 2015–16 and 2016–17 at the Instructional Farm of Uttar BangaKrishiViswavidyalaya, Pundibari, Cooch Behar, West Bengal, to assess the residual impact of integrated nutrient management applied to different buckwheat varieties on the subsequent green gram crop within the buckwheat–green gram cropping system. The experiment followed a split-plot design with three replications. The main plot treatments comprised three buckwheat varieties: Himpriya (V1), Shimla B1 (V2), and VL Ugal-7 (V3), while the subplot treatments included various integrated nutrient management strategies, namely 100% inorganic, 100% organic substitution, 50% organic substitution, and 25% organic substitution. The recommended dose of fertilizers (RDF) at 40:8.6:16.6 kg ha⁻¹ of N, P, and K was supplied through a fully inorganic NPK mixed fertilizer (grade 10:26:26) and urea in the 100% inorganic treatment. In contrast, the 100% organic treatment received the complete RDF through Vermicompost and Azotobacter. The data from the current experiment were analyzed using a multi-year combined analysis of variance (ANOVA) in a split-plot arrangement for two pooled cropping cycles, as described by McIntosh (1983).

Results and Discussion:

I. Yield parameters of buckwheat

The highest seed yield of buckwheat was observed in the Shimla B-1 variety, producing a 40.1% greater yield compared to VL Ugal-7. The Himpriya variety also recorded an 11% higher seed yield than VL Ugal-7. Among different nutrient management practices, integrated nutrient management with 50% organic substitution using vermicompost and Azotobacter led to an 18.7% increase in yield compared to the inorganic-only nutrient regime (Figure 1). Additionally, the complete replacement of inorganic nutrients with organic sources resulted in an 11.5% higher buckwheat yield than plots receiving only inorganic nutrients. Buckwheat, being a nutrient-demanding crop, requires a readily available and well-balanced nutrient supply. Inorganic fertilizers can effectively meet these demands in the short term (Martinez et al. 2022). Among organic options, vermicompost provides nutrients more quickly than farmyard manure, though its release rate remains slower than that of inorganic sources (Xue et al. 2022). Fully replacing inorganic fertilizers with organic sources led to poor buckwheat performance, as the slow nutrient release failed to meet the crop's peak demand.

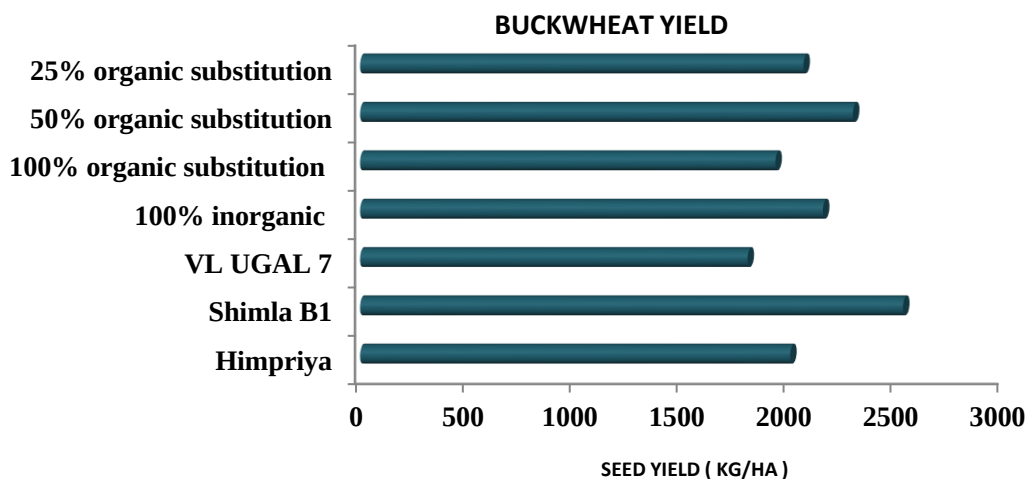


Figure 1. Impact of different buckwheat varieties and nutrient management schedules on seed yield of buckwheat.

II. Yield parameters of green gram

The seed and stalk yield of green gram were significantly affected by the residual influence of different buckwheat varieties and nutrient management practices applied to the preceding crop. The highest seed yield of green gram was observed following the VL Ugal-7 variety of buckwheat, showing a 10.2% increase compared to green gram grown after Shimla B1. Additionally, green gram cultivated after the Himpriya variety recorded a 5.5% higher seed yield than that grown after Shimla B1. The application of a fully organic nutrient regime to the preceding buckwheat crop resulted in a significantly higher seed yield of green gram (Table 1). A complete organic substitution led to a 26.4% increase in green gram yield compared to the fully inorganic nutrient regime, while a 50% organic substitution still enhanced yield by 12.7% over the inorganic-only approach. The highest stalk yield of green gram was also recorded when grown after the VL Ugal-7 variety of buckwheat, showing a 7.9% increase over Shimla B1. Organic supplementation of nutrients helps to release the nutrients slowly over seasons and these nutrient sources are therefore, less prone to nutrient losses from soil (Muhammad et al. 2019). The poor performance of an exhaustive crop in the system creates temporary nutrient surpluses, which can either be quickly utilized by the succeeding crop or lost through various pathways (Kumar et al. 2021 and Saha et al. 2023). Adequate nitrogen availability during the early growth stages of green gram is beneficial before active nodulation begins (Abd-Alla et al. 2014). These conditions can support early legume growth, leading to more vigorous plants and improved yields.

Table 1. Residual effect of integrated nutrient management on yield attributes and yield of mung bean under buckwheat–mung bean cropping system (Pooled data of 2 seasons)

Treatment	Seed yield (kg ha ⁻¹)	Straw yield (kg ha ⁻¹)	Harvest index (%)	Test weight (g)
<i>Buckwheat varieties</i>				
Himpriya	866 ± 29b	1949 ± 11a	30.82 ± 1.1a	41.26 ± 2.1a
Shimla B1	821 ± 38c	1865 ± 21b	30.56 ± 1.3a	40.98 ± 1.8a
VL UGAL 7	905 ± 51a	2012 ± 34a	31.16 ± 1.5a	41.29 ± 1.7a
<i>Integrated Nutrient Management</i>				
100% inorganic	755 ± 21d	1705 ± 17d	30.72 ± 1.5a	40.79 ± 1.2b
100% organic substitution	954 ± 44a	2192 ± 32a	30.34 ± 1.3a	42.77 ± 1.1a
50% organic substitution	895 ± 35b	2026 ± 24b	31.63 ± 1.6a	40.97 ± 0.7b
25% organic substitution	851 ± 28c	1841 ± 31c	30.68 ± 1.6a	41.18 ± 1.3b
<i>Interaction</i>				
	S	S	NS	NS

Note: Values sharing same letters are statistically at par at $p < 0.05$; S: Significant; NS: Non-significant.

III. Economics

From an economic perspective, the highest gross return from the buckwheat crop was recorded for Shimla B-1, which was 28.7% higher than VL Ugal-7 (Table 2). However, green gram yielded the highest gross returns when grown after VL Ugal-7, surpassing Shimla B-1 by 10.25%. Overall, the combined gross returns from the system were highest for Shimla B-1, leading to the greatest net returns and benefit-cost ratio (B:C) (Table 2). Shimla B-1 achieved a remarkable 40.1% higher net return from the system compared to VL Ugal-7. Both crops exhibited distinct responses to different nutrient regimes. Buckwheat achieved the highest gross returns when grown with a 50% organic substitution in nutrient inputs, whereas a complete 100% organic substitution resulted in the lowest returns. In contrast, green gram performed best under 100% organic substitution, benefiting from the residual fertility left by buckwheat and achieving the highest gross returns. Overall, the highest system gross return was recorded with a 50% organic substitution in the nutrient schedule.

A similar trend was observed in net returns. A 100% organic substitution resulted in the lowest net returns, which were 20.9% lower than those from a 50% organic substitution, primarily due to higher costs. The highest benefit-cost ratio (B:C) was recorded under 100% inorganic fertilization, though it was statistically similar to the 50% organic substitution treatment.

Table 2. Economic analysis of the Rainfed Buckwheat-Green Gram cropping system (Pooled data of 2 seasons)

Treatment	Return from Buckwheat (USD ha ⁻¹)	Return from Green gram (USD ha ⁻¹)	Gross return (USD ha ⁻¹)	Net return (USD ha ⁻¹)	B:C
Buckwheat varieties					
Himpriya	1644 ± 124b	649 ± 54b	2294 ± 123b	1022 ± 56b	2.17 ± 0.31bc
Shimla B1	2076 ± 165a	616 ± 12c	2691 ± 203a	1274 ± 87a	2.71 ± 0.22a
VL UGAL 7	1481 ± 179c	679 ± 34a	2160 ± 167c	909 ± 67c	1.93 ± 0.19c
Integrated Nutrient Management					
100% inorganic	1769 ± 157b	566 ± 39d	2336 ± 108b	1047 ± 71b	2.30 ± 0.19a
100% organic substitution	1588 ± 145c	715 ± 28a	2303 ± 129b	892 ± 49c	1.47 ± 0.12c
50% organic substitution	1884 ± 187a	638 ± 54c	2522 ± 156a	1128 ± 65a	2.28 ± 0.20a
25% organic substitution	1695 ± 172bc	671 ± 45bc	2366 ± 109b	996 ± 44b	1.87 ± 0.16b
Interaction					
	S	S	S	S	NS

Note: Values sharing same letters are statistically at par at $p < 0.05$; S: Significant; NS: Non-significant.

Conclusion

Under challenging environmental conditions, growing green gram without fertilizer or manure inputs is feasible. When cultivated after suitable buckwheat varieties within an integrated nutrient management system, it can serve as a sustainable option. Integrating vermicompost and Azotobacter as organic nutrient sources alongside inorganic fertilizers helps maintain a positive nutrient balance in the system. In contrast, relying solely on inorganic fertilizers led to nutrient depletion when two

crops were cultivated. These resource-efficient practices not only enhance farm resilience under environmental stress but also contribute to increased farm income.

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Incorporation of Protein Isolates and Concentrates for meat analogues: A Comprehensive Review of Production, Nutritional, and Environmental aspects

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Abstract

Global dietary transitions toward plants have sparked the creation of meat analogues that duplicate both the taste and dietary value of conventional animal meat. This protein transition relies on plant protein isolates and concentrates to provide sustainable ethical animal protein alternatives. Plant proteins derived from soybeans, peas, wheat and almonds contain high quantities of protein coupled with minimal fat and carbohydrates. Meat analogues gain better nutritional make-up and functional performance when these proteins are used for integration. Protein isolates with an active protein content exceeding 90% serve as a usable protein ingredient for shaping specified textures or flavors. These proteins synergize with protein concentrates that normally consist of 60-85% protein content to combine beneficial performance properties with economic considerations. Soy protein isolates offer exceptional versatility leading to meat-like fibrous textures yet pea protein isolates present a mellow taste without common allergenic responses. Achieving appropriate meat analogue texture remains a crucial challenge. High-moisture extrusion and fibre alignment serve as developed methods to handle this concern. The high-moisture extrusion process employs steam pressure to break down plant proteins which generates a fibrous assembly. Mechanical processing used for fibre alignment creates protein fibre arrangements which produce tissue structures identical to those found in muscle. Protein isolates and concentrates contain essential amino acid blends and vital minerals with vitamins which can become enhanced with necessary nutrients for meeting unique dietary specifications.

Keywords: Meat analogues; Plant proteins; Protein isolates; High-moisture extrusion; Fibre alignment; Nutritional enhancement;

1. Introduction

The increasing market need for environmentally-friendly food options has generated substantial interest toward developing alternative protein alternatives which particularly focus on meat analog products. The exponential growth of the human population and mounting environmental concerns from traditional animal agriculture has generated a need to develop various protein isolates and concentrates from diverse sources [1]. Producers trying plant-based options and protein alternatives made protein isolates and concentrates into a fundamental method for creating high-quality meat substitutes. The production of meat analogs depends significantly on

these protein components which exist in various plant and microbial and newly developed sources to replicate the characteristics of conventional meat products [2]. The combination of environmental aspects together with moral principles and consumer dietary needs leads consumers toward alternative animal-free protein sources. Manufacturing protein isolates and concentrates for meat substitutes presents a viable alternative protein choice with good digestibility and suitable characteristics. The existing challenges involve improving the processing techniques and developing better sensory qualities as well as ensuring raw material sustainability [3]. This research investigates protein isolates and concentrates in meat substitute production through a complete analysis of functional properties and environmental and nutritional results. The paper examines protein origin points alongside manufacturing methods and addresses how these influences outcome quality alongside market reception. A thorough evaluation of sustainability outcomes follows in the text regarding alternative proteins in meat analogue production through analyses of resource optimization and carbon dioxide emissions reduction and waste management metrics. Research of this type enables better prediction of plant-based and alternative protein technology developments throughout the food sector [4].

2. Production of Protein Isolates and Concentrates

2.1. Protein Sources

2.1.1 Plant-based sources

Advantage of using plant protein isolates concerns their fat reduction potential, in particular saturated fats, compared to animal proteins. Excessive consumption of saturated fats is linked to unfavorable health problems such as cardiovascular disease. On the other hand, it has been shown that protein isolates derived from nuts and seeds provide healthy unsaturated fats, with a more favorable lipid profile for those seeking to maintain cardiovascular health.

2.1.1.1 Soy Protein

Soy protein isolate stands as a widely produced plant-based protein isolate because it contains more than 90% protein content. The protein content of protein concentrate stands at around 70% according to general standards. Drinking water or alkaline solutions extract protein content from both dehulled and defatted soybeans. A powder results after the separation and purification of the production process followed by drying. Soy protein provides all necessary amino acids which makes it suitable for use in plant-based meat products and protein powders as well as dairy alternatives like soy milk and nutritional snacks [5].

2.1.1.2 Pea Protein

The protein content of standard pea protein isolate reaches between 80 to 90 percent. Various studies show that pea protein concentrate contains between 50 to 60 percent protein content. The manufacturing of peas involves cleaning procedures followed by dehulling before grinding the product. The extraction process of protein from wet milling techniques leads to separate isolation methods consisting of water-based extraction or dry fractionation. Multiple food items such as plant-

based meat products with burger and sausage shapes and protein drinks along with snack meals and baked goods widely incorporate pea protein. Pea protein production needs additional proteins like rice to achieve complete amino acid content [6].

2.1.1.3 Wheat gluten protein

The wheat gluten protein isolate contains between 85% of wheat protein (gluten). Washing starch out of wheat flour dough remains the standard method to obtain gluten for extraction. The gluten extraction process requires wheat flour mixture with water followed by intensive starch washing. Scientists have established methods for both gluten separation and concentration advancement. Manufactured through the process of wheat protein extraction seitan serves as a main meat substitute in vegetarian and vegan products. The ingredient also appears in various processed foods as well as baked goods [7].

2.1.1.4 Rice Protein

The protein content found in rice protein isolate extends between 80–90 percent. Rice protein concentrate consists mainly of 60% protein by weight. The production method includes milling rice to extract protein then using mechanical or enzymatic extraction systems for processing. The manufacturing of rice protein powder takes place following protein drying procedures. Companies produce rice protein through bars together with drinks and protein-powder and meal-replacement products. Pea protein serves as an addition to rice protein for enhancing both its quality profile and amino acid characteristics [8].

2.1.1.5 Faba bean protein

The protein content in faba bean protein isolate reaches between 80–90 percent while faba bean protein concentrate typically contains 50–60 percent of protein. The extraction process occurs after faba beans become powdered and dehulled to productively separate the protein component. The protein goes through drying before the product is transformed into powder. Plant-based meat products along with high-protein snacks and drinks use faba bean protein as an essential component. Research indicates that lysine exists in this plant protein at beneficial amounts because this essential amino acid is commonly absent from other plant sources [9].

2.1.1.6 Lentil protein

Most lentil protein isolate contains between 60 and 90 percent protein content. The protein content in lentil protein concentrate amounts to 40–50% on average. Lentils require dehulling then grinding followed by processing steps to obtain protein extraction. Lentil protein extraction can be conducted through either wet or dry methods of processing. The consumption of protein-rich products from lentil ingredients includes proteins derived from both snacks and drinks and substitutes for meat. Lentil protein offers exceptional improvement to plant-based protein blends because it contains essential amino acids at high concentrations [10].

2.1.2 Microbial and fungal sources:

2.1.2.1 Mycoprotein

Mycoprotein is a kind of fungal protein that comes from the filamentous fungus *Fusarium venenatum*. It is made via fermentation and has grown in popularity as a high-quality, sustainable plant-based protein source, especially for vegan and meat alternative goods. Mycoprotein is a very feasible choice for the synthesis of protein isolates and concentrates due to its distinct composition and several benefits in terms of nutritional value, texture, and functional qualities [11].

2.1.2.2 Algae

The increasing recognition of algae proves them to be a sustainable protein supply particularly for protein isolates and concentrates. The two main categories of algae are microalgae which include *Chlorella* and *Spirulina* as well as macroalgae which contain Kelp and Nori seaweeds. The food and supplement industries give precedence to microalgae over macroalgae because microalgae yield higher protein rates when used for extract production [12].

2.2 Nutritional Aspects of Protein Isolates and Concentrates

The incorporation of protein isolates and concentrates within meat analogues leads to sustainable and nutritious meat alternative development. The proper application of protein isolates and concentrates demands complete knowledge about their amino acid makeup together with digestion capabilities and suitable fortification methods and health-related consequences.

2.2.1. Amino Acid Profile and Digestibility

2.2.1.1 Bioavailability and Digestibility Concerns

Anti-nutritional factors including phytates and tannins together with trypsin inhibitors affect the digestibility and bioavailability of plant-based proteins. The presence of these compounds in plant-based proteins reduces amino acid and essential mineral absorption which results in decreased protein utilization within the body [13]. Heat processing and enzymatic hydrolysis and fermentation methods enhance plant protein isolate digestibility by diminishing their numbers of unfavorable anti-nutritional substances. Through fermentation the protein structures become more digestible since complex structures break down into accessible forms.

3. Techniques Employed in Texturization for Production of Meat Analogues

3.1 Extrusion

Plants use extrusion technology as a common fabrication approach to develop meat-like textures. Through this process proteins in dough are strained under controlled temperature and pressure while

undergoing shear forces which subsequently aligns the protein structures to match meat fibrousness. HMEC extrusion cooking techniques prove most effective when producing food textures that replicate animal meat characteristics. Because this method effectively converts proteins and polysaccharides into fibrous forms [14].

3.2 Shear Cell Technology

Shear cell technology represents a new approach to develop protein fibers with structures which simulate meat components. The technique employs shear force in combination with heat to support protein fiber formation as an equivalent method to extrusion process [15]. The efficient process of protein fiber alignment using this technique has become essential for meat analogs research.

3.3 3D Printing

The process of three-dimensional (3D) printing allows users complete control over dimensional characteristics and structural details in meat analog production. The protein-based formulation printing method allows generation of intricate products which provide authentic meat like sensory experiences [16]. Researchers conducted recent investigations into the utilization of plant and animal proteins in creating soft-textured hybrid meat analogues through 3D printing methods.

3.4 Fibre Spinning

Fibre spinning represents a production method used for transforming plant proteins into fibrous forms for texturization. The process here entails making fibers by spinning protein solutions before assembling them to achieve meat-like texture [17]. Properties of plant proteins experience texturization through various techniques including extrusion and spinning and freeze structuring and 3D printing and simple shear flow.

3.5 Functional Properties in Meat Analogues

Meat analogues succeed from structural mimicry of meat alongside functional properties that regulate texture and juiciness and affect the sensory dimension.

3.5.1 Gelation, Emulsification, and Water-Holding Capacity

The essential property of proteins to shape gel-based networks allows them to trap water molecules leading to firmer and cohesive meat analogue textures. Emulsification enables a product to maintain stable oil-water mixtures which ultimately results in juicy mouth feel along with the desired juiciness of the final product. Plant-based and analog products need water-holding capacity to hold moisture during cooking which guarantees both succulence and prevents dryness. Plants proteins need these functional capabilities to produce meat replacements that duplicate animal meat textures.

3.5.2 Texturization and Binding Properties

Texturization involves modifying the protein structure to achieve a fibrous, meat-like consistency, as discussed in the extrusion and shear cell technology sections. Binding properties are essential to ensure that the various components of the meat analogue adhere together, maintaining structural integrity during processing and cooking [18]. Proteins with good binding properties help in forming a cohesive product that can withstand handling and thermal treatments. Understanding and optimizing these functional properties are vital for creating high-quality meat analogues that meet consumer expectations.

Table 1: Production of meat analogue by incorporating protein isolate and concentrates

Source of protein isolate & concentrate	Percentage	Technique employed	Process condition	Functional properties	Reference
1.Soy Protein Isolate (SPI)	~90%	Alkaline extraction & isoelectric precipitation	pH 9-11, 40-60°C	Gelation, emulsification, water-holding capacity	[19]
2. Pea Protein Isolate	~80-85%	Dry/Wet fractionation	Mild temperature & aqueous process	Solubility, viscosity, foaming	[20]
3. Wheat Gluten	~75-80%	Wet milling	Washing & separation of gluten	Elasticity, extensibility, water absorption	[21]
4. Rice Protein Isolate	~80%	Enzymatic hydrolysis	Enzyme-assisted alkaline extraction	Solubility, digestibility, foaming	[22]
5. Potato Protein Isolate	~85%	Heat coagulation & membrane filtration	Thermal separation	Gelling, emulsification	[23]
6. Mycoprotein	~60-70%	Fermentation	Controlled pH & temperature	Fiber-like structure, water retention	[24]
7. Lupin Protein Concentrate	~50-60%	Aqueous extraction	Neutral pH, low-temperature drying	Emulsification, gelation	[25]

8. Faba Bean Protein Isolate	~80%	Air classification	Dry fractionation	Solubility, emulsification, foaming	[26]
9. Sunflower Protein Isolate	~85%	Enzymatic-assisted extraction	Mild pH, enzymatic hydrolysis	Emulsification, solubility	[27]
10. Chickpea Protein Concentrate	~60-65%	Dry/Wet fractionation	Mild thermal processing	Foaming, water-holding, emulsification	[28]

4. Changes in Nutritional aspect

4.1 Protein content & amino acid profile

4.1.1 Protein content

Protein isolates are very pure proteins that contain at least 90% protein by weight. They significantly increase the total protein content when added to meat substitutes. For example, soy protein isolate typically contains a protein content of 90–95%, while pea protein isolate has similarly high protein content [2]. Less processed than isolates, protein concentrates typically contain 60–85% protein by weight. While not as high as for isolates, protein concentration will increase with the inclusion of protein concentrates. For example, approximately 65–70% of soy protein concentrate is protein.

4.1.2 Amino acid

The type of source of protein (soy, pea, rice, etc.) will also contribute to the amino acid profile in the protein meat substitute. Many plant-based protein isolates, such as soy and pea, are considered complete proteins because they provide each of the nine essential amino acids in adequate amounts. If not combined with other protein sources, the limiting amino acids present in some plant proteins, such as methionine in legums, can result in an unbalanced amino acid profile.

4.2 Vitamin & minerals enhancement

4.2.1 Vitamin

Pea protein contains vitamin B1 (thiamine) and vitamin B3 (niacin), whereas soy protein contains folate (B9) and vitamin B6. To fulfill vegan requirements, fortification with B12, often sourced from microorganisms, can also be added. While vitamin D2 and D3 derived from lichen may be used in food additives, vitamin D does not exist naturally in appreciable amounts in proteins from plant foods. Beta-carotene in plant proteins such as sweet potatoes is converted into vitamin A. Alternatively, it can be through retinol fortification. Though soy protein has trace amounts of vitamin E, alpha-tocopherol is often added as a fortifier.

4.2.2 Minerals

Non-heme iron is found in soy and pea proteins. Treatment with iron salts (such as ferrous sulphate), often in overt amounts, raises the levels for vegetarians. Soy and pea proteins contain zinc, although the zinc may not be as bioavailable. Zinc levels can be raised by adding zinc salts, for example, zinc gluconate. Meat substitutes represent an excellent dairy calcium replacement substitute, because protein soy can supply some of that calcium if enriched. It is enhanced through fortification and thoughtful application of plant-based sources of proteins to satisfy dietary requirements through meat substitutes' nutritional richness.

5. Future prospective & Challenges

Innovations in protein structuring for improved texture and taste

The textural characteristics determine how consumers accept such food products. Research has proven that producing factory-made plant-based alternatives that imitate both chopped meat texture and whole cut juiciness represents an ongoing manufacturing challenge. The development of plant-based meat formulations through extrusion process combined with fermentation techniques works to achieve meat-like texture experiences that match animal protein eating experiences. Texturization techniques for plant-based proteins include high moisture extrusion, shear cell technology, and 3D printing. The former creates fibrous structures that may mimic meat muscle fibers. Shear cell technology produces layered, fibrous textures. 3D printing builds layers of plant proteins, giving precise control over texture. Protein blends, for example, isolates, soy, pea, and rice, may balance amino acid profiles in complementary blends for enhancing texture and mouth feel. Molecular cross linking and gel formation improve texture by producing stronger protein networks; gelling agents, such as alginates or agar, provide firm, stable textures [30]. It involves fermentation to create complex flavors which are reminiscent of meat, enhance the sweet and savory "umami" taste, and improve upon the digestibility and nutrient profile of plant-based proteins. Controlling the Maillard reaction can create browned, roasted flavors which are characteristic of cooked meat. Fat mimicry uses plant-based fats such as coconut oil and canola oil to be combined with proteins to enhance mouth feel and juiciness.

Enhancing consumer acceptance through sensory and nutritional optimization

The acceptance process for consumers becomes increasingly confusing because of their thoughts about the environment. The desire for sustainable eating habits drives consumers toward adopting containeous plant diets according to (LIMA et al., 2022). The meat analogue is enhanced by sensory optimization. Fermentation and umami-rich ingredients enhance the savory taste and aroma. High moisture extrusion and shear cell technology mimic the fibrous texture of meat. Plant-based fats such as coconut oil and canola oil enhance juiciness and flavor [31]. It covers complete protein blends, micronutrient fortification, and process technologies to ensure that antinutrients like phytates and lectins are minimized during processing to adequately meet the nutrition needs of plant-based diet consumers.

Policy and regulatory considerations for protein ingredient use

The regulatory frameworks create additional obstacles which impact the meat analog industry. International manufacturers face hurdles because regulatory systems between different geographical areas maintain substantial differences. GRAS Status or Generally Recognized as Safe, Regulatory Approval and Food Safety Isolation of proteins from rice, soy, and peas, protein isolates from a safety point of view are assessed. Some of them might be GRAS, but most will need some form of approval from the FDA or EFSA for other components or different processing techniques [32]. Novel Foods Regulations Before a new source of protein could be sold in the EU, it may have to undergo a Novel Food clearance process to ensure that it meets safety and nutritional standards.

6. Conclusion

In addition, sustainability considerations are becoming increasingly prominent in the analog sector of the meat. The challenge lies not only in minimizing environmental impacts during production, but also in addressing the sustainability of materials used for isolate and protein concentrates. Research is directed to the development of alternative protein sources that require fewer resources and have a lower carbon footprint compared to conventional crops (Ismail et al., 2020). Protein isolates and concentrates incorporated in meat analogues offer a significant solution to increase the production level of plant-based alternatives, for which demand has been rising considerably. These proteins improve the nutritional profile with all the characteristics such as complete proteins, essential amino acids, and the potential fortification with added vitamins and minerals. Advanced techniques like extrusion, cross linking, and 3D printing can improve the texture and mouth feel of meat analogues in order to approach the characteristics of traditional meat products. However, there are concerns about allergenicity, antinutritional factors, and regulatory requirements that need to be addressed. Yet, the positive impacts of such innovations increased sustainability, consumer acceptance, and dietary diversity make protein isolates and concentrates a valuable ingredient in plant-based food production in the near future.

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Study on Drying Kinetics and Energy Consumption During Microwave Drying of Green Banana Peel (*Musa* spp.)

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Abstract:

Globally, India is the leading producer of banana (*Musa* spp.) which is a highly perishable tropical fruit. So, large amount of banana peel is thrown away as a waste. However, banana peel has a huge potential to be used in various food products due to its health beneficial properties. Drying technique can be employed to preserve banana peel. Recently, microwave oven drying is gaining attention due to certain features like easy handling, shortened time of drying, lesser occupation of space, energy saving and improved product quality. Green banana peels were pretreated with 1% KMS at 65°C for 5 mins prior to microwave drying at 360 W, 540 W and 720 W. Results show that, increase in microwave power reduced the drying time from 630 sec to 300 sec. 9 empirical models were applied to understand the thin layer drying characteristics of green banana peel drying. Results revealed that the Demir et al. model [13] was most suitable due to its lowest root mean square error (RMSE) value. The effective moisture diffusivity (D_{eff}) ranged from 3.2693×10^{-9} to 7.1108×10^{-9} m²/s. The activation energy (E_a) was estimated to be 96.376 W/gm. The energy consumption and specific energy consumption decreased with increasing power level. The microwave power level of 540W consumed the least energy amongst the three power levels.

Keywords: Green banana peel, microwave oven, thin layer modelling, activation energy, energy consumption

1. Introduction:

Around 45% of the total crops produced are wasted worldwide [18]. Generally, the agricultural wastes are generated during harvesting in the field (14.4%), post-harvest processing (6.9%), industrial processing (8.5%), distribution (7.1%) and consumption (8.8%) [18]. Grown in more than 112 countries, bananas (*Musa* spp.), including plantains, are the second most important fruit crop after citrus, constituting up 16% of global fruit cultivation [10]. India being one of the largest producers of banana generate huge amount of waste and by-products of banana from food industry, household and market. However, banana peel has a great potential to be used in functional foods as it exhibits health beneficial properties. Banana peel is a dense source of dietary fiber, resistant starch, polyunsaturated fatty acids, amino acids, polyphenols, carotenoids, catecholamine and potassium [16]. Given the rising prevalence of diabetes, obesity, and cardiovascular conditions, bananas may be an effective food for lowering cholesterol, reducing constipation, and preventing colon cancer [19]. So, to promote banana peel intake and improve human health, a new economic approach is to turn green bananas peels into dried flour and use the flour in a variety of functional foods [19]. Drying is

a widely used preservation method which involves partial or complete elimination of water from food materials [4]. It lowers water activity, postponing degradation and contamination during storage period [3]. In addition to reducing water activity, drying also impacts the functional, physicochemical, and sensory aspects of food products [14]. Over the years several drying methods have been developed for drying fruits and vegetables [6]. Microwave oven is one such emerging drying technology which has gained attention recently. Microwave offers volumetric heating by targeting even the smallest amount of moisture within the food matrix, raising the internal temperature and accelerating the evaporation [2]. It is advantageous over other drying methods due to certain salient features such as, shorter drying time, easy handling, lesser space consuming, energy saving and better product quality [9]. In this study the drying kinetics, activation energy, energy and specific energy consumption during microwave drying of green banana peel is observed. It is done to investigate the effect of microwave power level on drying characteristics of green banana peel.

2. Materials and Methods:

2.1 SAMPLE PREPARATION:

Green bananas were purchased from the local market in Kolkata. The fruits were washed and peeled using a peeler. Then the peels were cut into thin slabs of 2.26 mm. The peels were blanched with 1% potassium metabisulphite (KMS) at 65°C for 5 mins. The banana peel slices were then dried at three different microwave power level of 360W, 540W and 720W using a microwave oven (Model No.-EF28CBGK-MGZ, Electrolux, Aurangabad, India). The dried samples were packed in airtight plastic bags and stored at 4°C for further analysis.

2.2 DRYING CHARACTERISTICS

Moisture content of the green banana peels was estimated using the following equation [17]:

$$M_t = \frac{W_t - W_{dry}}{W_{dry}} \quad (1)$$

Where, w_t was the weight of sample at time t , w_{dry} was the weight of dry matter in the sample and M_t was the moisture content of the sample (Kg of water/ Kg dry matter).

The Moisture ratio (MR) of the sample was calculated as follows [5]:

$$MR = \frac{(M_t - M_e)}{(M_0 - M_e)} \quad (2)$$

M_e , M_0 and M_t represented equilibrium moisture content and moisture content at time 0 and t respectively.

Effective moisture diffusivity (D_{eff}) for the slab geometry of green banana peel was determined using the equation [17]:

$$\ln(MR) = \ln\left(\frac{M_t}{M_0}\right) = \ln\left(\frac{8}{\pi^2}\right) - \left(\frac{\pi^2}{4L^2} D_{eff} t\right) \quad (3)$$

Where L was the half thickness of the sample (1.13 mm). Equilibrium moisture content was negligible hence, ignored.

Thin layer drying models are usually used to analyze the drying kinetics of vegetables and fruits [7]. The drying data of green banana peel at three different microwave power level were fitted using 9 empirical drying models presented in Table (1). Where, t was time in sec, k represented drying rate constant (min^{-1}) and a,b,c were all termed as constants.

The most suitable model was adjudged by considering the minimum value of the root mean square error (RMSE). The RMSE was calculated by using the equation below [7]:

$$\text{Root mean square error (RMSE)} = \sqrt{\frac{\sum_{i=1}^n (x_i - \hat{x}_i)^2}{N}} \quad (4)$$

Moreover, in order to compare the model results and choose the modeling equation most appropriate for this investigation, Akaike's information criterion (AIC) and the Bayesian information criterion (BIC) were used [12]. The AIC and BIC equations are as follows:

$$AIC = n * \ln\left(\frac{RSS}{n}\right) + 2k \quad (5)$$

$$BIC = n * \ln\left(\frac{RSS}{n}\right) + k \ln(n) \quad (6)$$

Where, n denoted the number of observations and RSS was residual sum of square.

2.3 ACTIVATION ENERGY:

Activation energy is crucial to drying process modeling and optimization and is strongly influenced by the thermal energy and moisture content of the sample [15]. The Arrhenius equation demonstrates the relationship between the temperature and activation energy (E_a). As, microwave drying usually depends on power level, so, the Arrhenius equation is modified and described below [12]:

$$D_{\text{eff}} = D_0 \exp\left(-\frac{E_a m}{P}\right) \quad (7)$$

Where, D_0 was pre-exponential constant (m^2/s), E_a denoted activation energy (W/gm), m was mass of the sample (gm) and P was termed as Power (Watt).

2.4 ENERGY CONSUMPTION AND SPECIFIC ENERGY CONSUMPTION:

The energy consumption during microwave drying and specific energy consumption of different power level is calculated using the equations below [11]:

$$E_c = \frac{P \cdot t}{36,000,00} \quad (8)$$

Where, E_c was the energy consumption (kWh), P was the power (Watt) and t was the drying time (sec).

$$E_c^* = \frac{E_c}{m} \quad (9)$$

Where, E_c^* was the specific energy consumption (kWh kg^{-1}), m was the water released (kg).

2.5 STATISTICAL ANALYSIS:

Nonlinear regression analysis of MR data for each microwave power level have been observed in Minitab 17.0 (Minitab, Inc., Pennsylvania, PA)

3. Result and Discussion:

3.1 DRYING BEHAVIOR:

The study revealed that the drying process required 630 sec, 390 sec and 300 sec to complete at power levels of 360W, 540W and 720W respectively (Fig. 1). The increase in power level decreased the drying time. Fig. (1) displays the MR vs Drying time graph which shows that the speed of moisture evaporation decreases as the drying time progresses. It was noted that the moisture elimination largely happened in the falling rate period of the drying process. The falling rate period can be denoted by the effective moisture diffusivity (D_{eff}). The effective moisture diffusivity ranged between $3.2693 \times 10^{-9} \text{ m}^2/\text{s}$ to $7.1108 \times 10^{-9} \text{ m}^2/\text{s}$ (Given in Table 2.). The effective moisture diffusivity increased with increasing the power level. Similar results were observed in microwave and microwave convective dried pomelo [20].

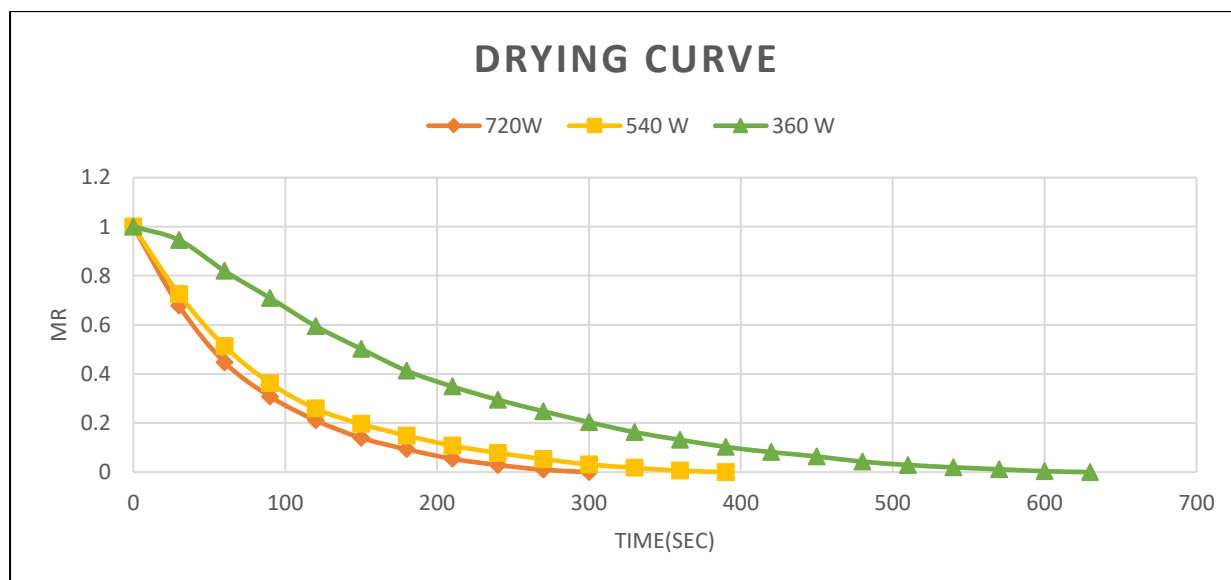


Fig. 1: Drying curve of MR vs Time (Sec) for green banana peel dried at 3 microwave power level of (a) 720 W, (b) 540 W and (c) 360W.

Thin layer drying models can be classified into 3 groups namely, theoretical, semi-theoretical and empirical models. The empirical and semi-theoretical models are often used to analyze the drying behavior [7]. In this investigation, 9 empirical models were utilized to observe the drying characteristics of green banana peel. The thin layer drying models used in this study along with the statistical analysis is described in Table (1). The results showed that the Demir et al. model [13] was the best fitted one as it exhibited the minimum root mean square error value in all the microwave power level.

Table 1. Statistical Analysis of Different Thin Layer Drying Models [17, 13]:

Processes	Model: Lewis Equation: $MR = \exp(-kt)$								
	k	a	b	c	n	Intercept	AI C	BI C	RMSE
360 W	0.0051	-	-	-	-	-	- 67. 2	- 65. 1	0.0455
540 W	0.011	-	-	-	-	-	- 83. 2	- 82. 1	0.0088 1
720 W	0.0133	-	-	-	-	-	- 59. 4	- 58. 8	0.0107
Processes	Model: Page Equation: $MR = \exp(-kt^n)$								
	k	a	b	c	n	Intercept	AI C	BI C	RMSE
360W	0.000996	-	-	-	1.3	-	- 127	- 124	0.0108
540W	0.011	-	-	-	1	-	- 81. 2	- 79. 5	0.0092
720W	0.0116	-	-	-	1.03	-	- 59. 3	- 58. 4	0.0103
Processes	Model: Modified Page Equation: $MR = \exp(-kt)^n$								
	k	a	b	c	n	Intercept	AI C	BI C	RMSE
360W	0.0049	-	-	-	1.3	-	- 127	- 124	0.0108
540W	0.011	-	-	-	1	-	- 81. 2	- 79. 5	0.0092
720W	0.0132	-	-	-	1.03	-	- 59. 3	- 58. 4	0.0103
Processes	Model: Henderson Pabis Equation: $MR = a \exp(-kt)$								

s	k	a	b	c	n	Intercept	AI C	BI C	RMSE
360W	0.00594	1.17	-	-	-	-	-98.4	-95.3	0.0212
540W	0.0111	1	-	-	-	-	-81.3	-79.6	0.00916
720W	0.0135	1.02	-	-	-	-	-58.3	-57.4	0.0109
Processes	Model: Logarithmic Equation: $MR = a \exp(-kt) + c$								
	k	a	b	c	n	Intercept	AI C	BI C	RMSE
360W	0.00503	1.18	-	-0.0586	-	-	-147	-143	0.00647
540W	0.0107	1	-	-0.00763	-	-	-81.2	-79	0.00891
720W	0.0123	1.01	-	-0.023	-	-	-70.5	-69.3	0.0057
Processes	Model: Midilli et al. Equation: $MR = a \exp(-kt^n) + bt$								
	k	a	b	c	n	Intercept	AI C	BI C	RMSE
360W	0.00534	1.13	-8E-05	-	-	-	-140	-136	0.00766
540W	0.0108	0.993	-2.3E-05	-	-	-	-82.3	-80	0.00856
720W	0.0127	0.988	-7.2E-05	-	-	-	-72.7	-71.5	0.00511
Processes	Model: Demir et al. Equation: $MR = a \exp(-kt^n) + b$								
	k	a	b	c	n	Intercept	AI C	BI C	RMSE
360W	0.00267	1.07	-4.7E-05	-	1.12	-	-165	-160	0.00418
540W	0.0314	1.18	-7.8E-	-	0.8	-	-	-	0.0043

			05				99. 3	96. 5	4
720W	0.0251	1.1	- 0.0001 2	-	0.86 8	-	- 82. 6	- 81. 1	0.0030 5
Proces s	Model: Weibull								
	Equation: $MR = \exp((-t/a)^b)$								
	k	a	b	c	n	Intercep t	AI C	BI C	RMSE
360W	-	204	1.3	-	-	-	- 121	- 118	0.0106
540W	-	90.8	0.998	-	-	-	- 76. 2	- 74. 8	0.0086 2
720W	-	75.9	1.02	-	-	-	- 55. 4	- 54. 8	0.0090 6
Proces s	Model: Wang & Singh								
	Equation: $MR = 1 + at + bt^2$								
	k	a	b	c	n	Intercep t	AI C	BI C	RMSE
360W	-	- 0.0038 1	3.64E- 06	-	-	0.0181	- 89. 3	- 85. 3	0.023
540W	-	- 0.0053	8.78E- 06	-	-	-0.185	- 40. 2	- 38. 3	0.0375
720W	-	- 0.0067 7	1.41E- 05	-	-	-0.168	- 34. 3	- 33. 6	0.0282

3.2 ESTIMATION OF ACTIVATION ENERGY:

The activation energy (E_a) is basically the energy required to break the bonds between moisture particles [8]. It is largely dependent on microwave power and sample thickness. The activation energy for green banana peel was estimated to be 96.376 W/gm. While the pre-exponential value D_0 was 1.59×10^{-8} m²/s. The value of activation energy was in accordance with the value of 90.87 W/gm and 107.56 W/gm for beetroot and banana slices respectively [1,12].

3.3 DETERMINATION OF ENERGY AND SPECIFIC ENERGY CONSUMPTION:

Energy and specific energy consumption during microwave drying at varying power level are presented in Table (2). Results revealed that both the energy and specific energy consumption

decreased with increasing power level. Increasing the microwave power level leads to more heat generation, As a result, the sample losses its moisture rapidly and the drying time is decreased. Thus, lesser energy is required at higher microwave power level to dry the sample. However, in this study, the 540W power level exhibited lower values. Similar trend was observed in banana blossoms dried at microwave power level 160W to 800 W, where minimum energy was consumed at 640W [8].

Table 2. Effective moisture diffusivity, energy consumption and specific energy consumption at different microwave power levels:

Process	$D_{eff} (m^2/s)$	Energy Consumption(kWh)	Specific Energy Consumption (kWh kg ⁻¹)
360W	3.2693×10^{-9}	0.063	12.2093
540W	5.7613×10^{-9}	0.058	11.4706
720W	7.1108×10^{-9}	0.06	11.6279

4. Conclusion:

This work takes into consideration the energy factors spanning the microwave power spectrum as well as fitting the thin-layer drying kinetics models of green banana peel. The drying time was greatly reduced and the peels were successfully dried using microwave drying in this study. 9 empirical thin layer drying models were employed where the Demir et al. model [13] was adjudged the most suitable one as it produced the lowest value of root mean square error (RMSE). The effective moisture diffusivity and rate of moisture removal increased with increasing the microwave power level. The effective moisture diffusivity varied from 3.2693×10^{-9} to $7.1108 \times 10^{-9} m^2/s$. The activation energy was 96.376 W/gm. The energy aspects during the drying procedures declined with increasing power level. However, the 540 W displayed the least amount of energy and specific energy consumption. This study has revealed the effectiveness of microwave drying in terms of shorter drying time and energy related factors.

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Removal of anti-nutritional component from Tamarind Kernel Powder and its application in the production of Fermented Baking Goods

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Abstract:

Tamarind (*Tamarindus indica*), a member of the Fabaceae or leguminous family, is predominantly produced in India, which accounted for over 162,000 metric tons in financial year 2023. While the tangy fruit is widely used in global cuisines, a significant portion of tamarind by-products, particularly seeds, remains underutilized, with over 90% reported as waste. Tamarind seed kernels contain rich protein, carbohydrates, dietary fiber, and minerals but possess some anti-nutritional factors in the form of tannins and phytic acid, trypsin inhibitors that greatly limit its direct application in food products. Reduction of undesirable anti-nutrient components are essential to improve the nutritional quality and functional properties tamarind kernel powder (TKP). Processing methods such as fermentation, roasting and soaking have been reported to remove anti-nutrients from TKP previously. In this regard, the objective of this study was to enhance the nutritional quality and functional properties of TKP through fermentation and its subsequent utilization as a natural preservative in baked goods. The fermentation process can reduce undesirable components, making nutrients more bioavailable and contributing to desirable flavors and textures in products like baking goods. The study also investigates partial replacement of wheat flour and ragi flour with tamarind powder to lower gluten content while preserving sensory attributes and textural qualities. Furthermore, the investigation of functional properties of TKP shows the possibility of tamarind seeds to use as a valuable ingredient in the food industry based on their nutritional profile, improved physio-chemical characteristics which will be integrated within baked goods that will address the underutilization of the seeds.

Keywords: Tamarind Kernel Powder; Anti-nutrient; Fermentation; Baking Goods

Introduction:

Tamarind (*Tamarindus indica*), a member of the Fabaceae or leguminous family. The tamarind tree, is an African origin tropical fruit tree, commonly cultivated in many tropical and subtropical locations around the world, including Asia, India, and the Caribbean. The name tamarind is derived from the Arabic word "tamr hindi," which translates to "Indian date," indicating that it is widely used in India and other parts of South Asia. According to Statista data total tamarind production in India in financial year 2023 amounted to over 162.15 thousand metric tons. Major tamarind producing states includes Tamil Nadu, Karnataka, Kerala, Andhra Pradesh, Telangana, and Maharashtra.[1] Tamarind is a versatile ingredient used in cuisines around the world as it is rich in fiber, antioxidants, and vitamins, contains over 13% of dietary fiber and non-starch polysaccharides. It aids in treating constipation, regulating bowel movement, binding toxins, and protecting colon mucous membranes.

It also contains volatile phytochemicals, minerals, and vitamins, including thiamin, vitamin A, folic acid, riboflavin, niacin, and vitamin C [2]. The pulp of tamarind fruit is soft, thick, blackish-brown, acidic, sour to sweet in taste and has a firm seed. Seeds are reddish- or purplish-brown color and solid with gloss. 30-50 % of the fruit pulp comprises of up of ripe fruit, 11-30% is made up of shell and fiber, and 25-40% is made up of seeds. The kernel, otherwise referred to as endosperm, occupies 70–80% of the seed, while the Testa or seed coat occupies 20%. [3]. Tamarind seeds are a by-product of the tamarind pulp industry that is frequently wasted once the pulp is extracted. Less than 10% of tamarind seeds are used by the non-food business includes powders, oil, and extracts to be utilized for use in cosmetics, skin moisturizers, and industrial products while over 90% of them are recorded as waste each year. [4]

Seed kernels are packed with oil and fatty acids besides crude protein, amino acids. The major portion of proteins comprises lysine, phenyl alanine, tyrosine and leucine. "Jellose" or "polyose" polysaccharide that are found within tamarind seeds, is a good gelling agent and TKP act as a good stabilizing emulsifying agent. Before using kernel powder in baked products, it would need to be freed of the anti-nutrients found in the seed coat since they could interfere with nutrient uptake and lead to toxic or gastrointestinal upset. It is clearly known that some of the anti-nutrients like tannins, phytates, and lectins that bind minerals like calcium, iron, and zinc in the body lower their absorption. There are 56.2 g of tannins per kilogram of tamarind seed, which have the ability to bind proteins, lower digestibility, and possess trypsin inhibitory activity (TIA) of 10.8. [5] There are various reports that tamarind seeds are found to contain 20–40 mg tannin, 8–15 mg phytic acid, and 2.5–5.0 mg trypsin inhibitor. It also contains trace levels of alkaloids, oxalates, and saponins. [6]

The present work is based on processing methods such as soaking, boiling, or fermenting to reduce the level of anti-nutrients in tamarind seed coats to make them safe and nutritious for human consumption. The work comprises the manufacture of fermented bread items and an analysis of their characteristics. The goal is to supplement wheat and ragi flour with TKP and prepare TKP enriched multigrain bread using the sour dough method. Sourdough is a probiotic and prebiotic-rich naturally fermented bread with low glycemic index, improved nutrient uptake, and high digestibility. Three types of sourdough are Type 1, daily-fed Type 1, Type 2, fermented under controlled temperature and moisture conditions, and Type 3, dehydrated or inactivated. [7] The purpose of this experiment is to formulate TKP-enriched multigrain bread through type 1 sour dough process and determine its quality.

2. Materials and Methods:

2.1 Materials

Ripe tamarind pods were purchased in local market of Kolkata. The tamarind pods were de-podded manually. For this purpose, the pods were opened gently to expel the seeds. The study only used whole seeds that showed no signs of contamination. As the content of moisture, protein, tannins, and fiber of ripe and unripe tamarind seeds are different, ensuring that the tamarind was fully ripe was crucial.

2. Methodology

2.2.1 Preparation and Analysis of Tamarind Kernel Powder (TKP)

2.2.1.1 Preparation of TKP: The soaking technique of making tamarind kernel powder usually involves a number of steps, from soaking the tamarind kernels to drying and grinding them into a fine powder. The tamarind kernels were cleaned prior to that to remove any dust, dirt, or pieces of fruit pulp that may have stuck to them. This is done by washing the seeds with water until they are completely clean. Thereafter, the seeds were soaked overnight in distilled water containing baking soda and salt. The excess water was drained off, and the seeds were boiled for a short period before the seed coat was removed. The cotyledons were then manually obtained by squeezing between the fingers to eliminate the seed coat. The soaked and peeled kernels should then be completely dried to remove the moisture. This can be achieved by using tray dryer, temperature was kept between 50 - 60°C. [8] The dried tamarind kernels then grounded using a grinder or mortar and pastel to produce fine powder. The powdered tamarind kernel powder can be sieved to get rid of any bigger particles to ensure uniformity. To keep moisture absorption and deterioration at bay, the tamarind kernel powder was stored in an airtight container in a cool dry place for further use.

2.2.1.2 Determination of Sedimentation Value of TKP: The sedimentation value of TKP was determined using the Zeleny sedimentation test. A 50ml distilled water was combined with Bromophenol blue, TKP, and lactic acid solution in a Sedimentation beaker. The blend was shaken with a centrifuge or shaker for 5 minutes. The beaker was then left on a standing rack for 5-10 minutes. The marginal scale reading of the beaker was then taken. The procedure entailed a careful examination of the mix. [9]

2.2.2 Preparation and Analysis of TKP incorporated Multigrain Bread:

2.2.2.1 Hybrid sourdough preparation: Type 1 sourdough production methods were modified. 100 gm flour and 100 gm water were mixed in a vessel and back slopped daily at room temperature (20-30 °C) for 3 to 4 days to keep the sourdough LAB and yeasts metabolically active. Then 1% Baker's yeast was added for a short (1-2 hour) fermentation time to accelerate the sourdough's fermentation.[7]

2.2.2.2 Determination of Dough Yield (DY): The dough yield was determined in terms of a baker's percentage, which indicates the total dough weight as a proportion of the flour used. It helps bakers determine how much their recipes should be hydrated and adjust them to meet different manufacturing needs.[10]

2.2.2.3 Determination of pH of the dough: pH of the sample was checked by using Digital pH meter. Small amount of sourdough samples was taken in a beaker and diluted with distilled water, and pH 7 buffer solution was utilized for calibration. The transmitter rod then submerged into the sample water, transmitting the data as an electrical signal.

2.2.3 Preparation of TKP fortified Multigrain bread:

Three different sample compositions were prepared using tamarind kernel powder, wheat flour, and ragi flour in the following proportions: 100% TKP, 90%TKP and 5%wheat four, 5%ragi flour,70% TKP and 15% wheat flour,15% ragi, to prepare multigrain bread and analyze which was better in terms of texture and taste. The basic formula of bread making was used with some modifications. Approx sugar 2 g; salt 1 g; milk powder 2 g; and some amount of water used for TKP fortified multigrain bread. Baking conditions were as follows: prove for 1 hour at 34°C, bake for 180 to 200° C, and finally bake for 25 minutes. [11]

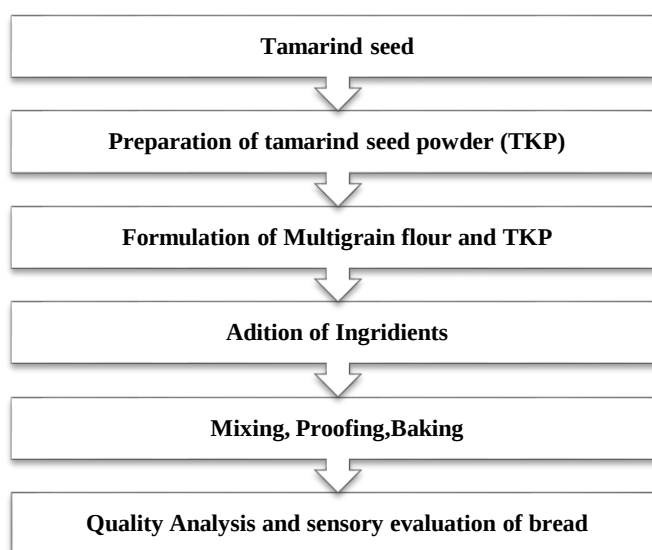


Figure 1: Flowchart of TKP fortified Multigrain bread

2.2.3.1 Proximate analysis: Proximate composition (moisture content, ash content, crude protein, crude fat content, reducing sugar content) of the wheat flour-based bread and the composite flour-based bread samples were determined using AOAC methods [12]

2.2.3.2 Sensory evaluation: Using a 9 hedonic scale, 5 semi-trained panellists assessed the multigrain bread sample overall acceptability as well as their taste, look, odour, and texture.

2.2.4 Removal of Anti-nutrient content:

Several anti-nutrients are present in tamarind seeds. Anti-nutrients need to be removed from Tamarind Kernel Powder (TKP) to improve its nutritional and functional properties. As mentioned earlier, soaking and fermentation are often used as a pretreatment to deplete tannins and phytic acid from different types of seeds. It took 16 hours of water or bicarbonate solution soaking to substantially reduce the antinutrients. [12] Since phytate is water-soluble, it can be reduced by pouring out the soak water. When salt is added, in most cases, it gets associated with phytate, which is an aggregate of salts and other minerals such as potassium, calcium, or magnesium. Two factors that could influence the phytic acid concentration on soaking are endogenous phytase activity and

pH-dependent leaching of soluble phytate salts into soaking media. The soaking medium pH and the nature of phytate could influence phytic acid leaching. In a study on how soaking time influences phytase activity in different food constituents. An experiment investigating the effect of soaking time on phytase activity in different dietary components showed that extended soaking times caused a reduction in phytase activity (10–60%).[13] Phytases can be of lactic acid bacterial origin in sourdough, and sourdough fermentation can lead to a pH favoring the activation of endogenous phytases present in flour. The dough of pearl millet fermented for 14 hours at 30 °C is reported to decrease the pH from 6.6 to 3.8 and reduce the content of phytic acid by 59.7%. Therefore, the measurement was restricted to tannin content.[14]

2.2.4.1 Analysis of Tannin content by using Spectrophotometry method: Using measurements of absorbance at 300 nm, the spectrophotometric method calculates the tannin content using their ability to produce colored complexes with specific reagents. The potassium ferric cyanide, ferric chloride, and HCl methods were used to measure tannin. Solutions of tannic acid of different concentrations were employed to construct a standard curve, which was mixed with other materials, analyzed for absorbance, and graphed as a calibration curve. Upon filtering and dilution of the seed-soaked water extract, TKP, and multigrain bread, the absorbance was related to the standard curve to measure the concentration of tannin. The contents were mixed and optical density was measured at 300 nm. Tannin content was expressed as mg of tannin per gram of plant tissue (mg TA/g).[15]

2.2.4.2 Analysis of Tannin content by using Fourier Transform Infrared (FTIR) spectroscopy:

FTIR is a quantitative analytical approach for detecting various tannin types based on distinctive infrared absorption peaks. It yields information regarding a Tannin's molecular structure and composition. Distinguishes between different tannin types based on characteristic peaks.[16]

3. Result and Discussion:

3.1 Characterization of Sourdough:

The pH range of sourdough was between 4.0-4.2 which makes it best suited for bread making; it has 200 more DY yield, and so it is slack and extensible; it will form open crumb structures and requires more dough strength; higher DY accelerates upward fermentation due to active yeast and bacteria in wetter conditions; it is more lactic acid forming but will, if unchecked, result in overfermentation because it holds more moisture for longer. [17]



Figure 2: Sourdough

3.2 Characterization of TKP:

TKP has a sedimentation value of 25. Although it has not been examined as much as wheat flour, it can nonetheless reveal information about the hydration and swelling characteristics of its polysaccharides mainly xyloglucan, particularly TKP. The sedimentation behaviour of tamarind seed powder is different from that of wheat flour because it contains a significant amount of hydrocolloids and non-gluten-forming proteins. [18]



Figure 2: Tamarind kernel powder (TKP)

3.3 Characterization of TKP incorporated Multigrain bread:

Among three samples—100% TKP, 90%TKP and 5%wheat flour, 5%ragi flour,70% TKP and 15% wheat flour,15% ragi flour the composition 70% TKP and 15% wheat flour,15% ragi has shown the most acceptable texture colour appearance; for this reason, it is being subjected to further examination.



Figure 3: Different samples



**Figure 4: 70% TKP and
15%wheat flour+ 15% ragi flour**

The incorporation of tamarind seeds in wheat and ragi breads can enhance their nutritional value by enhancing protein, fat, fiber, and mineral content. The nutritional composition of these breads varies with the level of tamarind seeds incorporated and the formulation used. Multigrain bread generally contains 30-40% moisture and 1-2% ash. It generally has 8-12% protein, and the inclusion of tamarind seeds could raise the overall. The fat content is generally low, approximately 2-5%, but can vary depending on the recipe. Multigrain bread generally has 50-60% carbohydrates, and the inclusion of tamarind seeds could marginally raise the carbohydrate level [19[]]. However, the

moisture and the ash content level of this TKP-fortified multigrain bread appears to be within the range of 38.40% and 1.7%, respectively. the entire amount of sugar is low because we only used wheat and ragi flour and no additional sugar. Since we didn't add any more, the fat content is modest. However, the protein concentration appears somewhat low, which could be because there is still tannin present. Protein concentration may appear lower in analytical methods that measure only soluble proteins because tannins bind to proteins through hydrogen bonding and hydrophobic interactions, forming insoluble complexes that cause protein precipitation and make proteins less soluble and difficult to extract.

Parameter	Content
Moisture content	38.40 (% dry basis)
Ash content	1.7%
Total sugar	0.5 (Dextrose Equivalent)
Protein content	2.72
Fat content	1.6

Table 1: Proximate analysis of TKP fortified multigrain bread

3.4 Characterization of Tannin content:

Based on spectrophotometric analysis, the tannin content of water-soaked seed was 127.27 mg/100g, but TKP and multigrain bread contained 40 mg/100g and 40 mg/100g of tannin, respectively. It is definite that tannins are decreased by heat degradation in soaking, boiling, and fermentation. However, tannins are natural preservatives and can possibly possess antibacterial and digestive properties. Yet again, bread containing a lot of tannins will be slightly bitter. Too much tannin can bind to proteins acting as an anti nutrient component and reduce their availability. [20]. The removal of tannin content in tamarind paste followed by multigrain bread has been evident from bond stretching of hydroxyl and carbonyl groups found in FTIR spectra analysis.

In FTIR analysis tannins possess characteristic absorption bands because of their functional groups, mainly hydroxyl (-OH), carbonyl (C=O), and aromatic (C=C) structures. They consist of broad O-H stretch ($\sim 3200\text{--}3600\text{ cm}^{-1}$), C-H stretch ($\sim 2800\text{--}3000\text{ cm}^{-1}$), C=O stretch ($\sim 1600\text{--}1700\text{ cm}^{-1}$), C=C aromatic ring ($\sim 1400\text{--}1600\text{ cm}^{-1}$), and C-O stretch ($\sim 1000\text{--}1300\text{ cm}^{-1}$), which suggest the existence of ether and ester linkages in condensed tannins. Hydrolysable tannins display stronger peaks around 1700 cm^{-1} because they are involved in extensive hydrogen bonding, whereas condensed tannins display more intensive aromatic C=C stretching ($\sim 1500\text{ cm}^{-1}$). FTIR scanning is able to differentiate between types of tannins, measure the concentration of tannin, and cross-compare to reference spectra from known tannins. [21]

Spectrum of tannins present in TKP fortified Multigrain bread compared with tannic acid shows a decrease in many peaks located at 1700, 1600, 1400, 1300 and 1100 cm^{-1} which are not sharp and strong as is observed in tannic acid. O-H Stretch (Alcohols, Phenols, Carboxylic Acids) with a strong, broad peak shows at $3200\text{--}3600\text{ cm}^{-1}$, N-H Stretch (Amines & Amides) with peaks for primary amines and a single peak shows at $3300\text{--}3500\text{ cm}^{-1}$ for secondary amines, and C-H Stretch

(Alkanes, Alkenes, Alkynes, Aromatics) with a strong and sharp peak at 3300 cm^{-1} . According to this approach, we can say that most of the tannins are removed in pretreatment, which includes soaking and boiling, and that a few tannins are also removed during fermentation.

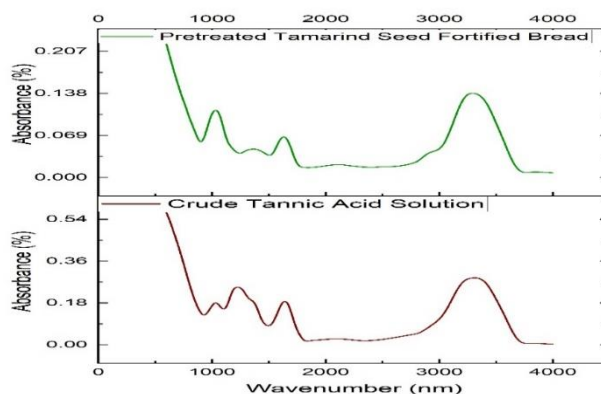


Figure 5: FTIR graph of crude tannic acid vs. multigrain bread

3.5 Sensory Evaluation: According to the Hedonic rating done, Multigrain Bread sample are most accepted in terms of taste, texture color. Texture is improved with addition of TKP up to 70% afterwards it was not much accepted by the consumers due to stickiness of the product. The color of the multigrain bread is slightly darker due to presence of hard seed coat particles.

4. Conclusion:

The development of TKP-added multigrain bread was the primary concern of the study. To determine the acceptability of the bread, sensory evaluation was conducted. Cookies made of 70% TKP, 15% wheat, and 15% ragi flour were very satisfactory. The bread is light, soft in texture. Compared to traditional bread prepared with wheat flour alone, the loaf contained a slightly dry aftertaste. The bread has a taste similar to ragi bread. It is observed that the protein content is low; this may be due to tannins' ability to bind to proteins, forming insoluble complexes that precipitate proteins and render them less soluble and difficult to extract. The sensory attributes and overall quality of the cookies were influenced by incorporating tamarind seed flour into the wheat flour. The prime goal of the use of tamarind seed flour in the multigrain bread was to reduce the gluten level in an attempt to make bread. The research aimed to offer a solution for those sensitive to gluten or who prefer low-gluten products by introducing tamarind seed flour. Moreover, sourdough enhances the digestion, nutritional value, and storage life of the bread, rendering it a better solution than regular bread. In general, the research demonstrated that tamarind seed flour can be utilized effectively in multigrain bread formulations but it does affect the quality and sensory attributes of the final product.

5. Future Scope:

Tamarind Seed, a byproduct of the Tamarind industry, can be utilized in multiple industrial applications. It can be utilized to prepare fortified cookies, which are nutritious and can be a gluten-free substitute for ordinary wheat-based cookies. This study demonstrates the cost benefit of utilizing

waste products as raw materials, reducing expenses by almost half. It also provides an avenue for a multitude of applications of food waste products and minimizes post-harvest losses all over the world. The research is process-oriented, and the quantification experiments in the future will give a better insight into the cookies enriched with Tamarind Seed Powder. This antioxidant and stabilizer-dense powder may be employed to create more economical and nutritious food products.

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Tragacanth Gum: A Multifunctional Ingredient Revolutionizing the Food Industry

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Abstract:

Tragacanth gum is a natural, multifunctional gum exudate obtained from the dried sap of different species of Astragalus plants. It is a heterogeneous polymer majorly consisting of anionic and acidic polysaccharides along with minor amounts of neutral polysaccharides, proteins, starch and cellulose. This naturally occurring hydrocolloid is widely used in food, pharmaceuticals and cosmetics industries due to its unique rheological characteristics and pseudoplastic behavior. This review paper studies the versatile roles of Tragacanth gum in food industries including dairy, bakery, confectionery, sauces, dressings, beverages and many other food products. Its high viscous nature and high stability allow it to be utilized as stabilizer, thickener, texture modifier, emulsifier, gelling agent and binding agent for the processing of various food products, edible films and nanoencapsulation of different food ingredients. Additionally, this paper explores the diverse application of tragacanth gum as food packaging material. Due to its hydrocolloidal edible properties tragacanth gum is being used as a suitable biodegradable food packaging biopolymer to produce edible packaging films and coatings enhancing the shelf life of food by inhibiting moisture loss. However, this paper also presents some negative aspects and challenges related to its use in food industries as well as the future aspects of the novel industrial applications of tragacanth gum in a more sustainable way.

Keywords: Tragacanth Gum; Hydrocolloid; Food Industries; Thickener; Food Packaging; Edible Coatings and Films.

1. Introduction:

In reaction to mechanical injuries or biological attacks, certain trees and shrubs naturally release gums, which are sticky secretions that often solidify to seal the wound and provide protection. Tragacanth gum is produced from Astragalus plants (Astragalus genus, Leguminosae family and Papilionidae subfamily) in semi-desert and hilly regions of south-west Asia [1]. Due to its chemical nature and the availability of water, they disperse readily in water and can form a gel, colloidal solution, dispersion, or viscous suspension [2]. They have been used for ages in many fields of applications such as food, beverages, medicines, cosmetics, textiles, agrochemicals and many others. Most of the above-mentioned industries, mainly the food industries, are of high interest in this product because of its multifunctionality imparting food texture, consistency and overall quality to consumers. This potential interest will only increase consumers' demands for more natural clean-label products, which increases the demand for sustainable plant-based food additives and reduces the use of synthetic additives. Thus, natural Gum Tragacanth (also called Gum Katira) has become one of the favorite choices to replace synthetic additives [3]. The last 20 years have seen a number of

investigations carried out to determine its properties and possible uses. This paper reviews the properties, applications and challenges associated with tragacanth gum in the food processing and packaging industry and discusses its future potential to provide readers with a comprehensive understanding.

2. Structural Composition:

Tragacanth gum is distinct from other hydrocolloids due to its origin as well as its special structural makeup. Its unique characteristics, which set it apart from other widely used gums like Xanthan or Gum Guar, are mostly caused by this structural variance. Tragacanth gum contains 8.79-12.94% moisture, 83.81-86.52% carbohydrate, 0.31-3.82% protein and 1.8-3.2% minerals. Based on variety of species and cultivation conditions these compositions may be different. It consists of several minerals among which calcium and potassium contents are relatively higher [4]. The gum is mostly a complex polymer made up of galacturonic acid, galactose, glucose, xylose, fucose, arabinose and trace amount of rhamnose arranged in different ways on a thick gel network [5]. Different species of Tragacanth Gum are composed of different ratio of water-soluble fractions or SFGT (tragacanthin) and water insoluble fractions or IFGT (bassorin). *Astragalus gossypinus* consists the lowest ratio of tragacanthin and bassorin with higher proportion of galacturonic acid (37%) than other species [6].

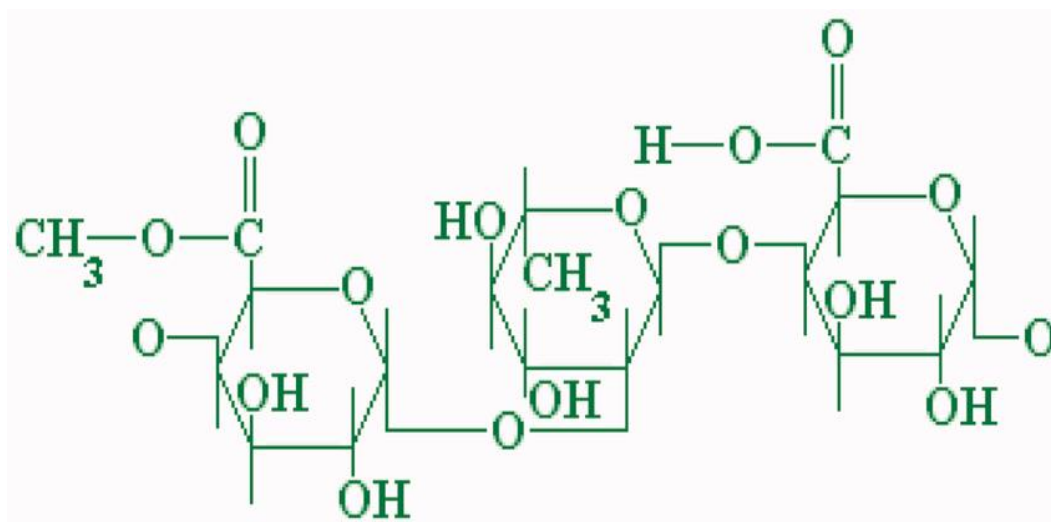


Figure 1: Chemical Structure of Tragacanth Gum [7]

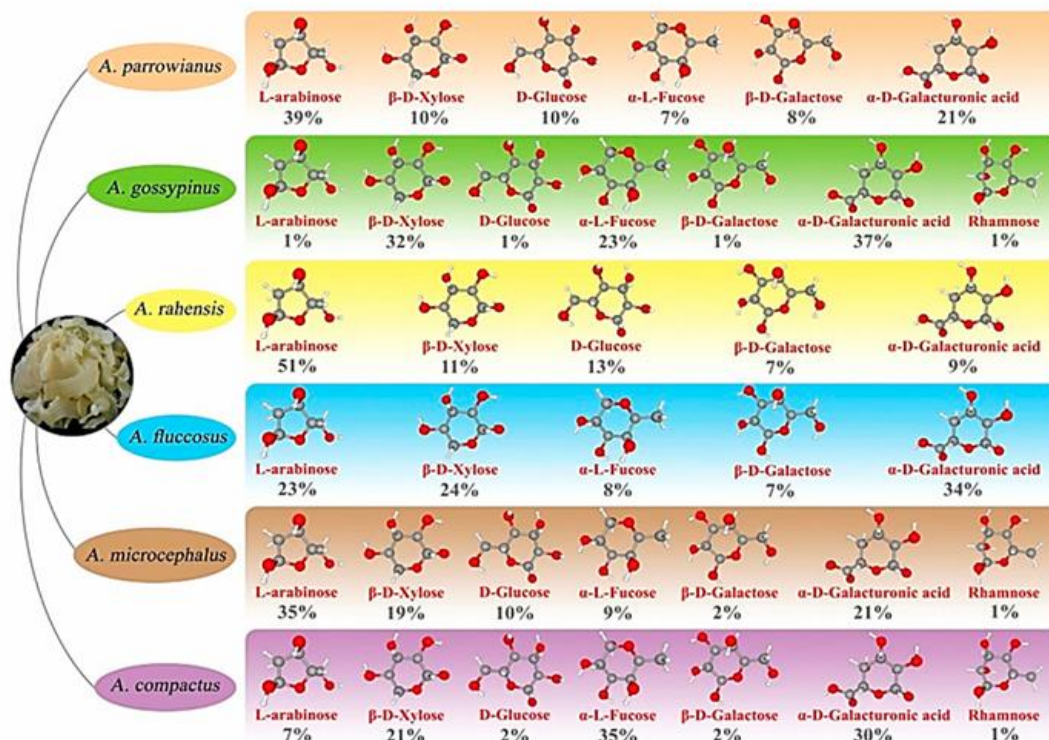


Figure 2: Chemical Composition of Tragacanth Gum in Different Species of *Astragalus* [8]

3. Production and Collection:

Tragacanth Gum is produced by the gummosis process in which the sap discharges from the wounds or injuries of *Astragalus* plants and dries into flakes or curled ribbons on the trunk. The quality and shape of the exudate gum depend on the type of incision and the sub-species of *Astragalus* plants [9]. The gum is generally collected in the months of July to September during summer days after 3-5 days of mechanical incision [1]. Later, it has to be cleaned (for the removal of bark, sand, rubbles), sorted and packed as raw gum or milled as whole gum powder. The physical properties of ribbons and flakes are different. For example, pulverizing of ribbons produces light yellow coloured powder, whereas the powder produced from the flakes is creamy to tan. Additionally, ribbons create higher viscosity than flakes, while the surface activity of flake is usually better than ribbons [9].

4. Rheological Properties:

The rheological behavior of the tragacanth gum is key to its function in food systems. When TG is mixed with water, its soluble part, tragacanthin or tragacanthic acid, dissolves and forms a viscous colloidal hydrosol, while its insoluble part, bassorin (60–70%), swells to form a gel [10]. Since TG is a pseudoplastic, it displays non-Newtonian fluidity, where the viscosity decreases as a result of shear strain, known as shear thinning. Among the natural plant gums, the aqueous solution of TG has the highest viscosity and remarkable heat stability. The viscosity of the substance varies with ionic strength and pH values because there is a large number of carboxylic groups in the TG structure, and

the peak viscosity occurs in between pH 5 to 6. Due to the decrease in ionic dissociation of the carboxylic group, the viscosity of TG solutions lowers with the drop in pH [11]. Its viscosity is concentration-, temperature-, and ion-dependent: for example, calcium ions lower the viscosity significantly [12].

TG has been utilized as a natural thickening and emulsifier in food processing, adhesives, cosmetics, and medications due to its rheological behavior, strong thermal stability, great solubility, and long shelf life. Oral ingestion of this substance is safe and biocompatible [13]. The shear-thinning and thixotropic characteristics of the gum make it highly suitable for ease of application along with stability of the product in time. The strong viscosity, hydrophilicity and stability across a broad pH range, will qualify it perfectly to be included in foods products.

5. Applications in Food Industries:

5.1. Applications in Food Processing:

Tragacanth gum has been declared as “generally recognized as safe” by the US Food and Drug Administration (FDA) since 1961. According to the FDA Code of Federal Regulations, TG can be added to foods at a concentration of 0.2–1.3 weight percent. On the list of additives E-number E413 has been approved for TG by the European Community's Scientific Committee for Food [10]. Table 2 presents the food products in which Tragacanth gum can be applied by FDA Code of federal regulations and the maximum amount of gum tragacanth which can be taken (percent) as allowed in foods.

Foods (as presented)	Percent (%)	Functions
Baking mixes and baked items	0.20	Stabilizer/thickener, emulsifier, emulsifier salt, formulation aid
Relishes and condiments	0.70	
Oils and fats	1.30	
Sauces and Gravies	0.80	
Animal Products (Meat)	0.20	
Fruit juices and processed fruits	0.20	
Other types of food	0.10	

Table 1: FDA Code of federal regulations for tragacanth gum [14]

Tragacanth gum is a polysaccharide food coating applied extensively in the food processing sector. The uses of TG as food coatings resulted in dehydration, enzymatic browning, and decreased respiration. This can be achieved due to TG serving as a semi-permeable barrier that eliminates water, steam, and gases from coming into contact with the foods thereby extending the shelf life [15]. Because of the early spoilage of fruits, TG has also been used as an edible covering material resulting decreased shrinkage, better tissue quality, reduced water loss, and improved rehydration [16].

Tragacanth Gums have been used as thickeners, gels, moisture-controlling agents, stabilizers, emulsifiers, dietary fiber, crystallization inhibitors, fat substitutes, and even as film-forming agents. It is largely used as a food additive in food preparations because of its high viscosity, low protein level, and edibility. It is also commonly used as a thickening agent to enhance the viscosity of food

and make emulsification easier. It is a very strong emulsifier that stabilizes the food systems because of its high resistance to heat and acidity [17]. Due to its surface-active qualities the gum is a suitable choice for use in these low pH products. Depending on the oil composition, typical usage levels range from 0.4 to 0.8% [14].

TG is used to create pourable dressings and low-calorie, oil-free sauces with a low viscosity to simulate the creamy mouthfeel and texture of distributed oil droplets. It is utilized as a stabilizing ingredient in cultured milk drinks and ice cream puddings, an adhesive improvement agent in processed restructured mutton chops, and a fat substitute in low-fat yogurt, white cheese, and low-fat sausage. These additions work as a reactive ingredient capable of changing or improving the rheological, physical, and functional characteristics of products like tomato ketchup, flavored milk drinks, milk protein, cheddar cheese, dried yogurt paste, salad dressings, relishes, sweet pickle liquors, soft jellied products, thick broths, beverage and pastry emulsions, ice and sherbets, and confectionery cream centres. Moreover, TG allows the development of human gut flora, thus implying possible prebiotic action. Therefore, prebiotic useful chemicals can be produced by applying TG for making functional foods [10].

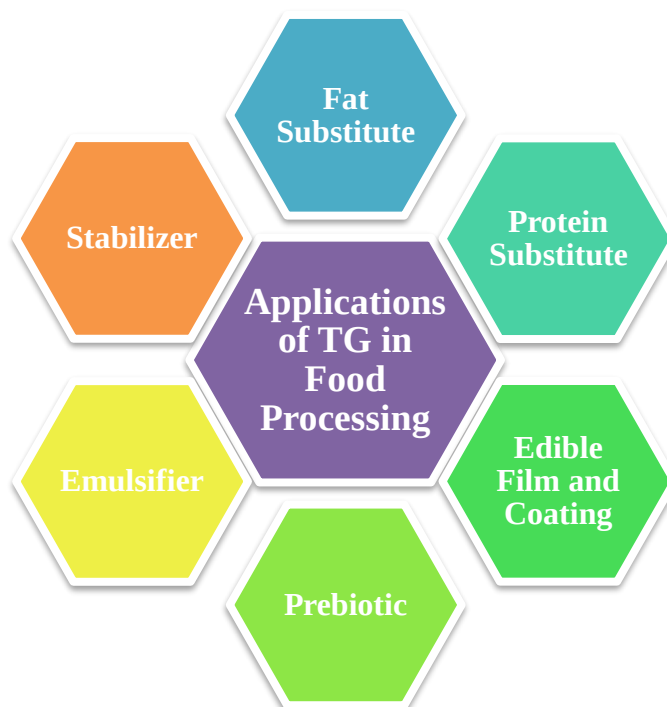


Figure 3: Applications of tragacanth Gum in Food Processing

5.2. Applications in Food Packaging:

TG packaging for food products is a natural and biodegradable alternative to synthetic petroleum-based films, which have disadvantages such as migration into food, recovery difficulties, and environmental contamination. Edible and biodegradable TG bioplastic has been used in food packaging to enhance the shelf life of food [17]. Other biopolymers and nanomaterials have been incorporated into TG-based films to overcome their poor permeability and physical properties. For instance, solution casting can be used to create a TG based bio nanocomposite film. To improve

mechanical qualities and lower film permeability, bio composite films based on TG have been created in conjunction with other biopolymers such as potato starch, chitosan, and soy protein/nanocellulose [18].

In modified atmosphere packaging applications, biobased films with high hydrophilicity, such as TG, are required because the CO₂ emission and oxygen scavenging processes both involve moisture. Gas exchange happens only after moisture has been absorbed from the food product or environment surrounding the package. TG biobased polymers containing glycerol as plasticizers have been designed for this purpose. Equilibration at 53% relative humidity within a controlled atmosphere improved the water-absorbing characteristic of biobased TG films and altered their mechanical properties to more significant extents [10].

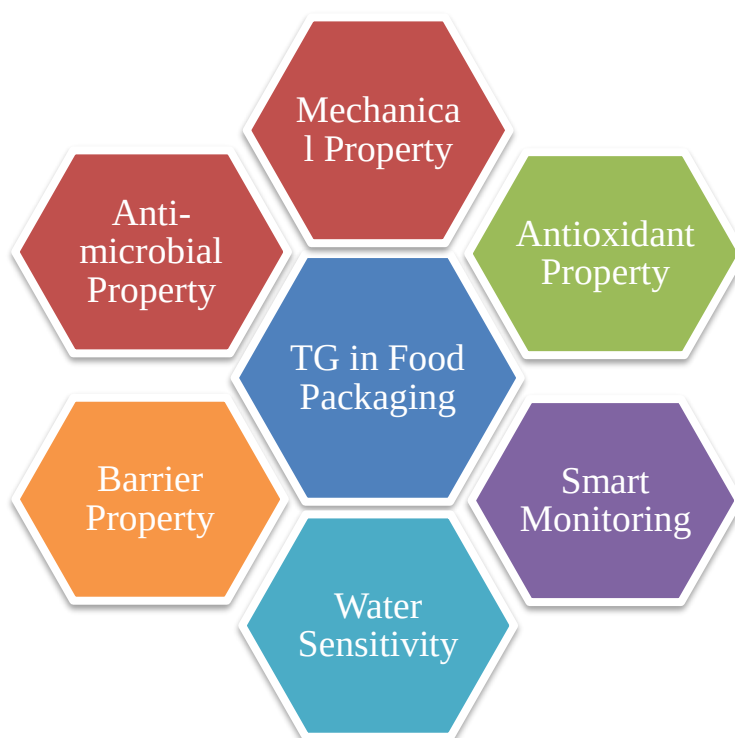


Figure 4: Functions of Tragacanth Gum in Food Packaging

6. Literature Review:

In cookie recipes, GT is utilized in place of oil. Consequently, dough was created and sesame oil was added to the GT solution. This reduced the breaking force and improved the cookie flavor preservation [19]. In another study, apple slices were treated with soybean polysaccharides and GT. While the brix was kept constant, the hardness of the apple slices enhanced, the amount of phenolic compounds dropped, and the rate of oxidation slowed down after the slices were coated [20].

Another study investigated the impact of adding hydrolyzed GT to low-fat yogurt. This was to check whether GT could generate prebiotic yoghurt and remove yoghurt fat. GT was extracted directly from the plant and ground up for their study. To prepare low-molecular-weight GT (30 kDa), GT

was hydrolyzed first. The results showed that, compared with the yoghurt, the hydrolysed GT improved the ability of the yoghurt to hold water in the sample. Additionally, the syneresis of storage was reduced due to the incorporation of the hydrolysed GT. However, the numbers of microorganisms were the same. Although hydrolysed GT has many other excellent advantages, the authors were not pleased with the overall textural effect on the yoghurt [21].

Tragacanth gum finds application in ice cream to yield a particular ice cream texture. It also prevents the textural changes induced by ice crystal formation during storage. In water ice, sorbets, and ice pops, the gum prevents the flavor and color constituents from moving during storage and consumption. Bakery fruit-based toppings and fillings are prepared with GT, which imparts them a creamy texture and a beautiful, transparent appearance [14].

7. Challenges:

However, despite its promising applications, several challenges still persist in its widespread use. Its potential allergenicity, careful formulation of products with safety measures and proper labelling are some major challenges which should be mitigated. The variability of the conditions of supply, processing, and final use can seriously affect the coherence and performance of the Tragacanth rubber in food products. In addition, the limited understanding of its interactions with other food components under mechanical stresses, changing pH levels, and temperature changes presents a barrier to the full exploitation of its multifunctional properties [22]. Researchers are always working to identify the natural relationship between edible gums and food ingredients. Moreover, the industrial and pharmaceutical application of TG can be hindered by its high cost and the accessibility of xanthan gum as less costly alternative [14].

8. Conclusion and Future Aspects:

Tragacanth Gum is one of the exudate gums of *Astragalus* species present in the rangelands of Southwest Asia, mainly Iran and Turkey. Due to its comparatively expensive cost, however, numerous food businesses remain interested in it due to some exceptional and characteristic properties, including high stability at very acidic conditions, good emulsification power, and silky and smooth mouthfeel. The rheological and compositional properties of GT exudates from the most important commercial species are now fairly well defined.

However, the future of Tragacanth rubber as a food ingredient is contingent on interdisciplinary approaches that integrate food science and nutritional studies. New extraction and modification techniques can also be studied to enhance the functional properties of Tragacanth Gum. Advanced analytical techniques like spectroscopy and chromatography may produce useful information on its molecular dynamics which could enhance its use as a natural ingredient for innovative processing methods. TG's demonstrated potential in hydrogel-based nanofibers and nanoparticles has opened a unique opportunity for its applications in environmental and biomedical fields.

Moreover, because TG is compatible with other natural compounds, its application in active packaging also requires comprehensive research; for example, the potential applications of edible films or coatings based on TG that are prepared as carriers of antibacterial agents appear to be an interesting topic to consider. Finally, the toxicological safety of GT-based nanostructures used in food products should be carefully considered. Therefore, continuous research is needed to deal with

existing challenges and unlock the full potential of Tragacanth Gum as a multifunctional ingredient in the food sector for innovation of healthier and more sustainable food products.

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“Peeling Back the Layers”- The Potential of Fruit Waste as a Sustainable Packaging Solution

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Abstract:

The on-going concern about plastic pollution and loss of fossil fuel sources demands the viability of alternative packaging materials. One promising route to eco-friendly packaging solutions is from fruit waste, a commonly available and underutilized byproduct of the food industry. This review looks at using fruit waste derived packaging to take advantage of its potential benefits and challenges. For producing bio based materials for packaging applications, various fruits have been used including the citrus peels, banana peels, mango peels, apple pomace. The inherent chemical composition of these materials makes them biodegradable, compostable, and potentially antimicrobial, but offers several advantages as compared with other materials. Fruit waste can be transformed into functional packaging during extraction and processing methods such as solvent extraction, chemical modification, and forming composites with other biopolymers. Yet problems remain, fruit waste composition is variable, the possibility of microbial spoilage exists, and mechanical properties (e.g. strength and water resistance) are not as well defined for plastics produced from fruit waste as for conventional plastics. Using this review, we assess how various fruit waste based packaging materials perform in terms of their processing characteristics and identify key research gaps. To scale beyond these limitations and enable sunset of conventional petroleum based packaging in Favor of fruit waste derived sustainable packaging, further advancements in processing technologies and composite material development are required. In this case however, this transition presents enormous environmental and economic gains by decreasing waste, encouraging resource circularity and helping to advance a more sustainable packaging industry.

Keywords: Fossil Fuel ; Biodegradable ; Antimicrobial ; Biopolymers ; Sustainable packaging

1. INTRODUCTION

The escalating plastic pollution situation has become one of the foremost environmental difficulties for the current twenty-first century. The United Nations environment program (2021) reveals yearly plastic production at 300 million tons but many societal solids amount to ocean and land pollution (United Nations Environment Program). Fruit waste integration into packaging enables two essential benefits by providing diminutive food waste management alongside environmentally friendly plastic alternatives. Various approaches for converting fruit waste into eco-friendly packaging materials have been studied in this research. This research area gained significant attention because of the production of bioplastics through extrusion and thermoplastic processing from fruit peels and seeds and pulp. The research shows that packaging materials based on fruit waste possess mechanical properties that match plastic packaging and also include biodegradability characteristics (1). The

above properties function as essential tools for managing plastic pollution by enabling waste decomposition in both waste management sites and industrial facilities to decrease environmental impact. Circular economic practice promotion stands as a key element to evaluate sustainable packaging solutions effectively. Under the circular economy approach resources maintain continuous use for the purpose of completing product lifecycle cycles through resources optimization to minimize waste generation. The incorporation of fruit waste into packages allows industries to lower their consumption of original materials and petroleum products and support their surrounding economies. Companies that apply entrepreneurial waste management principles to turn supply-chain waste into packaging materials create economic advantages alongside sustained agricultural practices through improved waste reduction (2). The shift supports sustainable development targets that focus on creating green consumption and production methodologies. This paper discusses how fruit waste generates packaging materials by exploring production methods and performance outcomes and obstacles together with emerging prospects for its utilization.

2.Fruit Waste as a Feedstock for Biodegradable Packaging

2.1 Sources of Fruit Peels and Pomace

The main components of fruit waste consist of peels, seeds along with pomace that result from juice extraction processes and fruit processing operations and agricultural activities. Fruit waste contains valuable biopolymers such as cellulose alongside starch and pectin in its thrown-away materials. The peel components of oranges and apples and banana skins together with processed fruit pomace receive current interest because of their substantial biopolymer levels that make them suitable for packaging applications. The residual materials from fruit processing operations represent an essential renewable resource within packaging industries because they can be used instead of conventional materials. Waste valorization serves two beneficial purposes as it reduces pressure on waste management operations and promotes homeostatic resource use in circular economic models (3). The vast amount of discarded fruit represents 45% of global production so using this huge waste supply would help eliminate both fossil resource dependence and waste disposal. Various fruit waste materials possess cellulose, hemicellulose and lignin elements which make them suitable for the production of biodegradable packaging components that fulfill diverse operational needs (4).

2.2 Industrial Byproducts

Industrial fruit waste consists of peels and pomace as well as secondary substances such as pulp generated from fruit juice and canned fruit processes. Environmental issues such as landfill overflow and methane emissions result from disposing of these byproducts since they exist in significant quantities. Packaging production from waste materials works toward environmental conservation and promotes sustainable waste management systems. These food by-products possess several beneficial phytoconstituents that include pectin together with polyphenols besides antioxidants and enzymes which demonstrate numerous biological activities. The bioactive fibers along with other substances contribute to carbohydrate digestion while influencing the glycemic index favorably (5). Sudha et al., (6) illustrate how the normal waste production stems from several home and industrial handling tasks that include fresh produce trimming and slicing and organization before culinary or consumption. Release of this material improperly into the environment results in both environmental

and health risks. The residual pomace and leftover materials such as fruit and vegetable peels and seeds originate from organic produce. The abundant nutrient content in waste materials includes fibers and phenolic compounds, antioxidants, omega fatty acids, colorful compounds and other compounds that protect against heart diseases, cancer, and degenerative health conditions. Nutritional content in bread products such as cakes, cupcakes, scones, loaf and cookies may increase when fruit and vegetable waste is combined. The mixture of multiple waste types and their concentration levels both affect product physical and chemical composition and improve performance. Despite this Manhongo et al., (7) argue that fruit production leftovers have potential use in biorefineries to produce renewable power along with fuel substances and valuable bioproducts. Commercialization of biorefineries that utilize fruit waste faces challenges because of lacking information about available feedstock quantities and process design requirements and scaling requirements. Poly-feedstock processing enables continuous biorefinery functioning throughout the year although co-production benefits sustainability by enhancing economic performance and environmental benefits. The residual materials contain high levels of nutrients along with anti-inflammatory and anti-cancer and anti-diabetic properties and antihypercholesterolemic activities. These residual materials have considerable future therapeutic potential because they contain nuts and functional foods along with bioactive chemicals.

3. Processing and preparation Techniques for fruit Waste-Based Packaging and recent works

The optimization of fruit waste-based packaging requires improved extraction and fabrication techniques because it directly affects the processing outcome. There are three proven methods for enhancing fruit waste-based materials: solvent extraction combined with thermal processing and biodegradable polymers. Strengthening the functional diversity of fruit waste in packaging uses depends on both additive inclusion and fruit by-product composite material creation according to analyses by Ali et al. (8) and Jamwal et al. (9).

3.1. Pre-Treatment

Fruit waste needs pre-treatment before conversion into packaging materials since the material demands purification steps followed by processing preparations. The waste fruit undergoes three procedures: washing followed by drying and then being ground into a fine powder state. The structure of the fruit waste can be modified through chemical treatments with acid and alkali substances to improve its properties for packaging purposes.

3.2. Extraction of Biopolymers

Fruit waste contains three essential biopolymers used for packaging materials development which are cellulose, pectin, and hemicellulose. Three main biopolymer extraction methods namely solvent extraction, enzymatic treatments, and mechanical methods are employed for extracting biopolymers from fruit waste. The main plant wall component cellulose enables production of packaging products including films along with foams during extraction processes. The carbohydrate material pectin functions perfectly as a matrix in biodegradable films and naturally occurs as a cell wall substance in fruits.

3.3. Formulation and Processing

The extracted biopolymers from fruit waste proceed to combine with other materials which results in functional packaging products. Manufacturers combine biopolymers with different substances which serve as plasticizers and crosslinking agents throughout the formulation process to enhance the material's barrier and mechanical characteristics and flexibility. The processing of fruit waste-derived packaging materials starts with three main production methods which include extrusion and casting followed by compression molding.

3.4 Recent Works

Recent works have the combination of various natural fibers derived from fruit waste cellulose with PLA biodegradable plastic allows researchers to produce composite packaging materials. The composites have great mechanical potential with their extended service time which makes them suitable for packaging needs. Sani et al. (10) present insights about the beneficial uses of fruit and vegetable waste by-products during biodegradable film production in their study. The evaluation shows that waste by-products preserve key characteristics suitable for developing sustainable packaging materials. The authors demonstrate that effective extraction and combination of biopolymers from waste streams allows manufacturers to produce composite materials with vital characteristics including biodegradability and hydrophilicity and biocompatibility. Sustainable packaging materials can degrade in natural environments thanks to their properties which also support rising market demand for eco-friendly products.

Table 1: Different fruits and vegetables waste byproduct and its characterizations(11)

Fruits	Waste/Byproduct	Valuables compounds/polymer matrix	Materials characterizations	References
Date palm	Date palm fruit waste (DPFW)	DPFW loaded chitosan (Ch)/polyethylene glycol (PEG) composite	The surface structure became rough, the films are hydrophobic in nature. The thermal stability. The DPFW extract displayed an impressive suppression effect against the identified pathogens in antimicrobial experiments.	(12)
Beetroot + Watermelon	Beetroot extract +Watermelon peel	Ph-sensitive indicator film incorporating	Reduction of OP and WVP and an	(13)

		beetroot extract encapsulated in pectin from watermelon peel	improvement of mechanical properties. The light transmittance films decreased and the thermal stability improved. A colorimetric response at a wide range (3–10) of pH values.	
Watermelon	Watermelon peel	Pectin (watermelon peel) + Ultrasound treatment	This caused the thickness, OP, WVP, transmittance, and TS to decrease and the density and elongation at break (EAB) to increase;	(14)
Date palm	Date kernel (DK)	Polymeric films of carboxymethyl chitosan (cmcs) + Carboxymethyl starch (CMS) + DK extract	DK extract did not affect the morphological structure of films. Create insoluble films in water to a large extent. Superior antimicrobial possibilities against	(15)
Indian gooseberry	Indian gooseberry pomace (IGP)	K-carrageenan-based bio-nanocomposite films incorporated with CNC derived from IGP	CNC-reinforced bio-nanocomposite films showed better barrier and mechanical properties. WVP of the films decreased with an increase in the TS. FTIR analysis	(16)

			showed that no structural changes took place in the polymeric matrix.	
Durian fruit	Durian skin (DS)	Biodegradable food trays from corn starch with additional extracted fractions (cellulose, hemicellulose, and lignin) from DS	Significantly affected the trays' physical and mechanical properties. All trays exhibited colour and structural changes during application storage for seven days at 25 °c.	(17)
Palm tree	Date seeds	Films from natural polymer (starch + Cellulose + Chitin) with incorporation of extracts from date seeds	TS of the films increased. The test suggested that the films could be easily degraded in composting soil by 5–7 weeks. Composite film imparted antioxidant and antimicrobial properties.	(18)
Mango	Mango kernel starch (MKS)	MKS+Glycerol, sorbitol	Films were thicker and higher moisture content. TS decreased, while elongation at break (%E) increased. Produced more TV films	(18)
Litchi	Seeds of litchi	Starch (litchi) extracted and cross-linked (CL) with sodium trimetaphosphate	Peak viscosity (PV) and breakdown viscosity (BV) of CL starches are	(19)

		(STMP)	lower in comparison to native starches. reduction in WVP values of CL starch films. Cross-linking significantly improves the TS of films; however, film elongation is lower than that of native starch film	
Pomegranate	Pomegranate peel	Bioplastic PHA	starch and glycerol concentrations exhibited different TV and E. Linear effects. Pomegranate Pomegranate peel Bioplastic PHA Various parameters, such as substrate concentration, temperature, pH, and time duration.	(20)

4. Properties and Performance of Fruit Waste-Derived Packaging

4.1. Biodegradability

The main benefit of packaging made from fruit waste is its ability to decompose naturally. The natural origin of these materials leads to complete decomposition in the environment while producing no dangerous residues. The speed at which these materials break down primarily depends on the packaging material composition in combination with the humidity level and temperature alongside the activity rate of microbes. The decomposition rate of fruit waste-derived materials outperforms conventional plastics because they require hundreds of years to decompose while the waste products shorten this duration and lower environmental pollution levels. The investigation of biodegradable coatings made from discarded fruit waste demonstrates promise when developing sustainable food packaging alternatives for plastic waste reduction efforts. Scientists investigated biodegradable materials through complete research in Jahangiri et al. (21) showing their viability as

oil plastic replacements. The authors present multiple benefits of using citrus and apple pomace from waste to develop innovative packaging materials. The main efficiency aspect Jahangiri et al. (21) investigated revolves around the biodegradable nature of these coatings. Studies demonstrate that coatings made from fruit waste maintain environmental durability at a lower rate than conventional plastics so they can provide an effective method to stop the buildup of discard and ocean debris. The degradation process of biodegradable coatings subscribes to circular economy principles through which materials stay in use for longer periods to reduce discarded materials.

4.2. Mechanical Strength

Commercial adoption of fruit waste packaging materials relies heavily on their ability to provide adequate mechanical performance. Packaging materials need sufficient stretchability and tensile force together with resistance to damage for proper shipment handling and storage alongside usage. The processing techniques including plasticizers and crosslinking agents and composite materials with recent innovations enhance the mechanical properties of fruit waste-based packaging. More research is necessary to enhance the characteristics of these materials for particular packaging requirements.

4.3. Barrier Properties

Food products require packaging materials with superior barrier resistance against moisture as well as oxygen and environmental factors to achieve security of quality and extended shelf life. Fruit waste-derived materials typically present weaker barriers for moisture and other environmental elements when compared to traditional plastic packaging. Scientists increased the barrier capabilities of these materials by adding natural waxes and coatings to the structure. Developing fruit waste packaging materials becomes more complex because raw material components vary naturally during development. The composition of polymers and sugars and fibers within fruit waste materials differs according to the citrus, apple or banana origin. The variable composition affects physical along with chemical aspects of finished packaging materials which could develop shortcomings in barrier properties. Biodegradable polymers produced from fruit by-products encounter numerous challenges toward their ability to block moisture and gases according to Wu et al. (22) since these properties determine shelf-life in packaged products. The barrier performance needs of robust materials cannot always be met by fruit waste since improving biodegradability poses a major engineering challenge.

4.4. Characteristics

Other attributes such as transparency and color and texture components together with mechanical properties and barrier properties determine how fruit waste materials function as packaging materials for consumers. Manufacturers can modify fruit waste-based packaging traits through processing changes that include color addition or film thickness control. Fruit waste-based packaging demonstrates extra advantages by offering the possibility to extract natural antioxidants and antimicrobial compounds from its waste material. Natural substances found in fruit peelings and seeds possess the ability to lengthen the product shelf-life through their antimicrobial properties that limit microbial growth and oxidative processes (23). These compounds enhance both packaging functional properties while elevating wasted resources value through a circular resource management method.

5. Challenges and Opportunities

5.1. Standardization and Quality Control

The implementation of fruit waste-based packaging faces potential obstacles which obstruct their general use as packaging materials. The outcome of final products depends heavily on processing parameters along with the feedstock components which requires extensive testing to match commercial requirements and end-user expectations. Research in this area focuses on developing effective methods to enhance the combination of fruit waste with biodegradable materials along with finding suitable additives that improve functionality (24). The successful commercial adoption of fruit waste-based packaging solutions needs a resolution to these problems since manufacturing resistance depends on matching these materials against petroleum-based products. Material stability represents one of the major barriers to implementing solutions based on fruit waste-derived materials. The mechanical traits and biodegradation rates of fruit waste-derived packaging materials show more variability compared to engineer traditional packaging because these materials originate from natural fruit waste sources. The inconsistency of properties in fruit waste stems from processing variations and ripeness differences as well as storage procedures which complicates the creation of standardized packaging solutions (25).

5.2. Regulatory Frameworks

Barriers due to regulatory standards become challenges in integrating fruit waste into packaging applications. Food contact material regulations currently demand lengthy safety and compliance tests thus creating obstacles for fruit waste biopolymers to complete their innovation to market approval phase. Development of standardized tests and rules focused on biodegradable items will help create better possibilities for market transitions and encourage innovative approaches. To make fruit waste viable as a sustainable packaging source the marketplace must solve multiple intricate obstacles that will bring forth environmentally friendly packaging solutions. The complete life cycle of regular packaging materials produces substantial greenhouse gas emissions starting from resource removal and product manufacturing and ending during disposal. Stoica et al .(26) establish that substituting standard materials with biodegradable alternatives from agricultural waste including fruit leftovers leads to major reductions of carbon footprints during packaging manufacture. The study shows that using biodegradable materials instead of traditional plastics leads to reduced environmental impact as well as economical advantages for producers and consumers so fruit waste becomes an appealing sustainable packaging solution.

5.3. Consumer Awareness and Acceptance

Consumer acceptance functions as a vital obstacle when adopting packaging solutions based on fruit waste materials. Environmental sustainability and food waste recycling have gained attention yet many consumers doubt the use of waste food for packaging because of quality and hygiene-related worries. Consumer reluctance to view fruit waste as acceptable material will harm the market potential of these products. The implementation of successful education programs about fruit waste-derived packaging must occur to change negative public perception while promoting consumer acceptance. The evaluation of sensory attributes of fruit waste packaging such as smell and feel and visual aspects needs thorough analysis to guarantee the packaging does not negatively impact

consumer interaction (27). Moreover there are doubts regarding the economic viability of manufacturing large amounts of packaging from fruit waste. The expense of collecting fruit waste alongside processing it into packaging substances surpasses the cost of conventional packaging materials thus making standard packaging solutions less expensive. A cost-effective economic structure requiring financial consideration of these costs should be established for manufacturers to adopt fruit waste materials. The study conducted by Montalvo et al. (28) shows that small producers might hesitate from integrating fruit waste processing because of the upfront costs but potential advantages in the long run could minimize their reluctance.

6. Environmental and Economic Implications

The packaging industry needs the valorization of food waste especially fruit waste to solve environmental and economic problems. The study by Gautam et al. (29) examines different viewpoints about food waste valorization while highlighting the necessity of converting traditional waste-items into usable resources. Research indicates that developing fruit waste into biodegradable packaging creates solutions for controlling simultaneously both waste overproduction and plastic pollution problems. Quality characteristics which include lightness with moisture resistance capabilities make packaging made from fruit waste desirable to customers seeking efficient packaging solutions. Using environmental materials derived from fruit waste allows for a cyclic approach that transforms packaging materials into soil nutrients thus benefiting soil health while reducing dependency on chemical fertilizers in agriculture. Standard plastic packaging maintains itself in the environment for long periods while causing microplastic pollution and adverse ecological damage. According to Stoica et al. (26) biodegradable packaging helps relieve waste management systems by decreasing landfill usage together with waste decomposition related emissions.

7. Future Prospects

Research demonstrates that sustainable packaging made from fruit waste offers several attractive opportunities. Better functional and property attributes will result from research improvements in biopolymers together with processing techniques. Commercial interest in sustainable packaging solutions together with plastic waste violence directs consumer demand toward large-scale implementation of fruit waste-derived packaging systems. Laboratory research showed that orange peel extract functions as an active agent for producing antimicrobial packaging materials which exhibit strong antimicrobial action against foodborne pathogens. Research investigated using limonene extracted from orange peel essential oil in packaging films and determined how film antimicrobial qualities rose with a delightful smell (30). Using fruit waste to create packaging materials shows that waste management and enhanced food quality can operate as an integrated beneficial technique. The development of sustainable commercial packaging options has become achievable because of academic institutions partnering with manufacturing companies. The Brazilian academic institution collaborated with a nearby fruit juice producer for creating new packaging through a research project that used dried mango waste. The new sustainable product acquired market success because it offered environmental friendliness together with affordability and function-specific features that consumers wanted to see in their purchases. Future research into fruit waste utilization requires both innovative processing technology development and multifunctional

packaging approaches which utilize waste properties according to Ali et al. (8) and Jamwal et al. (9). The development of scalable fruit waste production methods along with supply chain management systems will make the waste more attractive for sustainable packaging applications.

8. Conclusion

Various hurdles constrain the efforts to transition toward using fruit waste materials for sustainable packaging applications. Researchers together with industries must solve two fundamental issues regarding the scalability of processing methods and the supply chain stability of fruit waste. Thorough economic assessments must be conducted to determine commercial viability for manufacturing packaging materials from fruit waste resources. The industry should team up with academic organizations to create applicable business structures that leverage the dual benefits of eco-friendly and financial advantages in agro-industrial by-product implementation. Entrepreneurial proficiency regarding the environmental consequences throughout the entire life cycle of fruit waste packaging must be well understood. A combination of research indicates that fruit waste shows potential as a new packaging material yet life cycle assessments (LCA) must perform detailed evaluations to assess its full sustainability metrics against established packaging materials. The identification of possible adverse effects on land use and resource consumption during manufacturing enables better development of mitigation strategies that improve the ecological advantages of biodegradable packaging options. This literature review demonstrates the necessity to spread awareness about utilizing fruit waste benefits to both consumers and manufacturing industries. Markets will transform when advocacy programs join forces with educational efforts about biodegradable packaging since these efforts will push customers toward sustainable packaging choices. The initiatives led by policymakers will need support to push for adopted environmentally friendly materials and practices in the market.

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Paper Title: Edible Hydrogels: A Sustainable Approach for Delivering Polyphenols from Fruit Peel Waste

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Abstract:

The increased interest in sustainable food systems and waste repurposing has led to substantial studies into edible hydrogels as novel delivery systems for bioactive compounds. Fruit peels, which are often disposed as industrial waste, are high in polyphenols, which provide considerable health advantages. However, their volatility and limited bioavailability preclude their direct application. Edible hydrogels provide a possible alternative by encapsulating and preserving these bioactives, hence increasing their regulated release and bioaccessibility. This review focuses at the characteristics and applications of edible hydrogels in polyphenol delivery, with an emphasis on composition, classification, and hybrid hydrogels that improve stability and usefulness. Various techniques of production are reviewed, as well as critical qualities like physicochemical, morphological, mechanical, and rheological properties that determine their efficiency as carriers. The role of hydrogels in preserving the bioactivity of polyphenol and their release mechanisms is well investigated. Furthermore, recent case studies demonstrate the effective implementation of hydrogel-based polyphenol delivery in the food, nutraceutical, and pharmaceutical industries. While edible hydrogels offer an environmentally sustainable and effective method of using fruit peel waste, concerns such as large-scale manufacture, regulatory approval, and consumer acceptance persist. Future studies should concentrate on optimizing hydrogel formulations, increasing structural integrity, and investigating novel biopolymer-polyphenol interactions. This paper highlights the promise of edible hydrogels as an advanced technique for valorizing fruit peel waste while improving functional food development by combining food and culinary science, material engineering, and sustainability.

Keywords: Edible hydrogel; polyphenols; fruit peel waste; encapsulation; bioavailability; sustainability;

1. Introduction

The growing emphasis on sustainability and functional food development has prompted more studies into edible hydrogels as excellent transporters of bioactive compounds. Polyphenols generated from fruit peel waste are known for their antioxidant, anti-inflammatory, and antibacterial effects, but their instability and low bioavailability prevent direct application. Edible hydrogels offer a viable approach by encapsulating polyphenols, increasing their stability, and allowing for regulated release. Edible hydrogels are three-dimensional polymeric networks made from natural or synthetic biopolymers such as alginate, chitosan, pectin, or gelatin. These polymers are biocompatible, and biodegradable, and can preserve sensitive compounds from degradation. Hybrid hydrogel systems,

which combine various biopolymers, improve mechanical strength, physiological response, and functional stability [1]. This paper explores the classification, preparation methods, and important features of edible hydrogels that affect polyphenol encapsulation. It focuses on hybrid hydrogel developments, recent case studies in functional food applications, and the importance of hydrogels in maintaining polyphenol bioactivity. Despite its potential, challenges such as large-scale production, regulatory compliance, and customer acceptability prevent commercialization. Future research should focus on optimizing formulations, developing smart hydrogel systems, and improving biopolymer-polyphenol interactions. Edible hydrogels offer an unconventional method of utilizing fruit peel waste for improved functional food production by combining food science, material engineering, and sustainability [2].

2. The Concept of Hydrogel

Hydrogels are soft, three-dimensional, highly porous networks composed of molecules, fibers, or particles capable of holding much water or other aqueous media within their structure. Their Swelling characteristic and adaptability have enhanced the level of study interest [3]. These materials are typically made from water-soluble polymers with hydrophilic functional groups such as -OH, -CONH, -CONH₂, and -SO₃H that participate in strong water absorption [4]. Hydrogel classification may be made according to the source of the materials and type of cross-linking method, as well as environmental sensitivities. The interaction of water molecules with the polymer net is significant for hydrogel performance. Hydrophilic groups from the polymers attract water molecules, thus hydrogels swell by water absorption. The hydrogels' swelling behavior is a consequence of a delicate balance of forces, which includes hydrogen bonding, van der-Waals interactions, and ionic interactions.



Figure 1: Classification of Hydrogels.

Natural hydrogels made from biopolymers like chitosan, hyaluronic acid, and alginate are highly biocompatible and biodegradable, although they often lack mechanical strength. Synthetic hydrogels, such as polyvinyl alcohol and polyacrylamide, provide tunable characteristics and increased stability,

but may require changes to improve biocompatibility. Cross-linking can occur physically through non-covalent interactions, allowing for reversible swelling in response to stimuli, or chemically through covalent bonding, which provides structural integrity [6]. Smart, responsive hydrogels are being developed for drug delivery, wound healing, and tissue engineering applications that require stability, controlled release, and biocompatibility [4].

2.1 Types of Hydrogels

Hydrogels are multipurpose materials that can be characterized based on various criteria such as origin, cross-linkage, preparation, stimuli-responsiveness, appearance, charge, and configuration. With their advantageous properties of high water retention, responsiveness, and biocompatibility, hydrogels find significant applications in pharmaceuticals, bioengineering, and food technology.

Hydrogels can be classified on multiple criteria, which are discussed as follows:

2.1.1 Classification Based on Origin

Natural hydrogels derived from biological sources such as chitosan, pectin, and alginate have high biocompatibility but low mechanical characteristics. In contrast, synthetic hydrogels produced from polymers such as acrylic acid and Hydroxyethylmethacrylate (HEMA) provide higher structural accuracy; nonetheless, their biocompatibility sometimes remains a concern.

2.1.2 Classification Based on Crosslinking

Physically cross-linked hydrogels are reversible networks formed by weak connections including hydrogen bonding and ionic interactions, making them sensitive to environmental stimuli such as pH and temperature changes [7]. Chemically cross-linked hydrogels, on the other hand, are permanent structures held together by strong covalent connections, resulting in increased stability and strength.

2.1.3 Classification According to Preparation Methods

Homopolymers are hydrogels created from a single monomer, whereas copolymers are made up of two or more distinct monomers that have been combined to improve certain properties. Interpenetrating networks (IPN) are made up of two polymer networks that are intertwined without covalent bonding, whereas semi-IPN structures combine a cross-linked polymer network with a dispersed linear polymer, providing a combination of stability and flexibility [8].

2.1.4 Classification by Stimuli-Responsiveness

Hydrogels respond to stimuli (changes) in their environment such as pH, temperature, ionic strength, and external magnetic or electric fields.

2.1.5 Classification by Dimension

Macroscopic hydrogels are bulk polymers visible to the naked eye that are widely used in large-scale applications. Microgels, measuring between 100 nm to 10 μ m, are used for targeted drug delivery

and biosensors. Nanogels are even smaller, measuring between 10-100 nm, providing increased surface area and penetration for improved biomedical applications.

2.1.6 Classification by Electrical Charge

Neutral hydrogels lack charged groups, whereas ionic hydrogels have either cationic or anionic charges. Amphoteric hydrogels have both acidic and basic functional groups, whereas zwitterionic hydrogels have both positive and negative charges, providing distinct characteristics for a variety of applications.

2.1.7 Classification by Configuration

Amorphous hydrogels have a disorganized structure, whereas semicrystalline hydrogels have both amorphous and crystalline regions. In contrast, crystalline hydrogels have highly organized structures that provide unique mechanical and functional features.

2.1.8 Hydrocolloid-Based Hydrogels

Hydrocolloid-based hydrogels are recognized for their biocompatibility, biodegradability, and water-retention qualities, making them crucial in food, pharmaceutical, and biomedical applications [4]. Chitosan-based hydrogels generated from chitin have antibacterial characteristics and are utilized in wound healing and drug delivery. Pectin-based hydrogels create gels in the presence of divalent cations, allowing for controlled medication release and food application. Alginate-based hydrogels, crosslinked with calcium ions, are used in tissue engineering and bioactive chemical encapsulation. Carrageenan-based hydrogels derived from red seaweed are widely employed in food formulations and medication encapsulation due to their superior gelling capabilities. Guar gum-based hydrogels have excellent water retention and biodegradability, making them ideal for medicinal applications. Gum ghatti-based hydrogels aid in emulsification and medication delivery, whereas tragacanth gum-based hydrogels promote controlled drug release and wound dressing. Xanthan gum-based hydrogels, recognized for their high viscosity and stability, are useful for controlled drug release and food texturization. Hydrogels are being studied for their potential applications in medicines, cosmetics, and food stabilization [4].

2.2. Hybrid Hydrogels

Hybrid hydrogels, which are formed by combining natural and synthetic polymers, have gained a lot of research interest because of their better mechanical strength, biocompatibility, and reactivity to external stimuli [9]. Hydrogels are classed depending on their crosslinking methods, including physically crosslinked hydrogels that rely on hydrogen bonding and ionic interactions and chemically crosslinked hydrogels that are stabilized through covalent bonds [4]. Examples include alginate-PVA hydrogels, which are known for their use in wound healing due to enhanced mechanical stability [10]; chitosan-gelatin hydrogels, which are widely employed in tissue engineering [11]; and carrageenan-pectin hydrogels, which are utilized in functional food formulations for controlled nutrient release [12]. Guar gum-alginate hydrogels are being investigated for drug administration and food applications due to their high water retention, biodegradability,

and ability to produce stable gel matrices [13]. Hybrid hydrogels have potential in biomedicine for drug delivery, tissue regeneration, and wound healing because they imitate the extracellular matrix and allow for regulated therapeutic release. They are employed in the food business as stabilizers, texture enhancers, and encapsulating agents to increase nutrient and microbial bioavailability. Recent advances in smart hybrid hydrogels that respond to temperature, pH, and ionic strength have resulted in new applications in biosensors and regenerative medicine.

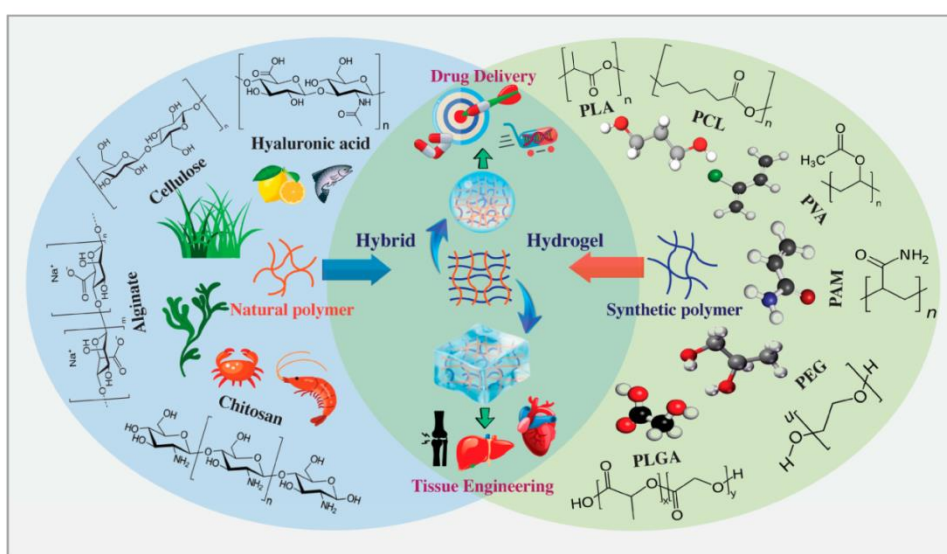


Figure 2: Hybrid hydrogels, composed of a combination of natural and synthetic polymers, serve a dual purpose in drug delivery systems and as scaffolds for tissue engineering applications. Adopted from Rana et al. 2024 [14].

3. Preparations of Hydrogels

Hydrogels can be produced via physical or chemical cross-linking processes, which affect their structural and functional properties. Physical cross-linking techniques, which do not require chemical agents, include heating and cooling, where polymers like carrageenan and starch undergo sol-gel transition upon temperature change [15], complex coacervation, which relies on electrostatic interactions between oppositely charged polymers such as xanthan and chitosan [16], and ionic gelation, where multivalent ions (e.g., Ca^{2+} for alginate) induce cross-linking. Another technique is freeze-thaw cycling, which produces physically entangled hydrogels with superior mechanical properties. Chemical cross-linking methods, on the other hand, generate covalent bonds, which ensure hydrogel stability and control degradation. Grafting polymerization, in which polymer chains are activated by chemical initiators or radiation, enables the attachment of functional monomers to improve hydrogel properties, whereas polymerization via irradiation (e.g., gamma rays or electron beams) allows for precise control over hydrogel network formation and bioactivity. Recent advances in hydrogel synthesis have focused on improving these technologies to improve biocompatibility,

mechanical strength, and tailored release, hence expanding their applications in biomedicine, food, and pharmaceutical industries.

4. Characteristics of Hybrid Hydrogels

4.1 Physio-Chemical Properties

Hybrid hydrogels have a unique combination of physical and chemical properties that make them useful in a variety of applications. These materials have a high water absorption capacity due to their hydrophilic polymeric networks, making them appropriate for biomedical and food applications [9]. Their porosity and swelling behavior affect diffusion properties, which are critical for drug delivery and nutrient encapsulation. The combination of natural and synthetic polymers in hybrid hydrogels improves their stability, providing mechanical strength while remaining flexible. Furthermore, their stimuli-responsive nature enables reversible sol-gel transitions in response to environmental changes such as pH, temperature, and ionic strength [17].

4.2 Morphological Properties

The morphology of hybrid hydrogels influences their performance, especially in tissue engineering and controlled release applications. These materials have a three-dimensional network structure that resembles the extracellular matrix, facilitating cell adhesion and proliferation [9]. Their porosity varies with polymer composition and cross-linking density, influencing their mechanical characteristics and permeability. Scanning electron microscopy (SEM) and atomic force microscopy (AFM) show that hybrid hydrogels have interconnected microporous or nanoporous structures that enable for effective diffusion of bioactive substances [18]. Furthermore, the hydrogels' surface roughness and fiber alignment improve their functionality in biomedical scaffolds and wound healing applications.

4.3 Mechanical and Rheological Properties

Hybrid hydrogels must have the appropriate mechanical and rheological qualities to withstand external stresses while preserving structural stability. Their mechanical strength is determined by polymer content, cross-linking density, and the presence of reinforcing agents [17]. Hydrogels with a high cross-linking density are more rigid but less flexible, whereas loosely cross-linked hydrogels have more elasticity and deformation capabilities. Rheological studies show that these materials have viscoelastic behavior, with storage modulus (G') and loss modulus (G'') providing information about their gelation and deformation properties [18]. Hybrid hydrogels have variable mechanical properties, making them ideal for injectable biomaterials, tissue scaffolds, and wound dressings. Overall, hybrid hydrogels provide a diverse platform for biomedical, pharmacological, and food applications due to their distinct combination of physiochemical, morphological, and mechanical features. Their continuous development strives to improve stability, responsiveness, and biocompatibility for specific applications.

5. Polyphenols and Their Benefits

Polyphenols are chemical compounds found in plant-derived materials, such as fruit peels, that are well known for their antioxidant, anti-inflammatory, and antibacterial properties [19]. These substances are classified as flavonoids, phenolic acids, stilbenes, and lignans, with flavonoids being the most common in fruits and vegetables. Polyphenols have been shown to reduce oxidative stress, modulate gut microbiota, and prevent chronic diseases such as cardiovascular disorders, neurological diseases, and some types of cancer [20]. Despite their benefits, polyphenols have low bioavailability due to poor stability, rapid metabolism, and degradation during physiological circumstances [21]. Encapsulating edible hydrogels offers a unique way to improve their stability and controlled release. Hydrogels serve as protective carriers for polyphenols, enhancing absorption in the gastrointestinal system and increasing bio efficacy [21]. Fruit peel waste is a rich source of polyphenols, and incorporating it into hydrogel-based delivery systems offers a sustainable way to maximize nutrient usage in food and medicinal applications. The creation of edible hydrogels for polyphenol delivery can help to drive functional food innovations while minimizing agricultural waste.

6. Recent Case Studies

Recent advances in edible hydrogels have considerably improved the efficient encapsulation and distribution of polyphenols derived from fruit peel waste. These hydrogels provide increased bioavailability, resistance to environmental degradation, and regulated release of bioactive compounds. Several research have investigated various hydrogel matrix, cross-linking procedures, and encapsulation efficiencies to improve polyphenol delivery.

Table 1: Various hybrid hydrogel types used for encapsulating bioactive compounds, highlighting their effectiveness in retention, stability, and controlled release.

Hydrogel Type	Encapsulated Bioactives	Findings	References
Alginate-Pectin Hybrid Hydrogel	Chokeberry polyphenols and volatiles	Pectin addition enhanced polyphenol retention and antioxidant activity	[4]
Gelatin-Polyphenol Hydrogel	Tea polyphenols	Increased gel strength and thermal stability compared to gelatin-genipin hydrogels	[22]
Alginate-Pectin Hydrogel Beads	Citrus limon peel polyphenols	86.72% encapsulation efficiency, sustained release in gastrointestinal conditions	[23]
Xanthan Gum-Locust Bean Gum Hydrogel	Tea polyphenols	Improved stability in water-in-oil emulsions, over 70% polyphenol retention after 30 days	[21]
Binary Hydrogels (Protein-Polysaccharide)	Bioactive polyphenols	Effective as food matrices for bioactive compound delivery	[9]

Based)			
Citrus Peel Waste-Based Hydrogel	Phenolic acids and flavonoids	Encapsulation improved bioavailability and antioxidant activity	[24]
Edible Hydrogel Films (Gelatin-Starch Composite)	Phenolic compounds from fruit and vegetable waste	Reduced oxidation and improved stability in functional food applications	[25]
Encapsulated Polyphenol Hydrogels (Chitosan-Pectin Hybrid)	General plant-derived polyphenols	Improved bioaccessibility and clinical efficacy of polyphenols	[24]
Cellulose-Alginate Hydrogel	Grape skin polyphenols	High encapsulation efficiency, sustained release in food matrices	[26]

7. Future Direction

The future of edible hydrogels for delivering polyphenols from fruit peel waste depends on improving sustainability, functionality, and bioavailability. A primary focus is on advancing the development of biodegradable and eco-friendly hydrogel materials that have a low environmental impact while being effective. Emerging research focuses on plant-based and hybrid hydrogel systems that combine proteins and polysaccharides for increased stability and regulated polyphenol release. Another significant innovation is smart hydrogels that respond to environmental stimuli such as pH, temperature, and enzymes, ensuring tailored release in the gastrointestinal tract. These systems can enhance polyphenol absorption and bioactivity, hence increasing their potential health benefits. Another potential field is the implementation of nanotechnology in edible hydrogels, with nano-structured hydrogels increasing the solubility and permeability of polyphenols, overcoming their inherent instability. Emulsion-filled hydrogels and nanogels are being investigated to improve the controlled release of hydrophobic polyphenols. In food applications, hydrogel-based active packaging is gaining popularity due to its antibacterial and antioxidant capabilities, which improve food shelf life while also delivering health-enhancing polyphenols. Overall, multidisciplinary research that combines material science, food technology, and biomedical applications will advance next-generation edible hydrogel formulations for functional foods and nutraceuticals.

8. Conclusion

Edible hydrogels have evolved as a sustainable and innovative option for efficiently delivering polyphenols derived from fruit peel waste. Their biocompatibility, biodegradability, and ability to encapsulate and protect bioactives make them ideal for use in food, nutraceuticals, and pharmaceuticals. Edible hydrogels help address the issues associated with polyphenol degradation and limited bioavailability by improving their stability and regulated release. The combination of natural polymers like pectin, alginate, and chitosan with synthetic or hybrid materials has increased the mechanical strength and utility of hydrogels. These improvements have provided more control

over polyphenol release profiles, ensuring their efficacy in targeted delivery systems. Furthermore, hydrogel matrices have been proven to preserve polyphenols' antioxidant and antibacterial properties, making them useful for increasing food shelf life and providing health advantages. Despite these advances, there are still hurdles to optimizing hydrogel formulations for large-scale production and cost-effectiveness. Continued research into environmentally friendly fabrication techniques and regulatory issues will be critical for expanding their commercial applications. The creation of multifunctional edible hydrogels is an important step toward sustainable food innovation and the reduction of agricultural waste.

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Corn Waste Usages after Starch Extraction

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1. Abstract:

After starch extraction from corn, several valuable byproducts are generated, each playing a key role in various industries such as agriculture, food production, and bioenergy. The primary byproducts include gluten meal; germ; fiber; and distillers grains, which are utilized in diverse applications to maximize resource efficiency. gluten meal, a high-protein byproduct, is commonly used as animal feed, particularly for livestock and poultry. It is also utilized in some industrial processes and as a fertilizer due to its nitrogen content. corn germ, rich in oil, is processed to extract corn oil, a widely used ingredient in cooking and food processing. The residual germ meal, after oil extraction, serves as a nutritious animal feed, providing proteins and essential fatty acids. The fibrous material left behind after starch extraction, known as corn fiber, is used in various ways. It can be incorporated into food products as a source of dietary fiber, offering health benefits such as improved digestion. Additionally, fiber can be processed into biofuels, contributing to renewable energy production. Another significant byproduct is distillers grains, which are produced during ethanol production. These grains are rich in proteins; vitamins; and minerals, making them an excellent feed for livestock, especially in dairy and beef farming. Through the utilization of these byproducts, the corn processing industry significantly reduces waste and supports sustainable practices. By recycling the waste products into animal feed, biofuels, and industrial goods, the process contributes to the circular economy, helping reduce environmental impact and creating additional economic value across multiple sectors.

2.Introduction :

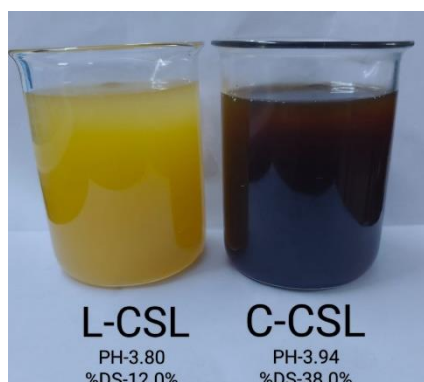


Corn, or maize (*Zea mays*), is one of the most important staple crops worldwide, cultivated across vast regions for its versatile applications. It serves as a major food source, a key ingredient in animal feed, a raw material for biofuels, and a primary ingredient in various industrial products. Corn's economic importance cannot be overstated, as it contributes to the global agricultural economy in many ways, particularly through the extraction of its starch. Starch extraction from corn, primarily through wet milling processes, plays a crucial role in supplying starch-based products like sweeteners (glucose, high-fructose corn syrup), ethanol (used in biofuels), and biodegradable plastics. However, the starch extraction

process generates a considerable amount of waste, often overlooked in terms of its potential value. These byproducts, which include corn bran, gluten, fiber, and germ, are often treated as waste materials or low-value products, yet they have considerable economic and environmental potential if repurposed appropriately. The realization that corn waste can be transformed into valuable materials for agriculture, energy production, biodegradable plastics, pharmaceuticals, and even food processing, has sparked an interest in the development of circular economic models in agricultural industries.

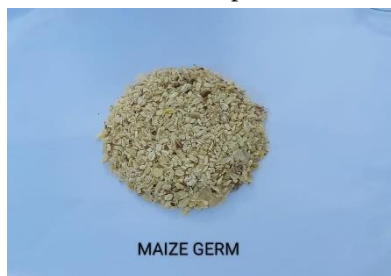
3. By-products of corn starch processing :

Milling schemes represent the principal procedure to yield corn starch and are conveniently classified as wet or dry while each has its characteristics. Dry milling is a gradually abrasive technique separating the bran and germ to obtain dry-milled corn flour. Its products mostly serve as feed, food, industrial material and as starch sources for ethanol production, fermentation processes and related starch conversions. Wet milling aims to fractionate different components of the kernel and release starch granules with minimal mechanical damage. High purity starch can be yielded by this technique, which is the distinct advantage over dry milling. Wet milling is used to produce high purity starches (99.95%), and more than 85% of corn starch is produced by wet milling. Corn kernel was firstly steeping by adding the sulfurous acid solution to increase the permeability of corn hull, to swell the kernel, reduce mechanical strength, and disrupt the protein wrapping around the starch granules. Then the germ, bran and protein can be easily separated in subsequent processing, such as grind screen and washing. This industrial process involves chemical, biochemical, and mechanical operations to separate pure starch fractions from corn kernels. Various products were isolated, including starch (about 68.0%), corn bran (12.0%), corn germ (7.5%), steep liquor (6.5%), gluten (5.6%), and others (0.04%)[1].



3.1 Corn steep liquor

During steeping, the corn was softened by steep water to produce optimum efficiency of grinding kernel and separating corn components. It involves maintaining the correct balance of sulfur dioxide concentration, temperature, water flow, and Pondus Hydrogenii value (pH) during soaking. Corn



kernels are generally soaked in steep water for 30–40 h at 48–52 °C. The germ cell membranes become porous and organic compounds are easily liberated intactly and separated from hull or endosperm. At this point, approximately 6.0%–6.5% (dry matter content) of the corn kernel is released into the condensed steep water, and mainly in the organic compounds of living cells, such as proteins (40%–50%), minerals, soluble sugars, amino acids, etc. The previous study indicated that about 50% of steep water-

soluble matter belonging to the corn germ, because of the high proportion (95%) of naturally soluble substances in the germ, such as germ protein (60%). In contrast, only 9% of the endosperm protein can be solubilized during steeping [2].

Potential Applications:

- **Animal Feed:** CSL is commonly used as a high-protein additive in animal feed, especially in the production of poultry and livestock feed. The high levels of amino acids and nutrients make it an effective supplement in animal diets, enhancing growth and health.
- **Fertilizers:** The high concentration of nutrients in CSL makes it a potential organic fertilizer. It can be applied directly to soil or mixed with other organic materials to enrich soil with essential nutrients, such as nitrogen, phosphorus, and potassium.
- **Biochemical and Pharmaceutical Applications:** Some components of CSL are utilized in the production of enzymes, antibiotics, and other bioactive compounds. Its rich nutrient content is ideal for fermentation processes, where it serves as a medium for the growth of microorganisms.
- **Wastewater Treatment:** Due to its high nutrient content, CSL is being explored as a potential medium in biological wastewater treatment systems, where microorganisms degrade organic waste in wastewater.

Nutritional Value of CSL

- **Proteins and Amino Acids:** Around 25-30% protein, with essential amino acids like glutamic acid, leucine, and lysine.
- **Carbohydrates:** Includes sugars like glucose, fructose, and sucrose, providing energy.
- **Organic Acids:** Contains lactic acid, acetic acid, and citric acid, beneficial for fermentation.
- **Vitamins and Minerals:** Rich in B vitamins (like thiamine and niacin), vitamin C, and essential minerals like phosphorus, calcium, and iron.
- **Nitrogen Compounds:** Includes ammonia and peptides, supporting microbial growth.
- **Lipids:** Small amounts of fats, including essential fatty acids.

3.2 Corn Germ

Composition and Characteristics: The corn germ is the part of the kernel that is responsible for germination and growth. It is rich in oils (mainly polyunsaturated fatty acids), proteins, and vitamins. The germ constitutes about 10-12% of the corn kernel's weight but is removed during starch extraction to avoid contamination of the starch product.

Potential Applications:

- **Corn Germ Oil:** The oil extracted from corn germ is a key by-product, known for its high levels of linoleic acid (an omega-6 fatty acid). It is widely used in food products, including cooking oils and margarine.
- **Animal Feed:** The protein-rich germ is used as an ingredient in animal feed, especially in poultry and swine diets. It provides a good source of essential amino acids and energy.
- **Bioplastics:** Corn germ protein can be processed into bioplastics, offering a sustainable alternative to petroleum-based plastics. It is particularly used in the development of biodegradable polymers, such as polylactic acid (PLA), which can be used for packaging and other eco-friendly applications.

Nutritional Value of Corn Germ

- **Protein** (20-30%), providing essential amino acids but low in lysine.
- **Oil** (40-50%), high in unsaturated fatty acids like linoleic and oleic acids, beneficial for heart health.
- **Carbohydrates** (10-15%), mainly sugars and some dietary fiber for digestion[13].
- **Vitamins**, especially **vitamin E** (antioxidant) and **B vitamins** (like thiamine and niacin)[13].
- **Minerals** such as magnesium, phosphorus, iron, and zinc, supporting various bodily functions[13].
- **Antioxidants** like beta-carotene, which supports immune function[13].

3.3 Corn Fiber (Corn Bran)

Composition and Characteristics: Corn fiber, often referred to as corn bran, is a by-product obtained after the removal of the starch from corn kernels. It consists mainly of cellulose, hemicellulose, and lignin, which are complex carbohydrates and structural components of plant cell walls. Corn fiber is rich in fiber but has low digestibility in its raw form[12].

Potential Applications:

- **Animal Feed:** Corn fiber is commonly used as an ingredient in animal feed, especially in the poultry and livestock sectors. The fiber helps in maintaining gut health and digestion in animals.
- **Biofuels:** The high cellulose content in corn fiber makes it an excellent candidate for bioethanol production through enzymatic hydrolysis or fermentation. Researchers are exploring efficient ways to break down the fiber into fermentable sugars to produce second-generation biofuels.
- **Biodegradable Plastics:** Some innovative applications have explored using corn fiber as a raw material in the development of biodegradable plastics and composites. The cellulose in the fiber can be processed to create bio-based materials that have applications in packaging, construction, and textiles.

Nutritional Value of Corn Fiber

- **High Fiber Content:** It contains both soluble and insoluble fiber, which aids digestion, promotes regularity, and helps control blood sugar levels.
- **Low in Calories:** It's low in calories, making it a good option for weight management.
- **Rich in Antioxidants:** Contains polyphenols that help protect the body from oxidative stress.

- **Minerals:** Provides small amounts of essential minerals like magnesium, phosphorus, and potassium.

3.4.Corn Gluten Meal

Composition and Characteristics: Corn gluten meal (CGM) is a high-protein by-product produced during the wet milling of corn, after the starch and germ have been separated. CGM contains a significant amount of protein (about 60-70%) and is rich in essential amino acids, especially methionine and lysine, which are important for animal nutrition. It also contains some fiber and fat.



Uses and Applications:

- **Animal Feed:** Corn gluten meal is widely used in livestock and poultry feed as a high-protein supplement. It provides a good source of protein and energy, making it ideal for feeding monogastric animals like pigs and poultry. Its high protein content supports growth and production efficiency, and it is often included in formulations for animal feeds to balance the amino acid profile[10].
- **Aquaculture:** CGM is also used in fish feed due to its rich protein content and nutritional value. It provides a sustainable alternative to traditional fishmeal, reducing pressure on marine ecosystems while ensuring the nutritional needs of farmed fish are met.
- **Biofuel Production:** Corn gluten meal can be utilized in the biofuel industry as a feedstock for the production of bioethanol or biogas. Due to its high protein content, it can also be used as a valuable source of nitrogen for the fermentation process in ethanol production[7].
- **Organic Fertilizers:** CGM can be used in organic fertilizers due to its high nitrogen content. As a slow-release nitrogen source, it helps improve soil fertility and is often applied as a natural fertilizer for crops in organic farming systems.
- **Pet Food:** Corn gluten meal is used as a protein supplement in the formulation of pet foods. It provides a digestible and cost-effective source of protein for dogs, cats, and other pets[3].
- **Weed Control:** In some agricultural settings, corn gluten meal has been used as a natural herbicide or pre-emergence weed control agent. It is believed to inhibit seed germination, making it useful in landscaping and organic farming as an eco-friendly alternative to chemical herbicides.

Nutritional Value of Corn Gluten

- **Protein Content:** Corn gluten meal is particularly rich in protein, making it an excellent supplement for animal feeds. It contains a significant proportion of essential amino acids, though it is lower in lysine compared to some animal-based protein sources. It is often balanced with other protein sources to create a complete feed.
- **Amino Acids:** The main proteins in corn gluten meal are zein and other prolamins. Zein is particularly important in the food industry as it can be processed into bioplastics, but it is also used in animal feed.

- **Energy and Fiber:** Corn gluten feed, with its higher fiber content, is an energy-dense feed for livestock. The fiber also plays an important role in promoting healthy digestion in ruminants.

3.5.Corn Husk and Stalks

Composition and Characteristics: Corn husks and stalks are the remaining plant materials after the corn kernels are harvested. These materials are primarily composed of cellulose, hemicellulose, and lignin, making them suitable for various applications, especially in the field of sustainable materials and energy.

Potential Applications:

- **Biodegradable Packaging:** The cellulose content in corn husks and stalks makes them a viable material for the development of biodegradable packaging and containers, offering a sustainable alternative to traditional plastic packaging[5][9].
- **Animal Bedding:** Corn husks are often used as bedding for livestock, particularly in dairy and poultry farms. The husks provide absorbent material that helps control odor and maintain cleanliness[6].
- **Biofuel Production:** Corn stalks, rich in cellulose, can be processed into biofuels such as bioethanol or biogas. The cellulose in these materials can be broken down into fermentable sugars and used as an alternative energy source[4][8].

3.6Liquied Glucose

Liquid glucose is a syrup made from starch and primarily composed of glucose molecules. It is widely used in various industries, particularly in food and pharmaceuticals. Here's an overview of its characteristics, composition, and usage:

Characteristics of Liquid Glucose:

1. **Appearance:** It is a clear, colorless to pale yellow, thick syrup.
2. **Viscosity:** It has a high viscosity and is sticky in texture.
3. **Sweetness:** Liquid glucose is less sweet than regular sucrose (table sugar), making it ideal for applications where less sweetness is desired.
4. **Solubility:** It is highly soluble in water.
5. **Hygroscopic:** It can absorb moisture from the air, which helps maintain the texture and moisture content of food products.
6. **Stability:** Liquid glucose is stable over time and does not crystallize easily, making it a reliable ingredient in many formulations.

Composition of Liquid Glucose:

Liquid glucose is primarily made up of:

- **Glucose (D-glucose):** This is the main sugar present in liquid glucose, derived from starch (usually corn or wheat starch).
- **Maltose:** A disaccharide sugar composed of two glucose units, found in varying amounts depending on the starch hydrolysis process.
- **Water:** Typically comprises a large portion of liquid glucose, contributing to its syrup-like consistency.
- **Other oligosaccharides:** Depending on the degree of hydrolysis, liquid glucose may contain trace amounts of other sugars like maltotriose or higher oligosaccharides.

Usage of Liquid Glucose:

1. Food Industry:

- **Sweetener:** It is used as a sweetening agent in candies, beverages, baked goods, and other confections[16].
- **Prevent Crystallization:** In products like ice cream and chocolates, liquid glucose helps prevent crystallization of sugars, providing a smooth texture[16].
- **Humectant:** It helps retain moisture in products like cookies, cakes, and marshmallows, extending shelf life[16].
- **Flavor Enhancer:** It enhances the overall flavor profile of food without adding excessive sweetness[16].
- **Caramelization:** Liquid glucose is used in the production of caramel, as it helps in controlled browning without burning[16].

2. Pharmaceutical Industry:

- **Sweetener in medicines:** Liquid glucose is used in syrup-based medicinal formulations[17].
- **Carrier for drugs:** It is used as a carrier or base for some liquid medicines and supplements[17].

3. Cosmetic and Personal Care:

- **Moisturizing agent:** Liquid glucose is used in lotions and creams due to its ability to retain moisture in the skin.

4. Industrial Uses:

- **Textile Industry:** It is used in the production of sizing agents and finishes for fabrics[16].
- **Manufacturing:** It is also employed in the production of certain adhesives, paints, and other chemical formulations[16].

Nutritional value of Liquid Glucose

The **nutritional value** of **liquid glucose** is similar to that of other simple sugars, as it primarily consists of glucose and other oligosaccharides. It is commonly used as a sweetener, humectant, and thickening agent in food products. Here's an overview of the nutritional content of liquid glucose, typically per 100 grams:[15]

Nutritional Breakdown (per 100 grams of Liquid Glucose):

1. **Carbohydrates:** ~80-85 grams.
2. **Sugars:** ~70-80 grams.
3. **Water:** Liquid glucose is primarily a syrup, and the water content can range between **10% to 30%** depending on the concentration of the syrup.
4. **Micronutrients (Vitamins and Minerals):** Liquid glucose is **not a significant source** of vitamins or minerals. It contains negligible amounts of nutrients like calcium, potassium, and magnesium[14].

3.7 Dextrose monohydrate

Dextrose monohydrate is a form of dextrose (a type of glucose) that is bound to one molecule of water. It is widely used in food, pharmaceutical, and other industries due to its properties and versatility.

Characteristics of Dextrose Monohydrate:

1. **Appearance:** It is a white, crystalline powder that is odorless and has a slightly sweet taste.
2. **Solubility:** Dextrose monohydrate is highly soluble in water, which makes it easy to use in liquid formulations.
3. **Sweetness:** It is less sweet than sucrose (table sugar), but it provides a quick source of energy.
4. **Hygroscopic:** It can absorb moisture from the air, which makes it necessary to store it in airtight containers to prevent clumping.
5. **Stability:** It is stable at room temperature and has a long shelf life when stored properly.
6. **Molecular Composition:** Dextrose monohydrate is composed of dextrose (D-glucose) and one water molecule (H_2O). The molecular formula is $C_6H_{12}O_6 \cdot H_2O$.
7. **Melting Point:** Dextrose monohydrate typically melts at around $146^\circ C$ ($295^\circ F$).

Composition of Dextrose Monohydrate:

- **Dextrose (D-glucose):** The primary component is glucose, which is a simple sugar and an essential energy source for the body.
- **Water Molecule (H_2O):** Each molecule of dextrose in dextrose monohydrate is associated with one water molecule. This gives it a crystalline form and affects its weight and hydration properties.

Usage of Dextrose Monohydrate:

1. **Food Industry:**
 - **Sweetener:** Dextrose monohydrate is used as a sweetener in many food products, including baked goods, beverages, candies, and sports drinks. It is commonly used in products where a quick-release form of sugar is required.
 - **Fermentation:** It is used in the fermentation process to produce alcohol, yeast-based products (like bread), and in the brewing industry.
 - **Energy Source:** Due to its rapid absorption by the body, dextrose is often included in energy drinks, sports nutrition products, and recovery formulas to quickly replenish glycogen levels.
 - **Preservative:** It helps in the preservation of certain foods by inhibiting microbial growth due to its hygroscopic properties.
2. **Pharmaceutical Industry:**
 - **Energy Source in Intravenous Solutions:** Dextrose monohydrate is used in intravenous (IV) solutions to provide quick energy to patients, especially in cases of dehydration, malnutrition, or during surgeries.
 - **Oral Rehydration Salts:** It is commonly found in oral rehydration solutions (ORS), where it helps in rehydrating and replenishing electrolytes in the body.

- **Drug Formulation:** Dextrose monohydrate can be used as a filler or excipient in the production of tablets, syrups, and other solid and liquid drug formulations.
- 3. **Cosmetics and Personal Care:**
 - **Humectant:** Dextrose monohydrate is used in skincare products to help retain moisture and improve skin texture.
 - **Conditioning Agent:** It is found in some personal care products like shampoos and conditioners for its ability to provide a gentle, non-irritating formulation.
- 4. **Industrial Applications:**
 - **Biochemical Production:** In the production of organic chemicals and bio-based products, dextrose monohydrate serves as a feedstock for fermentation processes.
 - **Textile Industry:** It can be used as a part of textile finishes, such as in the sizing or softening of fabrics.

Nutritional Value of Dextrose Monohydrate

The **nutritional value** of **dextrose monohydrate** is primarily related to its glucose content, as it is essentially a form of glucose (D-glucose). Since it is a simple sugar, it provides a quick source of energy but does not contain significant amounts of vitamins, minerals, or other nutrients. Here's a breakdown of its nutritional value:

Nutritional Breakdown (per 100 grams of Dextrose Monohydrate):

- **1.Carbohydrates:** ~100 grams.
- **2.Sugars:** ~100 grams.
- **3.Water:** Dextrose monohydrate is about 91% glucose and contains about 9% water (due to its monohydrate form).
- **4.Micronutrients (Vitamins and Minerals):**Dextrose monohydrate contains negligible amounts of vitamins and minerals, as it is primarily a sugar compound. It is not a source of significant nutrients like calcium, iron, or vitamins

4. Challenges and Future Directions

While there is immense potential in utilizing corn waste, several challenges remain. First, the technical and economic feasibility of converting corn waste into value-added products must be further explored. The need for efficient and scalable processing technologies remains a primary barrier to widespread adoption. Additionally, there are concerns over the potential negative effects of large-scale corn production on land use, biodiversity, and food security. Future research should focus on optimizing the extraction and processing methods, developing new biotechnological approaches for waste conversion, and ensuring that these practices align with sustainable agricultural systems. Furthermore, industry collaborations and policies that promote a circular economy can play a vital role in scaling the use of corn waste in diverse applications.

5. Conclusion

The potential for utilizing corn waste after starch extraction is vast and diverse. From biofuels to biodegradable plastics, corn waste offers opportunities for sustainable development across various sectors. The continued advancement of biotechnologies and sustainable practices is essential to fully

harness the value of these by-products. In doing so, the corn processing industry can minimize waste, reduce environmental impact, and contribute to economic growth in a circular economy.

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Nutritional Benefits, Functional Challenges and sensory adaptation by Incorporation of Millet in Baked Products: A review

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Abstract

Global dietary transitions toward plants have sparked the creation of meat analogues that duplicate both The increasing desire for nutrient-rich, gluten-free, and sustainable food options has generated interest in millet-based baked goods. Millets, ancient drought-resistant cereals, provide ecological resilience and nutritional benefits compared to standard wheat, supporting global health and environmental objectives. This abstract analyses the functioning, nutritional profile, and sensory characteristics of millet in baking applications, emphasizing its potential as a multifaceted component. Millet-based baked goods offer a viable substitute for conventional wheat, harmonizing sustainability with improved nutrition Millet is nutritionally superior as a substantial source of dietary fiber, phenolic compounds essential amino acids, and minerals such as iron, magnesium, and calcium. The low glycaemic index and elevated protein content serve diabetic and health-conscious individuals, while ant nutritional elements, such as phytic acid, are reduced through processing. In comparison to refined wheat, millet improves the nutritional composition of baked products, providing a functional food alternative for malnutrition and gluten-related conditions. However, the absence of gluten in millet presents difficulties in dough elasticity and product structure, frequently leading to dense or crumbly textures. Compared to refined wheat flour, non-gluten flours shown high apparent viscosity and improved dough viscoelasticity providing structural strength during dough expansions. To resolve this, formulations often combine millet with binding agents (e.g., hydrocolloids) or complementing flours (e.g., rice, cassava) to replicate gluten's viscoelastic characteristics. Sensory studies indicate that millet-based baked goods typically possess a nutty, earthy flavour and a somewhat coarse texture, necessitating the use of flavour enhancers or textural modifiers for improvement. Consumer acceptability is higher for biscuits and cookies, where millet's intrinsic characteristics enhance the desired crispness, colour and moistness. Despite functional limits and sensory adjustments, millet can diversify the baked products, providing healthconscious consumers with accessible, tasty, and nutritious alternatives.

Keywords: Millets, baking, rheology, nutrients, sensory

1. Introduction

Baking is an ancient process, with bakery products varying in complexity from the basic ingredients of a plain pastry to the multiple components of a cake. Wheat flour serves as the primary ingredient in the bakery, contributing essential bulk and structure to a majority of baked goods(1). Multiple diseases are identified as gluten-dependent, including immune allergic mechanisms, celiac disease, gluten ataxia, and dermatitis (3). Millets have served as a staple in the Indian subcontinent for centuries, owing to their resilience in arid climates and low water requirements, flourishing in conditions unsuitable for wheat. Millets are gluten-free and serve as significant food sources for millions of individuals with gluten intolerance, such as those with celiac disease, including diabetic patients, in both developed and developing nations(4). Millet is a rich source of protein, fiber, minerals, and phytochemicals. Processing methods can effectively reduce anti-nutrients, including phytic acid and tannin, in this millet to negligible levels (5). Their enhanced nutritional profile and adaptability to climate conditions establish them as a significant alternative in the bakery sector. The rising consumer demand for functional foods is driving the integration of millet(6). Millet-based bakery products utilize nutrient-dense flour, which increases fiber, protein, and mineral content, promoting a shift toward health-conscious and environmentally sustainable baking practices(7). Millets are transforming global bakery trends through the integration of tradition, innovation, and sustainability(8).

2. Incorporation of foxtail millet in baked products

2.1 Nutritional and functional properties

Foxtail millet (*Setaria italica*) is an important millet in Asia and Africa. Foxtail millet grains, owing to their gritty texture, are rich in calcium, dietary fibre, polyphenols and protein (9).

2.2 effect on baking and baked products

Biscuits were developed by the incorporation of foxtail millet flour .The foxtail millet (20%, 40%) and ginger powder blended wheat flours revealed cookies from 30% foxtail and 10% ginger powder had comparable scores (10). Gluten free biscuits were prepared, by employing hydrocolloids and the sensory, physico-chemical and nutritional properties were assessed. Compared to gluten free biscuits, wheat biscuits had higher scores (11).Addition of hydrocolloids improved the sensorial quality (12). There has been an increase in the number of nutritious snacks having low fat composition and total caloric value at 50% to 100% containing 20% fat. It had improved nutritional quality (13). The sensory parameters revealed that 100% of foxtail millet biscuits were acceptable (14). The starch digestibility of foxtail millet flour is lower than wheat flour(15). Both in vitro and in vivo tests suggested that boiling, steaming and extrusion enhanced formation of digestible starch and increased glycemic indices values. Cooked millet delay the development of type 2 diabetes (15). There was a higher percentage of protein and fat in control doughnut compared with substituted millet flour. Doughnut substituted with 40% millet flour showed highest score in overall acceptability (16). Moisture content of millets increased with increase in water temperature and regular increase in water absorption capacity was observed as temperature rose (17).

3. Incorporation of pearl millet in baked products

3.1 Nutritional and functional properties

Pearl millet, a gluten-free, healthy grain, is increasingly employed in baking products due to its unique qualities. High in protein, fiber, iron, magnesium, and B vitamins. It boosts energy and digestion with critical nutrients. The grain is low-glycemic, making it excellent for diabetic baking(18). The coarse texture, somewhat nutty flavor, and high water absorption of pearl millet flour affect the texture and flavor of bread, cakes, muffins, and cookies(19). High amylose content improves starch retrogradation, shelf life, and texture. Pearl millet flour, a gluten-free solution, maintains bread product taste.(20) found that its low glycemic index and peroxidase enzyme activity provide antioxidant advantages.

3.2 Effect on baking and baked products

Gluten-free pearl millet cookies are high in carbs, fiber, and Vitamin B. Grain-legume flour blends add protein, fragrance, and a yellowish-brown hue to biscuits (21). 50-100% cooked, fermented pearl millet flour (CFPM) cookies and bread are soft, gut-friendly, and digestible. The best combinations (10% CFPM in bread, 50% in cookies) taste nutty and are dark (22), (23). Protein-rich gluten-free biscuits made with pearl millet and millet flour (60:40 or 50:50 ratios) are high in Ca, Mg, and P. These dark brown, crunchy biscuits are a tasty wheat-free alternative. (24). Soft, delicious, yellowish-white cakes produced with 10-100% pearl millet flour instead of wheat have more protein and fat (25) (26). Good rheology and flavor remain (28). Color, texture, and flavor were appealing in fermented millet-wheat doughnuts. Quality, protein, fiber, and weight management were best with 40% millet flour (29). Five pearl millet cultivars provide whitish bread with 370 kcal/100g calories and good water binding (30). The substituted 10% millet flour substitution in wheat-millet which improved flavor and bread potential.

4. Incorporation of barley millet in baked products

4.1 Nutritional and functional properties

Barley based bakery products, including cakes, pasta, chapatis, cookies, bread, egg chips, and flakes etc., are innovative and nutritious options. They utilize barley's rich fibre, beta-glucans, and essential nutrients to create healthier alternatives to traditional baked goods, catering to modern dietary needs and health-conscious lifestyles (31). Dough made from barley focus on incorporating whole grains, alternative flours, and functional ingredients like fiber and antioxidants,improving nutritional value,heart health, regulate blood sugar (32). Hullless barley flour enhances wheat-based products by boosting fiber, antioxidants, and β -glucan, benefiting heart health and blood sugar regulation (33).

4.2 Effect on baking and baked products

Barley millet cookies supplemented with dietary fiber and antioxidants reduced cholesterol levels, enhance immunity and vitamin C (34). Modified starch gelatinization resulted in cookies with distinctive textures and properties (35). The cookie mixture comprising barley flour and whey protein concentrate enhanced digestion, regulated blood sugar levels, and fosters prolonged satiety (36). Cookies crafted from rolled oats and malted barley flour include enzymes that facilitate digestion and promote enhanced health (37). Cookies prepared using hull-less barley flour and high oleic sunflower seeds were shown to be abundant in beta-glucan, minerals, and vitamin E,

contributing to reduced cholesterol levels.(38) The cookies including barley flour, millet flour, whole wheat flour, and rolled oats are abundant in antioxidants, magnesium, beta-glucan, and dietary fiber, facilitating digestion and reducing cholesterol levels (39). The cookies prepared with barley flour exhibit heightened antioxidant activity owing to the presence of phenolics and flavonoids in barley, resulting in elevated total phenolic content and a reduction in cholesterol levels.(40).

Sponge cakes containing millet and barley flour exhibit improved nutritional qualities compared to traditional cakes. The inclusion of barley flour enhances antioxidant levels and lowers glycemic index.(41) Muffins made with barley and oat flours have the lowest glycemic potency, aiding in blood sugar regulation and promoting heart health.(42)

Multigrain breads, made from a variety of grains like wheat, barley, and oats primarily with barley enhanced nutritional benefits compared to 100% wheat bread. It supports healthy diets by improving fiber, protein, and mineral intake (43) (44).

Table 1. Describing the composition, change in Physicochemical & Sensory properties of foxtail, pearl millet, and barley incorporated bakery products

Sl No.	Type of bakery product	Composition	Nutritional & Physicochemical property changes	Sensory property changes	References
Foxtail millet					
	Cookies	Foxtail: 20%, 30%, 40% Ginger Powder: 5%, 10%, 15%	high phenolic content and antioxidant properties.	Similar score	10
	Cookies	Ratio of Foxtail Flour and Wheat Flour 60%, 50% and 45%.	Increase moisture, crude protein, crude fat, crude fibre and ash content.	highly accepted terms of texture, after taste and overall acceptability.	12
	Biscuits	foxtail millet and quinoa with the hydrocolloids.	Gluten free biscuits had higher nutrients.	Gum at 1% improved color, tastes, texture of foxtail millet biscuits.	13
	Doughnut.	Millet Flour: 20%, 30%, 40% and 50%	Higher percentage of protein and fat	with 40% millet flour showed highest score in overall	14

				acceptability.	
	Foxtail and lentil cookies	5% refined wheat, 10% malted foxtail millet and 30.5% malted lentil.	rich in fibres, protein, antioxidant and total polyphenols	Good Spread ratio, hardness and overall acceptability	16
	Bread	Three minor millets, foxtail, presco and pearl were taken.	increase in water absorption capacity	adversely affected the rheology	17
Pearl millet					
	Cookies	10- 50% pearl millet flour	High fiber cookies are darker, compact, and harder.	brightness decreased, good in taste and yellowish in texture.	21
	Breads,	10%, 15% and 20%, 25% of fermented pearl millet, 1:2, 1:3, 1:4 water with pearl millet flour.	Improve softness, structure, digestibility, anti-nutritional factors, with darkening for high phenolics.	Improved quality with softness, yellowish texture 10% for bread and 50% for cookies.	22
	Cakes	10%- 30%, 100% of PMF, 70%-90% of white flour, milk, oil, sugar, egg, butter, baking powder.	Rich in fiber, protein, and minerals, affecting moisture, texture, and color, making them denser and darker.	Have nutty flavor and coarse texture, slight softness due to flavor enhancers.	23
	Doughnuts	20%-50% of pearl millet flour	Boost protein, fiber, and minerals, while reducing moisture, fat, and ash, a firmer texture.	With 40% millet flour are soft, flavorful, and dark brown coarse texture.	25
	Gluten free biscuits	60%,50%,40% pearl millet flour.	Rich in fiber, minerals, and low glycemic index, bright darker texture, water absorption, and crispiness.	Have firm, crumbly texture, golden-brown color.	28

	Bread	Wheat-millet composite flours	Differ in color, from light to dark brown, and texture. Improved softness and rich in essential nutrients.	10% substitution well in appearance, aroma, taste, and flavor, with a slightly denser texture.	30
Barley					
	Cookies	60g of barley flour and other flour	high in fiber, protein, and essential minerals. color is darker, with natural brown	mildly nutty, earthy flavor with a hint of sweetness and chewier texture.	35
	Cookies	Rolled Oats: 50-60g, Malted Barley Flour: 20-30g	High in fiber, protein, and minerals. Denser and chewy texture. the colour is Golden brown.	Nutty and slightly sweet. The Texture is Soft yet firm, with a chewy mouthfeel.	36
	cookies	Hulless Barley Flour	higher in fiber, protein, and healthy fats. denser and softer texture	Nutty and slightly flavour sweet, Soft and slightly chewy texture.	38
	Multigrain cookies	Barley Flour ,Whole Wheat Flour, Rolled Oats	Higher in fiber, protein, and mineral. Denser and slightly crumbly texture colour is Darker, earthy tones.	Nutty and earthy, with a hint of natural sweetness. Texture is Chewy with a rustic feel.	39
	cookies	Lupine Flour and Barley Flour	High in fiber, protein, and antioxidants. Denser and softer texture.	Mildly sweet with earthy and nutty flavours.	40

			Color is reddish-brown.	Chewy and slightly crumbly texture.	
	Bread and cake made from barley millet	Sprouted Barley Flour 10-20%	Darker crust color. Enhanced moisture and tenderness, but slightly denser texture.	Nutty and slightly sweet flavour. Softer texture with a moist crumb.	43
	Muffins	Barley Flour 30-50%	Lower glycemic potency, higher dietary fiber, enhanced antioxidant levels, and a denser, moist texture.	Natural earthy flavor, mild sweetness, and acceptable texture.	44

5. Conclusion

In conclusion, millet holds immense potential as a versatile and nutrient-rich ingredient with beneficial properties such as a low glycaemic index, high protein content, and essential minerals. Its versatile physicochemical characteristics make it ideal for use in bakery products and traditional foods. Its incorporation enhances physicochemical properties, such as improved water absorption, emulsification, and textural attributes, while contributing to higher fiber, mineral, and antioxidant content. Sensory evaluations reveal high acceptability among consumers due to its unique flavor and texture, higher in shelf life, ensuring market viability.

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Process Standardization and Quality Evaluation of barnyard millet based Fortified Instant Khichdi: A Novel Approach to a Traditional Indian Staple

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Abstract

Barnyard millet, a nutrient-rich grain, has been incorporated into khichdi, a comfort dish that is cherished in Indian cuisine. This study examines the incorporation of barnyard millet into the conventional khichdi recipe, utilizing culinary research formulation, and nutritional analysis. It delves into the distinctive texture and sensory profile that barnyard millet contributes to the dish, as well as its potential health advantages, such as its gluten-free nature, high fiber content, and rich concentration of essential nutrients. The process for production of instant khichdi includes soaking, cooking and drying. The soaked green gram and barnyard millet were boiled in water for different times 3-9 minutes for masoor and 5-15 minutes for barnyard millet followed by drying in hot air oven for varying time (15 – 25 min.) at temperature(160 – 180 °C). One way ANOVA was used to analyse the data to optimize the process parameters for quick cooking. Soaking time and temperature had significant effect on the hydration capacity. Soaking of barnyard millet and masoor at 70 °C for 8 hours , cooking of masoor for 6 min and barnyard millet for 15 min and drying of dehat 172 °C for 18 min and drying of red lentils at 180 °C for 15 min produced instant khichdi with reconstitution time of 2 min.

Keywords: Instant khichdi, barnyardmillet, salt pretreatment, cooking, drying, rehydration

.1. Introduction

Instant foods give convenience to the consumer in terms of saving time to cook, invariant good taste, nutritional product, and a long shelf life. Hence, they are frequently called convenience foods. These can be formalized by using different processing techniques [1]. Instant foods are profitable for the fortified forces because when in combat conditions and inapproachable terrains where the force and medication of fresh food is delicate, they have to calculate on instant food products to sustain and gain energy [2]. Also, for the common people, instant foods have certain advantages. These foods can be consumed to break the monotony of regular foods and also make it possible to get varieties of cuisines in their authentic taste [3].

Instant foods offer not only ease in preparation but also possess an additional advantage over traditionally cooked dishes due to their convenient storage and transportation, facilitated by their lighter weight compared to conventional food items. There have been efforts directed towards creating instant millet-based khichdi, a popular dish in India[4]. Khichdi, typically made with barnyard millet and pulses, is renowned for its nutritional balance, as both ingredients complement each other well. Traditionally, barnyard millet and green gram dal are used in khichdi preparation, with or without husk. Instant khichdi, a pre-prepared version, requires minimal time for cooking. [5].

The khichdi made here incorporates barnyard millet, lentils, and clarified butter, seasoned with spices. Millets, often referred to as "small-seeded grasses," offer various benefits compared to traditional grains, such as higher protein content, rich sources of dietary fiber, phytochemicals, and micronutrients, and are easier to digest [6].

2. MATERIALS AND METHODS

2.1 Raw Materials

The process begins with the careful collection of raw materials. The collected materials, particularly barnyard millet, masor dal and vegetables. The barnyard millet was then soaked overnight for a duration of approximately 8 hours. This soaking step helps in softening the grains and preparing them for further processing. Following the soaking, the barnyard millet is boiled for 10 minutes, which partially cooks it and ensures it achieves the desired texture. Once the boiling is complete, the partially cooked barnyard millet is dried using a tray drier. This drying process is conducted for 4 hours at a controlled temperature of 60 degrees celsius, ensuring the barnyard millet is evenly dried without compromising its quality [7]

2.2 Preparation Of Vegetables

Beans and carrot were cleaned, peeled, and chopped into small, uniform pieces. Then the vegetables are boiled for 10 mins. These were then dried in a tray dryer for 6 hours. After cooling, the dehydrated vegetables were stored in an airtight container [8].

2.3 Drying Methods:

Once the boiling is complete, the partially cooked barnyard millet is dried using a tray drier. This drying process is conducted for 4 hours at a controlled temperature of 60 degrees celsius, ensuring the barnyard millet is evenly dried without compromising its quality. [9]

2.4 Preparation Of The Instant Khichdi:

Two Parts Of Cooked Barnyard millet Are Mixed With One Part Of The Prepared Dal Mix. This Combined Mixture Then Has One Part Of The Dried Vegetables Added To It. Finally, Everything Is Thoroughly Combined. To Prepare Instant Khichdi, Simply Heat 250ml Of Water In A Pan. Once Boiling Is Done, Add The Desired Amount Of Instant Khichdi Mix And Stir Well. Let The Mixture Simmer For 8-10 Minutes, Or Until The Barnyard millet And Lentils Are Cooked Through. Add Condiments For Extra Flavor And Taste [10, 11].

2.5 Proximate Analysis Of Instant Khichdi

Sample (barnyard millet and dal) was taken in the moisture analyzer to determine the moisture content. It operates on the principle of measuring the moisture content in a sample by determining

the weight loss after heating [12]. The ash content of the barnyard millet and dal were determined using a muffle furnace heated to 550 degrees Celsius for a duration of 4 hours [13]. Crude Fiber Analysis Was Conducted Using The Standard Method Employing A Soxhlet Apparatus In The Laboratory [14]. The Soluble Protein Content Was Determined Using The Folin-Lowry Method [15].

2.6 Water-Absorbing Capacity (WAC)

For water-absorbing capacity (WAC) at first 1g of samples was soaked in hot water for 10 minutes when a slide increase in weight was noticed the sample was Kept in water for 10 more minutes after a certain time there was no weight difference from that point the weight of the sample was calculated to determine the water absorption capacity of the sample[16] .

2.7 Oil-Holding Capacity (OHC)

Weigh 3g of the samples containing 2g of dal and millet and record the weight (W1) of it and then add a known volume of oil (V1) to the sample material while mixing.Mix the sample and oil thoroughly and allow it to equilibrate for a specific time after mixing Centrifuge the mixture at 4000 rpm for 5 minutes to separate the oil from the sample material. After the centrifugation process Measure the volume of oil retained by the sample material (V2). [17]

Oil Retention Capacity (ORC) is measured by using the following formula:

$$[ORC (\%) = ((V1 - V2) / V1) \times 100]$$

2.7 FTIR analysis

FTIR were used to determine the crystallization of instant millet and dal. Samples (2 mg) were utilized for the analysis as described earlier (Ji et al. 2010). The IR spectra of the samples were recorded by using an FTIR spectrophotometer at room temperature using SHIMADZU IRTRACER 100. Each sample was scanned for 32 times at a resolution of 4 cm⁻¹, crossing a region of 500–3500 cm⁻¹ [18].

2.8 Sensory Analysis Of Instant Khichdi

For The Purpose Of Sensory Analysis, Two Samples Were Prepared And 10 People Were Allowed To Test They Assessed Its Color, Texture, Taste, And Overall Likability Using A Nine-Point Hedonic Scale [19].

3. Result and Discussion

3.1 Proximate Analysis

Proximate analysis results indicate that barnyard millet varieties had significantly higher proximate values as compared to rice. Barnyard millet had significantly higher values of total dietary fibre. Soluble fibre helps in moderating blood glucose levels and lowering of cholesterol whereas insoluble fibre does not absorb or dissolve in water. It passes through our digestive system in close to its original form [20].

Table.1 Proximate composition of barnyard millet and dal

Nutrients (Mg/100g)	Barnyard millet		Dal	
	Uncooked	Cooked	Uncooked	Cooked
Total dietary fibre	0.806	0.72	.584	0.523
Polyphenol	1.278	0.29	0.375	0.127
Ash	1.84%	1.63%	0.91%	0.88%
Soluble protein	16.73	15.31	11.62	10.54
moisture	9.87	10.22	10.63	11.54

3.2 FTIR analysis:

After plotting the values, we identified a common functional group corresponding to the peak wavelength of the respective sample

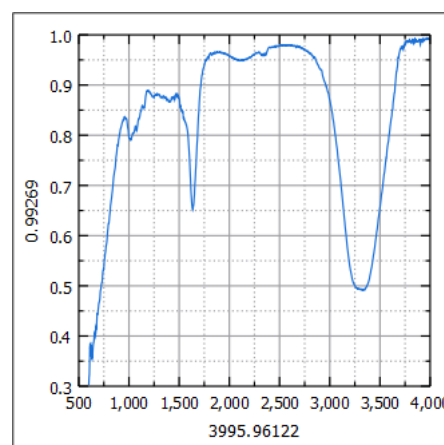
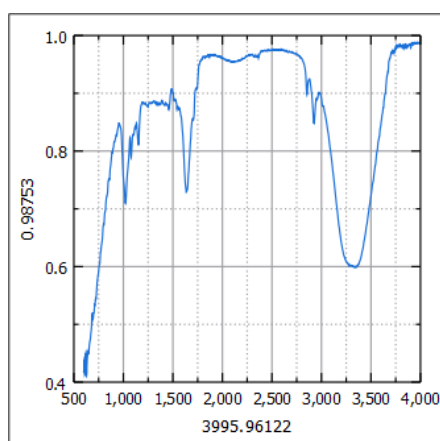


Fig 1: functional group representation of Barnyard millet and dal

3.3 Water-absorbing capacity (WAC) and oil-holding capacity (OHC)

The water-holding capacity (WHC) and oil-holding capacity (OHC) were low in the uncooked samples and they were high in cooked and instant millet and dal ($p \leq .05$). High WHC and OHC in the khichdi made using cooked and dried barnyard millet and dal and their combination could be attributed to the use of whole flour of sorghum and millet, which contain the bran that is rich in fiber and protein, and which are known to bind more water and oil in their structure [21, 22]

Table 2- Total Water Absorbing Capacity (WAC) and oil-holding capacity (OHC)

SL NO	SAMPLE	WAC (g/g)		OHC (g/g)	
		Uncooked	cooked	Uncooked	cooked
1	Barnyard millet	1.72	2.21	1.75	1.82
2	Masoor dal	2.16	2.24	1.92	2.16

3.4 Effect of Addition Of Carrot and Beans in the Instant Khichdi

Carrots bring a touch of sweetness and a pleasant textural contrast to the khichdi, adding beta-carotene, a precursor to vitamin A, crucial for vision and immunity. However, they lengthen cooking time slightly due to their slower cooking nature and require less water due to their moisture content [20]. The addition of beans to instant khichdi enhances its nutritional profile and taste. Beans are rich in protein, fiber, vitamins, and minerals. They improve the texture, add a subtle nutty flavor, and increase the meal's satiety value, making it suitable for a diverse range of dietary preferences. Moreover, beans complement the barnyard millet and lentils traditionally used in khichdi, creating a nutrient-dense, protein-packed meal ideal for quick and healthy consumption [23].

3.5 Sensory Analysis of Instant Khichdi:

Persual of Table 4 indicates that there was no significant difference in the sensory characteristics of khichdi prepared from barnyard millet and barnyard millet. The overall acceptability of barnyard millet khichdi and barnyard millet khichdi was 8.4 and 8.1, respectively on scale of 10. Hedonic scale rating depicts non-significant difference between khichdi prepared from barnyard millet and barnyard millet. Both were under “liked very much” category of Hedonic scale (Table 3).

Table 3- Sensory evaluation of instant millet based khichdi

Appearance	Colour	Flavour	Texture	Mouth Feelness	Overall Acceptance
9	8	8	9	8	8
8	9	9	8	8	8
8	7	8.5	9	6.5	7.8
9	8	7.5	9	8	8
8	8	9	8.5	8	9
7	9	8	8	7.5	8

3. Conclusion

The present investigation aimed towards instant foods like millet-based khichdi which offers a convenient and nutritious solution for busy lifestyles or barnyard millet-lenging situations like military deployment. Their portability, long shelf life, and quick preparation make them ideal for those with limited time or access to fresh ingredients. Moreover, millets, used in this innovative khichdi, boast additional health benefits due to their high protein content, fiber, and micronutrients.

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Preparation and characterisation of vegan mayonaise: ‘Gum-aqua-mayo’

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Abstract— The study explores the development of a vegan mayonnaise alternative, referred to as Gum-Aqua Mayo, utilizing aquafaba and tragacanth gum as key ingredients. The formulation process involved optimizing ingredient proportions to replicate the taste and texture of traditional mayonnaise. Rheological and spreadability analyses were conducted to compare the plant-based mayonnaise's physical properties with conventional egg-based mayonnaise. The nutritional benefits were evaluated, including assessments of fat content, moisture content, and phase separation stability. A market analysis highlighted the growing demand for vegan products and the potential competitive edge of Gum-Aqua Mayo. Additionally, the study examined the product's potential health benefits, such as anti-diabetic properties. This research indicates that Gum-Aqua Mayo not only meets consumer demands for plant-based alternatives but also offers potential health benefits and aligns with sustainable food trends.

Keywords— Vegan mayonnaise, Gum-Aqua Mayo, aquafaba, tragacanth gum, plant-based emulsifier, low-fat alternative.

Introduction

Mayonnaise is an iconic and globally beloved condiment, classified as an oil-in-water (O/W) emulsion. This seemingly simple yet intricate formulation consists of tiny oil droplets dispersed within a continuous water phase, typically stabilized by emulsifiers, most commonly derived from egg yolk [1]. The culinary origins of mayonnaise trace back to 1756 in France, where it was first created and later perfected by the famed chef Marie Antoine Carême, often regarded as the father of haute cuisine. Carême's refinements transformed mayonnaise into a versatile and luxurious sauce that became a staple of French cuisine [2]. While celebrated for its rich and creamy texture, the traditional mayonnaise formulation is predominantly high in fat, often containing around 70-80% oil. Although this high-fat content is crucial for the mouthfeel and flavor, has become a point of concern for health-conscious consumers [3]. The modern dietary landscape has significantly shifted towards lower-fat and healthier food options, driven by rising awareness of obesity, cardiovascular diseases, and other health issues associated with high-fat diets [4].

The demand for low-fat mayonnaise has surged, prompting extensive research into alternative formulations that can replicate the sensory attributes of traditional mayonnaise while substantially reducing its fat content [5]. However, the challenge of creating a low-fat mayonnaise lies in maintaining the sensory characteristics—such as creaminess, mouthfeel, and flavor—that consumers expect [6]. These qualities are inherently linked to the fat content, which is crucial to the product's

emulsion stability and textural properties [7]. To address this challenge, food scientists have explored the use of various hydrocolloids and thickeners, such as xanthan gum, microfibrillated cellulose, and different starches. These ingredients can enhance the viscosity, stability, and overall sensory experience of low-fat mayonnaise by mimicking the mouthfeel and body provided by fat [8]. Research has shown that specific combinations of these thickeners can successfully replicate the desirable properties of full-fat mayonnaise, offering consumers a healthier alternative without compromising on taste or texture [9]. Among the various thickeners and stabilizers explored, Tragacanth gum has emerged as a particularly promising candidate. Tragacanth gum is a natural polysaccharide derived from the dried sap of several species of Middle Eastern legumes, such as *Astragalus gummifer*. It is well known for having exceptional emulsifying power, high viscosity, and stability over a broad pH and temperature range, among other distinctive rheological characteristics. Because of these qualities, tragacanth gum is a great addition to low-fat mayonnaise to enhance its stability and texture. Moreover, its natural origin and compatibility with plant-based and vegan formulations align with current consumer trends favoring clean-label and plant-based food products [10].

In addition to its emulsifying and thickening properties, Tragacanth gum contributes to the overall spreadability and stability of mayonnaise, which are critical factors influencing consumer acceptance. The texture and consistency of mayonnaise are key determinants of its quality, affecting how the product behaves during application and consumption. Understanding the role of Tragacanth gum and other thickeners in achieving these characteristics is crucial for developing mayonnaise products that meet the high expectations of today's consumers [11].

The Food and Drug Administration (FDA) has recognized Tragacanth gum as a safe food additive, further validating its use in food products [12]. This certification ensures that Tragacanth gum meets rigorous safety standards, making it a reliable choice for food manufacturers aiming to improve the quality and stability of their products [13].

Materials and Methods

Materials

Gum tragacanth (1.3% w/v), chilled aquafaba (30% v/v), and vinegar containing 14.0% (w/v) acetic acid were sourced from a local grocery store. Sunflower oil, salt, and sugar were also included. All experiments used deionized water. The vinegar was diluted with water to achieve a 4.0% (w/v) acetic acid solution. All chemicals and apparatus are bought from merck. The gum tragacanth powder was soaked in water for 24 hours before preparing the mayonnaise. Black pepper, garlic powder, and herbs were used as flavor enhancers.

Mayonnaise preparation

The mayonnaise was prepared following literature methods with minor adjustments [14][15]. The formulation comprised 60.0% sunflower oil, 4.0% vinegar, 30% aquafaba, 1.30% gum tragacanth (GT), 1.5% sodium chloride, and 4% sugar (w/w). Variations in the amounts of aquafaba and oil prior to emulsification were tested at the following ratios: 0–100%, 50–60%, 40–60%, and 30–60%. A total of 150 grams of mayonnaise were prepared for each ratio. Initially, the salt, sugar, and a small portion of vinegar were combined and mixed using an overhead stirrer (Model 120S, Fisher Scientific, Waltham, MA) to create a spice mix. Concurrently, the GT was blended with water for approximately 60 minutes using the same stirrer. The aquafaba, oil, and spice mix were then chilled below 5°C in a refrigerator.

Once the ingredients were adequately cooled, the aquafaba was transferred to a 250 mL glass beaker and blended with a hand blender (Type HB08, Model 59762, Hamilton Beach, Glen Allen, VA) using the blending baton attachment for 1.5 to 2 minutes. The GT slurry was subsequently incorporated, and the mixture was blended for an additional 2 minutes. Oil was then added slowly using a measuring cylinder while blending at high speed, ensuring that no surface oil appeared before adding more. After one-third of the oil had been incorporated, the blender head was switched to a whisk attachment, and the remaining oil was added steadily as described.

To achieve a thick, commercial-style mayonnaise, any mixture adhering to the walls of the beaker was scraped down and blended for another 1.5 minutes. The blender speed was then reduced, and the remaining vinegar was dripped in slowly after emulsification. Once all the vinegar was incorporated, the spice mix was added, and the mixture on the beaker's walls was scraped down and blended for an additional minute.

Prepared sample of different Oil : Aquafaba ratio, where

sample 2 comes out to be texture similar to control one.

The prepared mayonnaise was stored in a refrigerator prior to further testing and analysis.

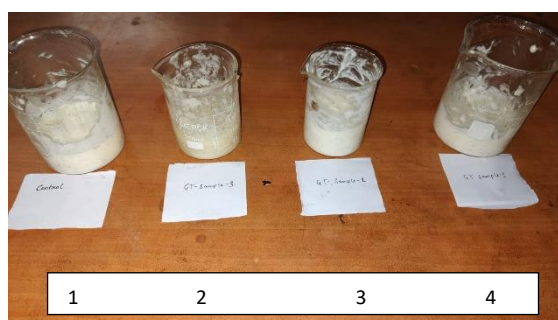


Fig 1 Prepared sample of different Oil : Aquafaba ratio, where sample 2 comes out to be texture similar to control one.

Characterization of Emulsion

Acid Value

This is determined by titration, a definite amount of sample is to be taken in a beaker, add neutral alcohol on it as per required. Heat the mixture, and after some time, add few drops of phenolphthalein indicator. Titrate this against NaOH solution.[16]

Peroxide Value

Peroxide value is also measured by titration method. Take a definite amount of sample which to be weighted into stoppered Erlenmeyer flask. Acetic acid, chloroform was added and swirled until the sample was completely dissolved. Add saturated KI solution. The Distill water is then added then titrate it against thiosulphate. After that add starch indicator and titrate it again until the end point appears.[17]

pH

Measured using pH meter. It is measured in a particular interval to check the stability of the mayonnaise till a layer separation of oil and water occurs.

WEEKS	GT 1	GT 2	GT 3	CONTROL
WEEK 1	6	5	4	5
WEEK 2	6	5	3	5
WEEK 3	5	4	3	4
WEEK 4	3	4	3	4



Fig 2 Layer separation after 28 days

Rheological properties

Rheological measurements of the mayonnaise were conducted using a Brookfield rheometer equipped with Rheology Advantage V5.5 software. A 40 mm parallel plate with a gap size of 1.0 mm was utilized for the experiments. Steady-state shear viscosity was assessed across shear rates ranging from 0.1 to 100 s⁻¹, following a pre-shear at 20 s⁻¹ for 10 seconds. Oscillatory measurements of the storage modulus (G') were performed through a stress sweep from 0.1 to 100 Pa. The yield stress was identified as the critical stress at which irreversible deformation occurs. All rheological tests were conducted at a controlled temperature of 25°C. The basic principle on which it works is given as:

The power law model applied $\tau = K(dv/dy)^n$ (1)

Where, τ = Shear Stress, k = Consistency index, n = Flow Index, dv/dy = Shear Rate

Result and Analysis

Acid value

Acid value should be 4.25 mg KOH/g of oil. After 45 days of storage at 4°C this value increases rapidly [18]. Sample 1 has the highest acid value (2.65 mg NaOH/g), indicating that this sample has the highest degree of degradation or hydrolysis of fats compared to the others. This could be a result of exposure to unfavourable conditions, such as higher temperatures, extended storage, or the presence of enzymes or microorganisms that promote fat breakdown. Samples 2 and 3 have the same acid value (1.53 mg NaOH/g), which is higher than the control, indicating some degree of fat degradation but to a lesser extent than Sample 1. Control has the lowest acid value (1.39 mg NaOH/g), suggesting that it is the freshest and least degraded sample.

pH

pH test is conducted for around one month at an interval of 7 days and after 7 days phase separation takes place.

Value of pH measured at an interval of one week

Layer separation after 28 days

Rheological properties

The rheological analysis using a Brookfield viscometer revealed that Gum-Aqua Mayo exhibited comparable shear stress and shear rate behavior to traditional mayonnaise.

Graph of Viscosity

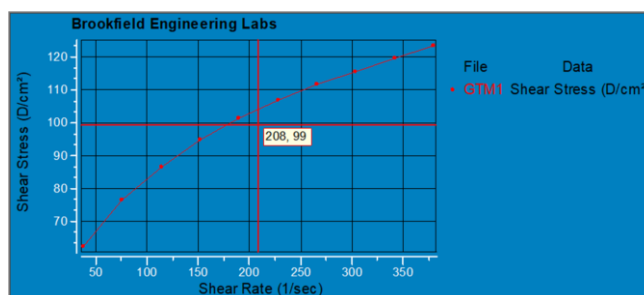


Fig 3 Graph of “gum-aqua-mayo” which is a parabolic graph showing the value of $n > 1$ means the product is dilatant in nature.

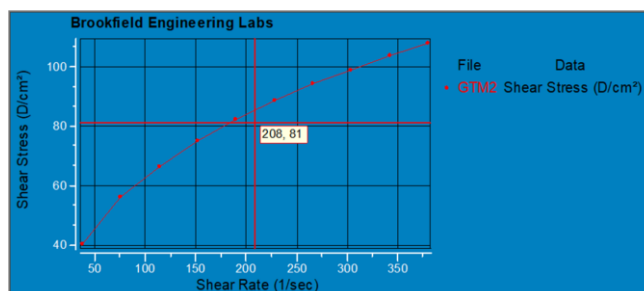


Fig 4 Graph of “control” which is a parabolic graph showing the value of $n > 1$ that means the product is dilatant in nature.

Conclusion

The development of Gum-Aqua Mayo, a vegan mayonnaise alternative using aquafaba and tragacanth gum, represents a significant advancement in the field of plant-based foods. The research demonstrates that this product can successfully replicate the sensory and physical properties of traditional mayonnaise while offering additional health benefits and aligning with sustainable food practices. Rheological and spreadability analyses confirmed that Gum-Aqua Mayo achieves comparable textural properties to conventional mayonnaise. Nutritional assessments indicated lower fat and calorie content, making it a suitable choice for health-conscious consumers.

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Drying Process Parameter Optimization for Instantification of Rice

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Abstract

Rice is the staple food of many countries and is widely consumed because of its nutritional value. Lack of cooking time and increasing urbanization is leading to higher demand for instant food products. Development of instant rice is of high market potential, but still it poses various problems related to rehydration properties and quality. In this study, experiments were conducted to study the effects of soaking time, soaking temperature, soaking solution, cooking solution, drying time and drying temperature on various properties like moisture content, color change, moisture content, whiteness index, hardness, chewiness, gumminess and springiness. Drying process was optimized by drying in hot air oven at conditions viz. drying time (22 – 32 min) and drying temperature (160 – 180°C). One way ANOVA was used to analyse the soaking and cooking process and response surface methodology was used to analyse and optimize the drying process. The values of different parameters varied from 1.861 – 8.004, 68.338 – 72.355, 3.83 – 34.67 % wb, 2.059 – 2.825, 4.46 – 11.72 N, 0.504 – 0.8 mm, 2.12 – 6.859 N, 0.9 – 4.2 mJ for total color change, whiteness index, moisture content, rehydration ratio, hardness, springiness, gumminess and chewiness respectively. Soaking in 2.5% conc. salt solution at 60°C for 20 min, cooking in 0.15% conc. citric acid solution for 7 min and drying at 170°C for 27 min gave instant rice with optimized product quality having reconstitution time of 3 min.

Keywords: instant rice, soaking, cooking, drying, sodium chloride, citric acid, rehydration, texture, color, moisture content

1. Introduction

Around 90% of the world's rice is produced and consumed in Asia (1). In India the total production of rice in the year 2021-22 was 105.45 million tonnes out of which 102 million tonnes are available for domestic consumption. Its daily consumption makes it one of the major source of nutrients (2). In today's world of busy schedule and lack of cooking time has led to increasing demand for instant foods. Instant rice would be high market value but long rehydration time and inferior quality limits the use of instant rice (3). In situations where saving of time is desired (convenience of preparation), or for those situated in very high altitudes, especially army personnel, the instant rice is of immense value (4).

The process of instantization of rice includes soaking, cooking and drying of the cooked rice (5). Soaking permits the desired degree of gelatinization to be obtained at the centers of the grains in a shorter time and cooking process is necessary for partial (80%) or complete gelatinization of rice in the process of preparation of instant rice. Drying is the most crucial step for the production of instant rice and all the physical and chemical changes taking place during different process highly affect the consumer acceptability (6). Drying is used to reduce the moisture content to an extent such that microbial stability of the product is assured and storage stability is also increases. In case of microwave drying, excessive drying at the edges and corners of the dried sample leads to subsequent lowering of the quality of the dried product (7). Hot air drying would subsequently prevent the burning of instant rice and save energy.

This study aims to develop instant rice, which can be prepared within 2-3 minutes just by adding it in hot boiling water and maximum retention of the physicochemical properties of cooked rice. Hot air drying is used to prevent the burning of instant rice and save energy. The instant rice developed would resemble the milled unprocessed rice in shape and after rehydration the volume would be 1.5-3 times that of dried rice, with its color, flavor and texture similar to that of cooked rice and there should be no hard or ungelatinized core at the center (8).

2. Materials and methods

Raw rice (*swarna variety*) samples was procured from the local market of Kharagpur, West Bengal, India. It was manually cleaned to remove the stones and stored in air tight containers for further uses. Proximate composition (moisture, protein, fat, fiber and ash content) of the dal samples were analysed using standard analytical procedure (9).

2.1 Optimization of drying process of instant rice

Experimental design and statistical analysis

Design Expert software (version 7.0.0) was used for determining the number of experiments to be done. Central Composite Rotatable Design (CCRD) with two variables was used to conduct experiments and optimization was carried out using response surface methodology (RSM). Statistical significance of the experimental terms was examined by analysis of variance (ANOVA) at a confidence level of 95%. The effect of drying time (22-32 min) and drying temperature (160-180 °C) was evaluated.

The relationship between the independent variables and the responses is given by quadratic second order polynomial equation and the generalized form of the equation is given as:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_1^2 + \beta_4 X_2^2 + \beta_5 X_1 X_2 \quad (1)$$

Where, Y is the response; X_1 and X_2 are variables and β_0 is the model intercept coefficient;

β_1 and β_2 coefficients of linear term.

β_3 and β_4 coefficients of quadratic term.
 β_5 is the coefficient of of interaction term.

Table 1: Factors for experimental design of the drying of pre-cooked rice

Factor	Name	Units	Type	Low Actual	High Actual	Low coded	High coded	Mean	Std. Dev.
A	Drying temperature	°C	Numeric	160	180.00	-1.00	1.00	20	3.992
B	Drying time	min	Numeric	22	32	-1.00	1.00	27	7.845

2.2 Analysis of various desirable properties of instant rice

2.2.1 Hydration capacity (%)

It refers to the water absorption percentage of a sample when it undergoes a hydration process (soaking/cooking). Hydration capacity (HC) is also known by the terms “hydration coefficient” and “hydration index,”

$$\text{Hydration capacity (\%)} = \frac{100(wf-w1)}{w1} \quad (3)$$

Where,

wf = final weight of the sample after soaking/cooking, g w1 = initial weight of the unprocessed sample, g

2.2.2 Moisture content

The moisture content of the samples were determined by using Mettler infrared moisture analyser, model, AND M-50.A sample of about 5 g is taken on the reset pan and the reading was noted down .

2.2.3 Colour parameters a) Total colour change(ΔE)

The colour of the soaked samples were determined by a Minolta colorimeter (Model: CR 300 Konica-Minolta, Osaka, Japan), calibrated with a white standard tile. Total colour difference (ΔE) which is a combination of parameters L^* , a^* and b^* values. The total colour change of the instant rice from the unprocessed rice were found out by the values of lightness/darkness (L^*), redness/greenness (a^*), and yellowness/blueness(b^*) (11).Each reading was taken in duplicate.

The following equation was used to calculate the total colour change:

$$\Delta E = [(L - L^*)^2 + (a - a^*)^2 + (b - b^*)^2]^{1/2} \quad (4)$$

L, a, b = values of the unprocessed rice L^*, a^*, b^* = values of the instant rice.

b) Whiteness index(WI)

Whiteness index is a measure which correlates the visual ratings of whiteness for certain white and near-white surfaces. It can be used for any material which appears white. The whiteness index was

calculated as follows: (12).

$$WI = 100 - [(100-L)^2 + a^2 + b^2]^{0.5} \quad (5)$$

2.2.4 Texture Profile Analysis(TPA)

Texture profile analysis of rice obtained for different processes (cooking/rehydration) was performed according to (13) using a Brookfield, CT 3 Texture Analyser (Brookfield Engineering Laboratories Inc, Harlow, Essex, England) with a 50 kg load cell using a two-cycle compression. A cylindrical probe with a diameter of 25 mm was used to compress the kernels at a pre-test speed of 1 mm/s. The resulting force- deformation data were analyzed and the average values of hardness, springiness, chewiness and gumminess were calculated.

2.2.5 Rehydration ratio

To determine the rehydration ratio, 5g of sample was poured into 50 ml boiling water (rice:water=1:10) (14). After 2 min the contents were filtered through strainer. The rehydrated sample was then weighed and the recorded weight is called rehydrated weight (W_r). Rehydration ratio is given by the following equation:

$$RR = W_r / W_1 \quad (6)$$

Where,

W_r = weight of the rehydrated rice, g. W_1 = weight of the dehydrated rice, g.

3. Results and discussion

3.1 Optimization of experimental conditions for drying:

According to CCRD, 13 experiments were done in different combinations of drying time and drying temperatures and their effects on different responses were studied. The different responses included moisture content, lightness, browning index, total color change of dried rice and properties like rehydration ratio, hardness, chewiness, gumminess of the rehydrated rice (15).

ANOVA for response surface quadratic model was done for all the response variables. The regression coefficients were also found out for all parameters. Quadratic model was found to be significant for all responses ($p < 0.05$) and for each response the significant model terms were also found out (Table 3). Taking the significant terms into consideration, regression equations for each response were formed (eqn 7 to 14). It must be noted that the independent variables were included in the models, if their interaction effects were significant although their sole effects appeared to be insignificant (16).

Table 2: Regression coefficients for different responses and their significance for instant rice

	Moisture content(%wb)	Total color change(ΔE)	Whiteness index(WI)	Rehydration ratio	Hardness (N)	Chewiness (mJ)	Gumminess (N)	Springiness (mm)
Model	11.80**	3.40**	71.16*	2.57**	5.76**	1.38**	2.93**	0.54**
A	-8.90**	1.12**	-0.97*	0.23**	-1.64**	-0.36*	-0.87**	7.416E-003
B	-3.80*	1.93**	-1.11**	0.13**	-1.41**	-0.15	0.26	0.042*
AB	7.23*	-0.36	0.060	-0.12*	0.80	0.092	1.20**	0.098**
A²	3.26	1.24**	-0.73	-0.048	1.19*	1.08**	0.82**	0.040
B²	-1.66	0.42	-0.10	0.042	1.64**	0.94**	1.32**	0.066**
Lack of fit	3.34	6.30	0.45	1.70	2.11	1.19	0.16	4.84
R²	0.883	0.869	0.792	0.939	0.898	0.919	0.955	0.853

A – Drying time, B –Drying temperature

*significant at $p < 0.05$ (5 % confidence interval), **significant at $p < 0.01$ (1 % confidence interval)

The experimental data of each response were fitted into these quadratic models (eqn 7 -14) in order to get the fitting values of coefficients (Table 5) as appeared in the following equations:

$$Y1 \text{ (Total color change)} = 3.40 + 1.12A + 1.93B + 1.24A^2 \quad (7)$$

$$Y2 \text{ (Whiteness index)} = 71.16 - 0.97A - 1.11B \quad (8)$$

$$Y3 \text{ (Moisture content)} = 11.80 - 8.90A - 3.80B + 7.23 AB \quad (9)$$

$$Y4 \text{ (Rehydration ratio)} = 2.57 + 0.23A + 0.13B - 0.12AB \quad (10)$$

$$Y5 \text{ (Hardness)} = 5.76 - 1.64A - 1.41B + 1.19A^2 + 1.49B^2 \quad (11)$$

$$Y6 \text{ (Springiness)} = 0.54 + 0.042 B - 0.098AB + 0.066B^2 \quad (12)$$

$$Y7 \text{ (Gumminess)} = 2.93 - 0.87B + 1.20AB + 0.82A^2 + 1.32B^2 \quad (13)$$

$$Y8 \text{ (Chewiness)} = 1.38 - 0.36A + 1.08A^2 + 0.94B^2 \quad (14)$$

Table 3 : Total effect (F value) of individual parameters on the responses of moong dal

A – Drying time, B – Drying temperature

*significant at $p < 0.05$ (5 % confidence interval), **significant at $p < 0.01$ (1 % confidence interval)

	Moisture content(%w b)	Total color change(ΔE)	Whitenes s index	Rehydratio n Ratio	Hardness (N)	Chewines s (mJ)	Gummines s (N)	Springines s (mm)
A	31.57**	16.50**	9.58*	71.73**	20.36**	5.86*	33.31**	0.20
B	5.76**	49.06**	12.44**	21.93**	15.11**	1.07	3.05	6.33*
AB	10.41*	0.85	0.018	9.65**	2.40	0.20	31.48**	17.38**
2	3.69	17.46**	4.73	2.71*	9.34*	47.21**	25.96**	5.10
A								
2	0.96	1.98	0.097	2.09	17.66**	35.26**	66.99**	13.68**
B								

Effect of drying time and temperature on various color , texture and rehydration properties

The effect of drying time and drying temperature on various properties of instant rice were evaluated and analysed. The effects and their respective levels has been illustrated in Table 4, wherein, Fisher's values (F) have been depicted for all the factors along with a star superscript to highlight the significant terms. Higher the “F-value”, greater is the effect of the terms on the response and lower is the corresponding “p-value”. The “p-value” < 0.05 indicates, the model is significant. Higher F value indicates greater effect of the factor on respective response.

3.1.2 Effect on moisture content

Effect of drying time and drying temperature on moisture content is shown in Fig.1a. The moisture content gradually significantly ($p < 0.01$) decreased with increasing drying time and temperature and it varied from 3.83 to 34.67% wb. Increasing in drying temperature provided higher drying rate, more removal of water, hence reducing the moisture content. It also might be due to rapid development of porosity during high temperature drying, facilitating transport of moisture (17). Higher F value of drying time (Table 4) revealed it to be more influential as compared to drying temperature, therefore increasing the drying time even at low temperature significantly reduced moisture content. (18) also found similar results for drying of instant jasmine rice.

3.1.3 Effect on colour parameters:

Total colour change

The total colour change of instant rice was calculated using the Eq. 4. The effect of drying conditions on the total colour change of instant rice was evaluated and analysed. The total colour change of rice significantly ($p < 0.01$) increased with increasing drying time and temperature (Fig.1b) and the values varied from 1.861 – 8.004. The lowest colour change took place by drying at 160 °C for 22 min. As the colour change was found out by taking all the color values (L^* , a^* , b^*) into consideration, more variation was found in L^* values i.e lightness. The lightness value mostly decreased due to thermal browning. High temperature and low final moisture content yielded more yellow color, thus

increasing the total color change. High drying temperature and low final moisture content yielded more yellow color and caused more color change (19). Lightness values of instant rice also decreased with increasing drying temperature even when dried by micro-wave assisted vibro fluidized bed dryer (20). Similar results were also found by drying of instant rice by microwave followed by convective hot air drying (21). It is more desirable for colour properties of instant rice to be as close to that of the unprocessed rice as possible, so determining the most precise dehydration conditions is of great economic importance.

3.1.4 Rehydration ratio

Rehydration ratio one of the most important characteristics of instant rice. It was calculated using Eqn. 6. The drying conditions had significant effect on rehydration ratio of instant rice. It showed significant ($p < 0.01$) positive effect with increasing drying time and drying temperature (Fig. 1d). The values varied from 2.059-2.852 in rehydration time of 2 min. Higher rehydration ratio is a result of higher porosity of the dried rice. High temperature drying leads to higher porosity. Higher the porosity of rice, lower is the bulk density and higher is the rehydration ratio (22) (23). Higher F values of drying time showed that it has more significant effect as compared to drying temperature (Table 2). High temperature and low time drying increased porosity and enhanced rehydration. (24) also found similar results in the process of instant rice making.

3.1.5 Effect on textural properties

The dried rice was rehydrated for 2 min and various textural properties were analysed. Hardness and Chewiness

Hardness refers to the force required to compress a substance between molar teeth (for solids) or between tongue and palate (for semi-solids). To develop a more palatable product, the hardness should be as low as possible. The effect of drying time and drying temperature was studied and evaluated. The value of hardness varied from 4.46 to 11.72 N. Higher values were found by drying at 160 °C for 22 min and 180 °C for 32 min. Drying at higher temperature for longer time increased the hardness due to destruction of the structure, resulting in case hardening (25). More absorption of water during rehydration will lead to softer texture and lower hardness (26). Higher hardness at 160 °C may be due to less porosity of the dried sample, leading to less water absorption and hence higher hardness value.

Chewiness refers to number of chews required for the cooked rice suitable for swallowing during mastication. The effect of drying time and drying temperature on chewiness of instant rice is shown in Fig 1f. The values of chewiness varied from 0.9-3.867 mJ. The decrease of chewiness is directly related to decrease of hardness. Therefore the response surface graphs for chewiness were similar to that of hardness. The F values for both hardness and chewiness shows that, drying time has more significant ($p < 0.05$) effect than drying temperature. Similar results for hardness and chewiness were found by (27) for optimization of instant jasmine rice.

Gumminess and Springiness

Gumminess refers to denseness that persists throughout mastication or energy required to disintegrate a semi-solid food to a state ready for swallowing. The effect of drying time and drying temperature on gumminess of instant rice is shown in Fig 1g. The values of gumminess varied from 2.12 – 6.589 N. From the F values, it was found that drying time had more significant effect as compared to drying temperature (Table 3). More the denseness of the rice means less will be the ruptured starch i.e less leached out amylose and amylopectin. If the leaching amount is more, the gumminess will be less. Higher values were found by drying at 160 °C for 22 min and 180 °C for 32 min. At 160 °C the less leaching of starch might be a reason for higher gumminess, whereas at 180 °C the gumminess might be higher because of same reason as that for hardness. Gumminess is a secondary parameter and is mostly dependent on hardness (28).

Springiness refers to the degree to which a rice returns to which original shape after being crushed between teeth. The effect of drying time and drying temperature on springiness is shown in Fig 1h. The value of springiness varied from 0.53 – 0.8 mm. Highest springiness was found by drying at 180 °C for 32 min. Highest value of springiness at this drying condition might be due to increase in elastic behaviour of rehydrated rice (29). Higher F values of drying temperature indicated its higher significance as compared to drying time.

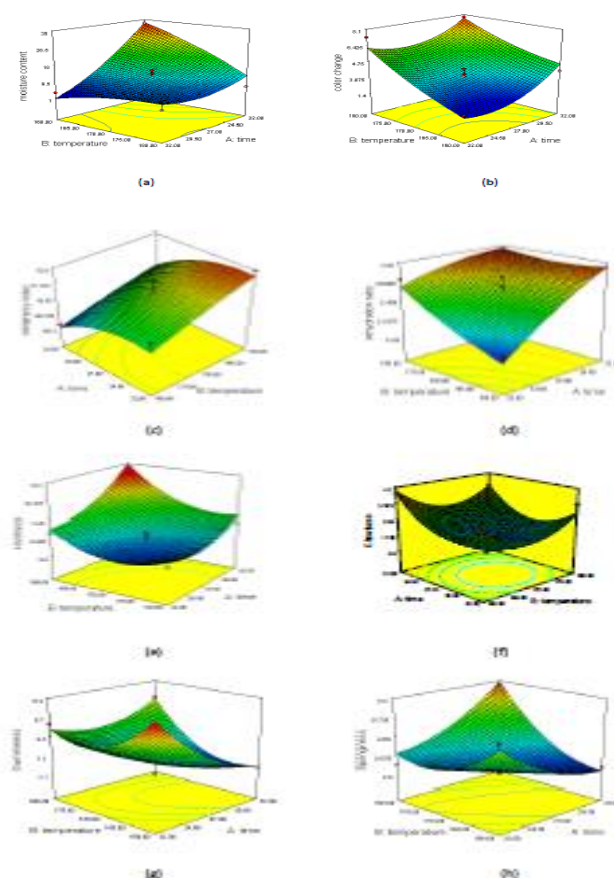


Fig.1. Effect of drying time and drying temperature on various responses

3.1 Numerical optimization and data validation

It was found that drying of precooked rice at 167° C for 28 min gave optimized response with desirability of 0.806. Both the variables were within the range of experimental conditions. Experiments were conducted in duplicate to validate the model (Table 3). The response variables were also found to be in the range.as in Table 4.

Table 4: Predicted and experimental values of different responses

Response variables	Predicted values	Experimental values	Error
Moisture content(%wb)	10	10.11	
Total color change(ΔE)	3.319	3.21	
Whiteness index(WI)	71.13	71.2	
Rehydration ratio	2.608	2.478	
Hardness(N)	5.892	5.64	<10%
Chewiness(mJ)	1.487	1.3	
Gumminess(N)	2.682	2.66	
Springiness(mm)	0.533	0.50	

Conclusions

All the processes (soaking, cooking and drying) had significant effect on the final product. Soaking in 2.5% conc. salt solution at 60 0C for 20 min, cooking in 0.15% conc. citric acid solution for 10 min and drying at 170 0C for 27 min gave instant rice with optimized product quality having reconstitution time of 3 min. The instant rice developed was acceptable to human palate and the process technology developed makes it a very economical process. Hot air drying is a very common method of drying and the quality of a food product is highly sensitive to drying temperature. It has been found effective in preservation and drying of many foods, hence commonly used in instant rice industry.

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List of abstracts

ETBFT-24-003

Influence of associated anions on the morphological responses and rhizospheric bacteria composition of *Celosia argentea* L. To sodic salinized soil

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ABSTRACT

This study examines the impact of associated anions on the morphological responses and rhizospheric bacterial composition of *Celosia argentea* L. grown in sodic salinized soil. Conducted in the University of Benin's Department of Plant Biology and Biotechnology botanic garden, the experiment aimed to elucidate the effects of sodic salinization on plant growth and microbial communities. Soil samples were collected, bulked, and distributed into 44 bowls, which were then sodicized with NaCl solution for six weeks to simulate saline conditions. Comprehensive analyses revealed significant variations in morphological parameters, including plant height (24.85-34.85 cm), leaf number (29.17-49.55), leaf area (19.11-30.93 cm²), seed weight (0.542-0.69 g), above-ground biomass (14.58-21.61 g), and foliar yield (4.128-6.914 g). Physicochemical characterization showed pH ranges of 5.75-5.85, electrical conductivity of 89.20-131.38 $\mu\text{S}/\text{cm}$, and varying levels of organic carbon (0.012-0.48%), total nitrogen (0.01-0.04%), and essential minerals (Na, K, Ca, Mg). These findings demonstrate the complex interactions between sodic salinization, plant growth, and soil properties. Molecular identification revealed a diverse array of bacterial strains, including *Klebsiella aerogenes*, *Serratia marcescens*, *Escherichia coli*, *Bacillus safensis*, and *Enterobacter cloacae*, inhabiting the rhizosphere of *C. argentea*. The study's outcomes suggest that optimal growth and development of *C. argentea* occur in moderately saline soils, with 100% germination achievable in NaCl-free nurseries and maximum growth upon transplantation to moderately saline soils. These findings have profound implications for enhancing food productivity and ensuring food security, particularly in regions with saline soils. The research provides valuable insights into the effects of sodic salinization on plant-microbe interactions, informing strategies for sustainable crop production in saline environments.

ETBFT-24-005

**Fabrication and Characterization of Dual Functional Smart Film and Evaluating its
Functionality in Active Packaging**

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Abstract

Active intelligent food packaging also known as smart packaging is an emergent technology in food industry. It is called smart packaging as it not only increases the shelf life of the food but it also indicates if somehow the food has spoiled. The bio polymeric film was prepared using potato starch and polyvinyl alcohol. As antioxidant lycopene extracted from tomato peels was incorporated in the bio polymeric film aiming to protect food from oxidative damage. Also, anthocyanin extracted from Jamun (*Syzygium cumini*) fruits was used in the smart packaging, since anthocyanins are pH sensitive means they can change colour in different pH conditions. The incorporation of anthocyanins significantly enhanced the water vapor and ultraviolet-visible light barrier ability, tensile strength and antioxidant potential of starch film. Antioxidant activity of the films were measured using DPPH assay. Colour change in different pH (2-13) was also observed and examined during this study using different buffer solutions. Meat spoilage can be indicated by the rise in pH of meat product. Application of the fabricated bio polymeric film in protecting the meat from spoilage was monitored in lab and the result showed that this dual-functional (antioxidant and pH sensitive) bio polymeric film protects meat from spoilage as well as it indicated clear colour variations with the change in the quality of meat.

Keywords Active packaging, Dual functional packaging, Smart Bio-polymeric films, Anthocyanins, Potato starch, Polyvinyl alcohol

ETBFT-24-007

Textural Dynamics of Cookies: The Interplay of Millet types

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Abstract

The textural properties of cookies are crucial determinants of consumer acceptance, and incorporating millets introduces unique challenges and opportunities. Millets with their nutritional profile, protein, dietary fiber, and essential minerals, makes them an attractive choice for baking applications. This study evaluates the interactions between different millet types—Sorghum, Bajra, Raagi and Foxtail—and their influence on cookie texture. Experimental formulations were developed using individual millet flours and their combinations, followed by instrumental and sensory assessments of hardness, crispiness, and chewiness. The percentage of besan flour and millet flour was maintained at 30% and 70%, respectively. Texture of cookies was evaluated using a specific probe by texture meter. Cookies with millet required higher peak force compared to control, indicating altered textural properties with inclusion of millet. Results revealed complex interactions between millet proteins and starches, significantly affecting the mechanical and structural properties of the cookies. Finger millet i.e. raagi, contributed to increased hardness due to its high dietary fiber content, while pearl millet(bajra) enhanced crispiness. Sorghum improved chewiness, attributed to its balanced starch composition. Combining these millets in specific ratios demonstrated synergistic effects, creating cookies with desirable textural attributes that surpassed those made with individual millets. This project aims to promote a sustainable economy for millet-producing regions by leveraging locally sourced ingredients and supporting small-scale farmers. Additionally, the study highlighted the role of processing conditions and particle size in modulating these effects. These findings provide insights into the design of millet-based bakery products with optimized texture and consumer appeal, contributing to the diversification of grain use and the promotion of sustainable, nutritious food systems.

ETBFT-24-011

**Computational Investigation of Inhibitors for Abl Kinases: A Potential Strategy for
Colo-Rectal Cancer Treatment**

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Abstract

The Abl kinases, a family of human proteins, play crucial roles in regulating cellular processes such as growth, survival, adhesion, and programmed cell death. Recent comprehensive studies have elucidated the significance of Abl and its related gene activation in solid tumors, characterizing these kinases as pivotal regulators that enhances tumorigenesis, cell proliferation and metastasis. In Colo-Rectal Cancer (CRC) the elevated expression of Abl kinases and the involvement in CRC cell invasion through matrigel have underscored the importance in the progression of this disease. Consequently, the present research is significantly imperative to identify the small molecules that selectively inhibit Abl kinases, so as to develop targeted anti-Abl therapies, particularly for CRC tumors. Nutraceuticals are recognized for their anti-neoplastic effects. In this investigation, the characteristics of ten selected nutraceuticals were examined. Computational methods as pharmacophore-based virtual screening, molecular docking, free-energy binding and ADME (Absorption, Distribution, Metabolism and Excretion) profiling were used. The results revealed that two nutraceuticals exhibited favourable docking scores of -8.83 and -8.35, with high absorption percentages of 100 and 70.69 respectively. The selected two compounds were subjected to further analysis through molecular dynamics simulation using Desmond, Schrödinger. The investigation elucidated the enhanced stability of these two nutraceuticals within the examined protein pocket and demonstrated interaction bonds with key amino acid residues.

Keywords Abl kinase; Colo-Rectal Cancer; Molecular Docking; Molecular Dynamics; Nutraceuticals

ETBFT-24-012

Development and Characterization of Bio-colour Enriched Herbal Beverages

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Abstract

Antioxidants are compounds that can inhibit oxidation usually autoxidation which is a chemical reaction that can produce free radicals. In this sphere, a study has been conducted to investigate the antioxidant properties of different milk beverages enriched with beetroot, turmeric and pomegranate extract. Accordingly, 4, 5, 6% beetroot, 0.4, 0.5, 0.6% turmeric and 10, 20, 30% pomegranate extract had been used to the milk samples. Sensory evaluation had been performed for optimization of those treated milk samples. Finally, milk beverages were developed using 5% beetroot, 0.5% turmeric and 20% pomegranate extract. Double toned milk as control was taken. Protein and lactose percent were found to be significantly lower in beetroot, turmeric and pomegranate milk beverages as compared to the control whereas ash content and viscosity were higher. In different pH level stability of betalain, curcumin and anthocyanin were also determined, which had shown that betalain has highest stability between pH ranges of 4-5 and for curcumin and anthocyanin, the highest stability lies within the pH range of 5-6 and 1-2, respectively. UV-Vis double beam spectrophotometer (765nm) was used to evaluate polyphenol content (mg GAE/ gm) of all the extracts and their corresponding milk beverages by using different solvent such as methanol, water, petroleum ether and ethanol. Methanolic extract of beetroot, turmeric and pomegranate extract exhibited highest total polyphenol content (4.12 ± 0.00 , 1.11 ± 0.00 and 8.11 ± 0.00 respectively) as compared to other solvents. Total polyphenol content of beetroot, turmeric and pomegranate milk beverages portrayed 24.81 ± 0.01 , 30.93 ± 0.07 and 15.12 ± 0.03 mg/gm GAE, respectively. The best result was found for the turmeric milk beverage in all aspects. A Hunter Colour Flex Calorimeter (USA) was used to determine the colour of biocolour enriched milk beverages. The calorimeter then recorded L (lightness), a (redness and greenness), and b (yellowness and blueness) values. It had been observed that control, beetroot milk beverage, turmeric milk beverage and pomegranate milk beverage differed significantly in terms of L, a and b values. On 0th day, the lightness, redness and yellowness were ranged from 67.68-79.9, -8.50 to -1.43 and 2.15-39.66 respectively. The lightness and yellowness degree was reduced whereas the redness was increased in control milk beverages as the storage time was increased. The stability of lightness degree with respect to the time of storage may be related to antioxidant activity, which has been seen to be higher in beetroot enriched milk beverages as compared to control and other beverages.

Keywords Betalain, Curcumin, Anthocyanin, UV-Vis double beam spectrophotometer, Total polyphenol content, GAE

ETBFT-24-019

Investigating the Physiological and Clinical potencies of few commercially-available, non-conventional Citrus Fruits: The First Reports

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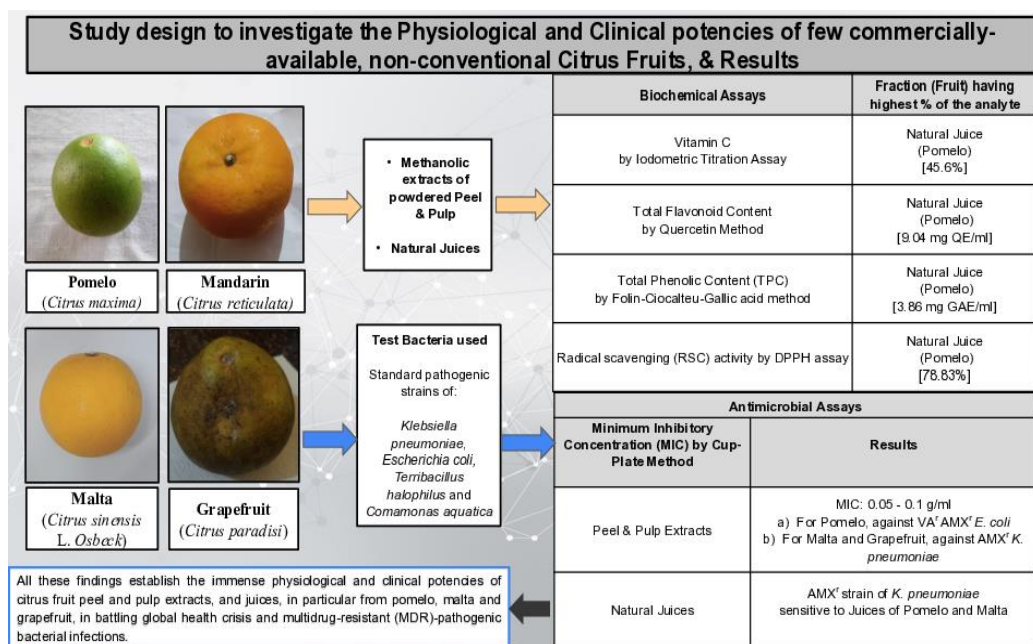
ABSTRACT

Citrus fruits impart multifaceted benefits on human physiology due to the presence of numerous phytochemicals with antioxidant activities and natural form of Vitamin C in abundance. Although juices of mostly oranges have been researched for their phytochemical composition, antioxidant activities and antimicrobial properties, similar studies with the extracts of peel and pulp, as well as juices of commercially available, non-conventional citrus fruits like malta, mandarin, pomelo and grapefruit have not been conducted till date. This research, a very first of its kind, used methanolic extracts of peel and pulp, and natural juices of malta (*Citrus sinensis* L. Osbeck), mandarin (*C. reticulata*), pomelo (*C. maxima*) and grapefruit (*C. paradisi*) for evaluation and comparison of the relative abundances of the major bioactive compounds like total Vitamin C, flavonoids and phenolics, radical-scavenging (antioxidant) properties, and antimicrobial potencies. Iodometric titration assay performed revealed higher Vitamin C content in natural fruit juices, with pomelo juice reporting the maximum (45.6%). Determination of the total flavonoid content by Quercetin method also revealed higher concentration of total flavonoids in the juices, with pomelo juice showing the highest content (9.04 mg Quercetin Equivalent/ml). Total Phenolic Content (TPC) were evaluated by using Folin-Ciocalteu-Gallic acid method, which showed pomelo juice exhibiting the highest TPC (3.86 mg Gallic Acid Equivalent/ml). DPPH-assay to determine radical scavenging (RSC) activity showed appreciable antioxidant activities in all samples, with pomelo juice again displaying the highest (78.83%). Since the radical-scavenging potencies of the plant extracts are attributed to their Vitamin C, flavonoid and phenolic contents, this novel preliminary screening may be useful in the isolation of bioactive principles from the mentioned fruits, in particular from pomelo, which may open up opportunities for development of antioxidant formulations from those in future. Besides, antibiotic susceptibility tests (ASTs) were carried out by Agar Disc Diffusion (Kirby-Bauer) method, using standard antibiotic-impregnated discs of vancomycin (VA), streptomycin (S), tetracycline (TE), ciprofloxacin (CIP) and amoxicillin (AMX), to determine their effectiveness against standard pathogenic strains of *Klebsiella pneumoniae*, *Escherichia coli*, *Terribacillus halophilus* and *Comamonas aquatica*, with results indicating VA- and AMX-resistance in *E. coli*, and AMX-

resistance in *K. pneumoniae*. Performing the same experiment with the methanolic extracts of peel and pulp, and juices of the citrus fruits by Cup-Plate Method, it was found that the peel and pulp extracts were highly effective against all the test bacteria, with pomelo peel and pulp extracts being highly active (minimal inhibitory concentration or MIC between 0.05-0.1 g/ml) against the VA^r AMX^r *E. coli*, and malta and grapefruit peel and pulp extracts being highly active (MIC between 0.05-0.1 g/ml for both) against the AMX^r *K. pneumoniae*, thus throwing light on possibilities of development of green pharmaceuticals from those in near future. AMX^r strain of *K. pneumoniae* was also found to be sensitive to juices of pomelo and malta, thereby unlocking one way of effectively tackling this pathogen. All these findings establish the immense physiological and clinical potencies of citrus fruit peel and pulp extracts, and juices, in particular from pomelo, malta and grapefruit, in battling global health crisis and multidrug-resistant (MDR)-pathogenic bacterial infections.

Keywords: antimicrobial potencies; citrus fruits; flavonoids; phenolics; radical-scavenging (antioxidant) properties; Vitamin C

Graphical Abstract:



ETBFT-24-020

Application of AI/ML in Dairy Cattle Management System: Efficiency and Productivity

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Abstract:

The use of Artificial Intelligence (AI) in dairy farming is reshaping to take care cattle and running farms in a organized way. By using tools like smart sensors and AI-driven analysis, farmers can closely monitor their cows' health, spot illnesses early, and ensure them to get the right amount of food and care. This helps in quick action and recovery while needed and doesn't create a delay. This not only helps keep the animals healthier and happier but also boosts milk production and farm efficiency. AI can also help farmers make smarter decisions in daily operations to meeting market demands, ensuring quality and reducing waste. At its core, this technology is about finding a balance—making farming more humane for the cattle and sustainable for the farmers. This paper delves into how AI is making a difference on both fronts, showing that technology and compassion can go hand in hand. A smart sensor (equivalent to a continuous glucose sensing device) can be installed to cattle's body (painlessly) for real time monitoring of different physical and biological factors (including body temperature, insulin spikes, hydration levels, fiber content in food, hormonal level detection for estrous calculation, inbreeding depression estimation). Device with its artificial intelligence, alert livestock owner in case of any disruptive emergency which needs earliest attention. This understanding would allow proactive interventions, and thus it would reduce the risks of disease and stress among cattle while at the same time maximizing efficiency, balance animal welfare with economic growth, creating a gateway for sustainable dairy farming practices that benefit farmers and consumers as well as helps to streamline supply chain operations in ensuring quality control as well as fulfilling market demands.

Keywords: AI/ML, real time monitoring, CGM sensor, holistic development, economic growth

ETBFT-24-021

Study of Extraction of Polyphenols from Food Wastes

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Abstract :

This research investigates the potential utilization of food wastes viz. potato , pointed gourd , cucumber peels etc. as a sustainable source of polyphenolic compounds . Polyphenols are a diverse group of naturally occurring compounds with multiple phenol units in their structure and can be broadly classified into four major categories which includes Flavonoids , Phenolic acids , Stilbenes and Lignans . It offers unique health benefits including antioxidative and anti-inflammatory effects to improved cardiovascular and cognitive health . This study explores the extraction of polyphenol using four solvents i.e., water , methanol , ethanol and acetone . The study focuses on evaluating the effectiveness of the solvents for various food waste and quantifying the polyphenolic content , which was represented as mg GAE (Galic Acid Equivalent) per gram of sample . The findings showed notable differences in polyphenol yields, showcasing the consequences of both the type of food waste and choice of extraction medium. This study not only underscores the importance of waste valorization but also reveals its future applications that includes significant potential to reduce the environmental waste , sustaining the bioactive potential of polyphenols and fortifying polyphenols and antioxidants in various food products to enhance their nutritional quality .

Keywords : Polyphenols , phenolic compounds , antioxidants , food waste

ETBFT-24-022

The role of new plant breeding technologies in sustainable development of agriculture and food security

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Abstract

The world is facing a serious challenge regarding food safety and security. Day by day, the population of our planet is increasing, but for that, the land for cultivation is limited. In addition to that, climatic stress, pests, and pathogen attacks, irregular precipitation, heat waves, and other weather extremes lead to reduced growth and productivity of crop plants. In this scenario, so many approaches have been used for crop improvement. Traditional plant breeding techniques result in the display of random characters, but it's time-consuming, which ultimately leads to hybrid plant production that results in enhanced food productivity. Nowadays, we need a transgenic approach in this regard so that the plants can be generated with a new character that is lacking and previously not observed. Various new plant breeding technologies, that include genetically modified and gene edited crops offer great potential for sustainable development of agriculture while also addressing the problems of traditional practices. *Agrobacterium tumefaciens* and particle bombardment are employed to convert plants, and marker genes are utilized to select transgenic plants. Depending on the requirement of a greater cause, scientists and researchers are trying to develop genetically engineered crop plants with supreme quality. Biotechnology provides updated methods such as genome editing, intragenesis, and cisgenesis for genetic engineering, which leads to a reduction in uncertain characteristics and breeding time. In this review, we analyzed the approach of genetic engineering, which has been taken into consideration for sustainable food production, and the plants that are currently used in sustainable farming for their improved qualities.

Keywords:

Food security, plant breeding, genetically modified plants, gene editing.

ETBFT-24-026

Advanced Assessment of Ghee Adulteration: A Comparative Approach of FTIR and GC for Goat Tallow and Vegetable Oil Admixtures

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ABSTRACT

Ghee, a clarified butter widely used in Indian cuisine, holds cultural, medicinal, and culinary significance. Known for its rich flavour and health benefits, ghee is traditionally made by simmering butter to remove milk solids and water. However, ghee adulteration has become a growing concern in India. Some manufacturers mix animal body fat and vegetable oils like palm or soy to increase volume and reduce costs. These adulterants compromise the purity, quality, and health benefits of ghee. Such practices have raised health and safety issues, prompting calls for stricter regulations and greater consumer awareness to ensure authentic ghee. In this present study Fat constants analysis of 10 branded and 20 regional ghee samples were done. Testing parameters are RM, P, SAP, Iodine value, BR reading, and FFA. All branded samples met the FSSAI standards, ensuring quality and compliance. However, several regional samples failed to meet the prescribed standards, indicating issues with quality control. These findings highlight the need for stricter adherence to regulatory guidelines, especially among regional unorganised sectors, to ensure consumer safety and product authenticity. Natural fats, including milk and goat depot fats, contain varying levels of saturated, monounsaturated, and polyunsaturated fatty acids. FTIR and GC analysis effectively identify ghee adulterated with goat body fat and vegetable oil. FTIR provides distinct spectral fingerprints, while GC analysis offers detailed fatty acid profiles, both enabling accurate detection of adulteration. These techniques complement each other, ensuring reliable differentiation between pure ghee and adulterated samples. Saturated Fats: While both pure ghee and adulterated ghee contain saturated fats, the proportions of specific fatty acids, particularly butyric acid (C4:0), palmitic acid (C16:0), and stearic acid (C18:0), may vary. Goat body fat contributes more medium-chain saturated fats. Monounsaturated Fats: Adulterated ghee with vegetable oil will have a higher concentration of oleic acid (C18:1), making the profile more similar to that of vegetable oils than to pure ghee. Polyunsaturated Fats: Linoleic acid (C18:2) is found in significantly higher amounts in ghee adulterated with vegetable oils, while pure ghee has negligible polyunsaturated fatty acids. Thus the study reveals that Pure Ghee has a different fatty acid composition as compared to Adulterated Ghee.

Keywords: Ghee, Tallow, Vegetable oil, FTIR, GC

ETBFT-24-027

Utilisation of Sesame and Soybean seed meals in preparation of prebiotic food products

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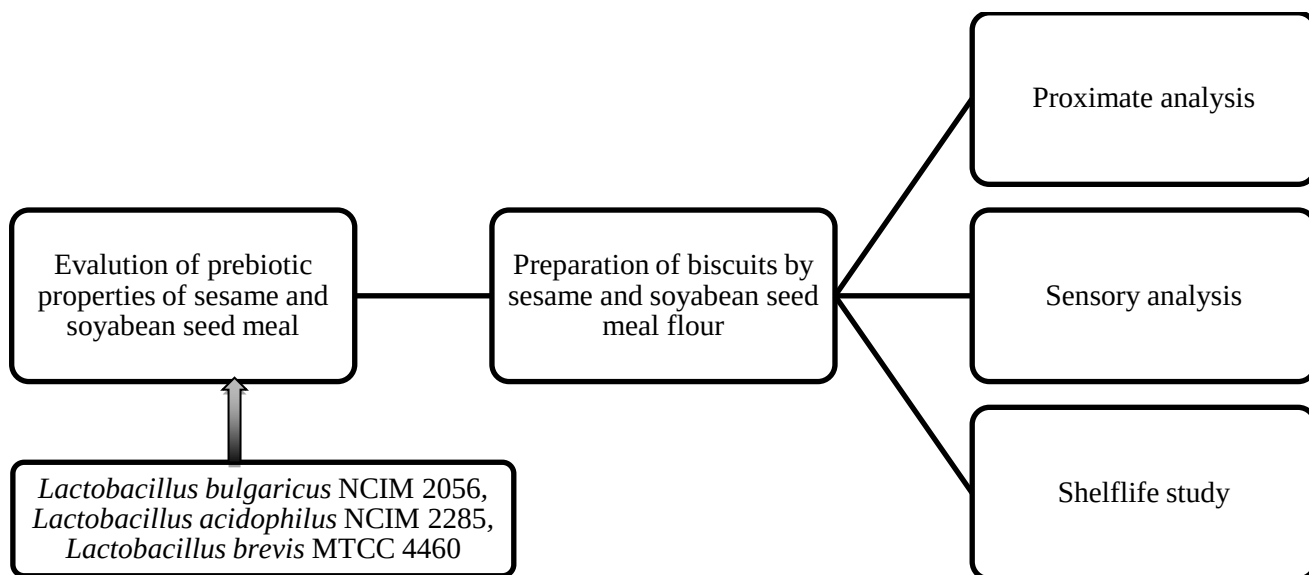
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Abstract:

Different oil seed meals like sesame, soybean and linseed have been identified as excellent prebiotic material which may be used for the preparation of various food products with medicinal importance. These fibre rich meals are also high in protein and loaded with polyphenols. In the present study, three *Lactobacillus* Strains e.g. *Lactobacillus bulgaricus* NCIM 2056, *Lactobacillus acidophilus* NCIM 2285, *Lactobacillus brevis* MTCC 4460 have been exploited for their growth on these seed meals as *Lactobacillus* bacteria plays an important role in improving human gut health. Based on prebiotic activity score, sesame and soybean seed meals have been identified as better prebiotic food material compared to linseed oil meals. Biscuits nowadays are most popularly used for fortification and recognised as an efficient vehicle for nutrient incorporation. Moreover, high consumer acceptance has led them to receive more attention for formulating functional foods or nutraceuticals. In the present research work, prebiotic biscuits have been prepared from the identified seed meal flour in varying proportion and so conventional refined wheat flour was replaced by these cheap as well as nutritionally rich raw materials. Sensory evaluation of the prepared biscuits indicates the overall acceptance of the products. The shelf life of the products were studied after storing for 6 weeks at room temperature. So, sesame and soybean seed meals which are available at thrown away prices can now be utilised for the preparation of low-cost prebiotic biscuits and like products with immense health benefits. Use of these seed meals for making prebiotics biscuits will serve as a cheap source of prebiotics along with will open up a new dimension of revenue earning for the oil industries. These biscuits will serve as a super food as they are protein and fiber rich and loaded with antioxidants. Future scope remains for development of synbiotic biscuits or synbiotic food products; which contains both prebiotics and probiotics.



GRAPHICAL ABSTRACT

Keywords: lactobacillus; seed meals; prebiotics; soybean; sesame; biscuits.

ETBFT-24-028

Ceramic membrane based bioreactor process for biohydrogen production from molasses wastewater

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Abstract

The gradual scarcity of fossil fuel resources and associated environmental restrictions opens the research avenues worldwide to explore on clean energy sources like hydrogen as a renewable and sustainable energy source with a high energy content and no negative environmental effects. Various organic wastes with high carbohydrate content are mostly used to produce biohydrogen by fermentation process in presence of suitable bacteria. In this regard, integrating a ceramic membrane into a fermentative reactor may be a desirable way to increase the production of biohydrogen. The present study is aimed to construct a novel ceramic membrane bioreactor where molasses wastes are fermented in presence of anaerobic bacteria *Clostridium sp.* to produce biohydrogen through dark fermentation process. The bioreactor study was done in a SS bioreactor (7 L) in batch mode with simulated molasses wastewater with controlled pH, temperature and stirring condition. Metal oxide based ceramic membrane was prepared on clay-alumina support and characterised by FESEM, EDX, FTIR etc. The performance was further measured in terms of clean water permeability (CWP), % recovery of volatile fatty acid, % production of hydrogen and chemical oxygen demand (COD) reduction. The gas samples and VFA were analysed using GC and HPLC, respectively. Biohydrogen production started after 48 h of fermentation in membrane bioreactor, reaching its maximum yield of 0.48 mol H₂/mol of carbohydrate after 120 h and wastewater COD was reduced by ~ 40 %. Optimization of wastewater composition, external physicochemical and microbial environment along with the ceramic membrane characteristics can be crucial in enhancement of bioH₂ yield towards establishing a sustainable pathway for waste to energy production.

Keywords: Membrane bioreactor, waste to energy, biohydrogen, dark fermentation

ETBFT-24-030

Application of promising characterized isolates for development of defined starter culture

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Abstract: 14 cocci (C1-C14) and 16 rod (R1-R16) isolates were selected based on purity and activity collected from different locations in West Bengal. Based on phenotypic characterization, the cocci and rods isolates were identified as *Streptococcus thermophilus* and *Lactobacillus* spp., respectively. Four *S. thermophilus* (C2, C3, C6, C7) and 4 *Lactobacillus* spp. (R1, R2, R5 and R6) were found to be potential for preparation of *misti dahi*. Further these cultures were found to be safe on the basis of negative for gelatin hydrolysis, hemolytic and DNase activities, and antibiotic sensitivity patterns. Co-culturing study was carried in skim milk with added sugar (25%) and in shop-prepared *misti dahi* mix. On the basis of acidification and curd setting profiles, 8 combinations (R1+C2, R1+C3, R2+C2, R2+C3, R5+C2, R5+C3, R6+C2, R6+C3) were found promising. Further, performances of R2+C2, R2+C3, R1+C2, R1+C3 culture combinations found better based on quality of *misti dahi* and among these, R2+C2 and R2+C3 were found best combinations. The combinations of *S. thermophilus* and *Lactobacillus delbrueckii* (R2+C2) and (R2+ C3) can be exploited for *misti dahi* at unorganized as well as organized dairy sectors.

Keywords: characterization, cultures, *misti dahi*, quality.

ETBFT-24-033

**Biogenic synthesis and characterization of Bioactive-compounds Using Shikakai
(*Acacia concinna*) Seed Extract and Evaluation of the Multifaceted Functional
Properties**

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Abstract

Shikakai (*Acacia concinna*) is gaining attention for its multifaceted characteristics including phytochemical, antibacterial, antifungal and bio-reducing agent in different sectors such as composite materials, food, pharmaceutical and various biological-related potential applications. This study shows the bioactive-compounds from Shikakai seed extract (SSE) to assess their biological and phytochemical activity. Shikakai seed has been collected and after that, the extraction process is performed as per the standard protocol. Identification of the functional organic-groups is undertaken and qualitative analysis has been performed by HPLC and FTIR. Antimicrobial and antioxidant studies have been performed to evaluate various biological activities. Phenols and flavonoids contain in a significant amount in Shikakai seed extract. *Acacia concinna* seed has performed antimicrobial activity significantly against different bacteria like *Burkholderia cepacia*, *Paracoccus* sp and *E. coli*. *Acacia concinna* seed containing silver nanoparticles (SNP) also exhibit potentially antimicrobial activity. This seed can be used to treat diabetes, cancer, gastrointestinal ulcers and hyperlipidaemia. Thus, this studied seed extract must be utilized cost-effectively to produce therapeutic drugs for different diseases.

Keywords: Shikakai seed extract (SSE), Phytochemical screening, Antioxidant, Antibacterial activity

ETBFT-24-034

Current Trends in Edible Films and Coatings

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Abstract:

The increasing demand for food quality and safety has driven significant advancements in biobased packaging, particularly edible films and coatings (EFCs). EFCs play a pivotal role in enhancing the sensory attributes of food products and curbing microbial contamination, offering a sustainable and eco-friendly alternative to conventional packaging. Composed of proteins, polysaccharides, lipids, plasticizers, emulsifiers, and active substances, EFCs are crafted from safe, biodegradable materials. The development of nanocomposite films further strengthens the structural network of biological polymers, enabling the incorporation of antioxidant, flavoring, and coloring agents to improve food quality, safety, and shelf stability. Recent innovations include gelatin-enhanced, fruit and vegetable-based EFCs, along with edible films derived from root plants such as potato, sweet potato, and cassava as well as novel ingredients like amylum, achira flour, ulluco, yam, and water chestnut. The physical properties of biopolymers depend on biochemical characteristics, compatibility, environmental factors, and application methods. Adherence to food safety regulations and GRAS standards is imperative. This review highlights recent progress in EFCs, emphasizing novel components and strategies that address global financial and environmental challenges while advancing sustainable food packaging solutions.

Keywords:

Edible films and coatings (EFCs), nanocomposite, sustainable development

ETBFT-24-037

EFFECT OF LACTIC ACID BACTERIA ADDITION ON THE PHYSICOCHEMICAL PROPERTIES OF SYNBIOTIC KULFI DEVELOPED FROM PEANUT MILK USING RED RICE

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ABSTRACT

Kulfi is a traditional frozen dessert from India, that is high in nutrients but low in medicinal value. Probiotics and prebiotics can be incorporated into kulfi, which has the extra benefit of being liked by people of all ages. This study investigates the development of a synbiotic kulfi, a traditional Indian frozen dessert, utilizing peanut milk and date syrup, enriched with non-starch polysaccharides (NSP) derived from red rice, and incorporating probiotic culture of *Lactobacillus rhamnosus* GG to it. The innovative formulation aims to offer a dairy-free, nutritious alternative while incorporating the health benefits of prebiotics and probiotics. Peanut milk serves as the primary base, providing a rich source of plant-based protein and healthy fats, while date syrup is used as a natural sweetener, enhancing the nutritional profile with its high fiber and antioxidant content. Red Rice NSP (RRNSP) is incorporated to act as a prebiotic, promoting the growth of beneficial gut bacteria. Also, the incorporation of RRNSP improved the viability of *Lactobacillus rhamnosus* GG in kulfi samples over 20 days of storage. Physicochemical properties, including texture, melting behaviour, and sensory attributes, are evaluated to ensure consumer acceptability. Additionally, the probiotic viability and prebiotic efficacy are assessed through in vitro digestion and microbiological analysis. The findings demonstrate that the synbiotic kulfi exhibits favourable sensory characteristics and maintains probiotic viability, making it a promising functional dessert with potential health benefits.

Keywords: probiotics, prebiotics, non-starch polysaccharides (NSP), plant-based protein

ETBFT-24-039

Exploitation of Waste Food for Biofuel Development

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Abstract:

The growing food waste crisis and increasing demands for sustainable energy sources could be curbed by introducing food waste for biofuel production. In the presence of thermochemical processes like pyrolysis, hydrothermal liquefaction, or anaerobic digestion, all sorts of food wastes - including fruits, vegetables, and leftover foods from the food industry- could be easily converted to biofuel. These methods break down the complex organic molecules in food waste into a liquid fuel we can use as a renewable energy source. The process reduces the environmental problems associated with food waste, such as methane emissions and global warming, and helps to reduce our dependence on fossil fuels. Moreover, biofuel from food waste has excellent chemical properties, which makes it a good alternative to the fuel derived from petroleum. This approach addresses the dual problems of food waste disposal and energy scarcity and significantly lowers greenhouse gas emissions by diverting organic waste from landfills and replacing conventional fuels. The process is compatible with diverse food waste streams, including household, industrial, and municipal sources, offering a scalable and circular solution. Recent improvements in catalytic upgrading and process optimization improve the efficiency and economic feasibility of this technique. Utilizing food waste for biofuel production represents a promising pathway toward achieving waste-to-energy goals and fostering a sustainable, low-carbon future.

Keywords:

Food waste, biofuel, heat treatment, anaerobic digestion, hydrothermal liquefaction

ETBFT-24-044

Synergistic Enhancement of Emulgel Properties Using Plant Protein and Saponin

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Abstract

Oil-in-water (O/W) emulsions in food products can reduce the high intake of solid fats and hence can be used as a fat substitute. It is also used for the enhancement of textural attributes of food products, encapsulation and control release of the bioactives. However, emulgels fabricated solely by protein shows less stability against environmental factors like pH and temperature and is more prone to lipid oxidation. This study explores the development of kenaf seed protein-based emulgels stabilized with fenugreek seed saponin, focusing on improving stability, functionality, and resistance to environmental factors like pH and temperature. Kenaf seed protein is used to develop the emulgel with an oil to aqueous phase ratio of 70:30 where fenugreek seed saponin (0.5% and 1%) is used as a co-surfactant to stabilize the emulgel. The higher storage modulus value over loss modulus confirmed the gel property of the emulsion gel. The addition of saponin in the emulgel at higher concentration (1%) enhanced the zeta potential (-52.59 mV) and reduced droplet size (2.85 μm), facilitating greater protein adsorption at the oil-water interface by lowering interfacial tension. The morphology (CLSM) of the emulgel showed a reduction in coalescence and flocculation of the oil droplets due to the incorporation of the saponin. Also, saponin as co-surfactant enhanced the stability of the emulsion gel against different pH and temperature and reduced lipid oxidation. For a 30 days storage study, the saponin co-stabilized emulgel retained better quality as compared to solely protein-based emulsion. The results demonstrate that saponin significantly enhances the emulsion gel's properties, including reduced droplet size, improved zeta potential, and extended storage stability, making it suitable for applications such as bioactive delivery, fat replacement, and direct consumption. Overall, saponin worked as an excellent co-surfactant for the development of kenaf seed protein-based emulsion gel.

ETBFT-24-045

Modification of Chickpea and Brown Rice Protein Isolates Using Dielectric Barrier Discharge Cold Atmospheric Plasma Technology

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Introduction: Plant proteins often have poor solubility, emulsifying, foaming, and gelling properties compared to animal proteins, which limits their use in food products.

Objective: The objective of this study was to investigate the effects of dielectric barrier discharge cold atmospheric plasma (DBD-CAP) on the techno-functional, physicochemical, and structural properties of Chickpea protein Isolate (CPI) and Brown Rice Protein Isolate (BRPI).

Methods: Protein isolates were subjected to DBD-CAP at a voltage of 30, 35, and 40 kV for different treatment durations (2,4,6,8 min).

Results: Solubility, water holding capacity (WHC), emulsifying activity and emulsion stability, foaming capacity, FTIR, SDS-PAGE, CD-spectroscopy, as well as protein structures were evaluated. Results indicated enhancement in WHC (2.74 ± 0.05 to 3.53 ± 0.13 g/g) OHC (2.11 ± 0.05 to 2.91 ± 0.17), foaming capacity ($42.41 \pm 0.65\%$ to $61.46 \pm 1.70\%$) and emulsifying property (34.65 ± 0.94 to 52.32 ± 0.78) were enhanced with voltages and time in CPI. Similar kind of results were also observed in BRPI. FTIR and circular dichroism (CD) results indicated partial denaturation, unfolding of the α -helix, β -sheets structures of CPI and BRPI followed by the formation of protein aggregates resulting at 8 min plasma exposure; microscopic images also confirmed these results. FESEM images of both samples confirmed the surface etching of protein molecules and increased smoothness.

Conclusion: The functionally modified Chickpea and Brown Rice Protein Isolates through cold plasma can serve as emulsifiers, stabilizers, and texture modifiers in plant-based meats, offering promising opportunities for the formulation and commercialization of plant protein-based food in the future.

ETBFT-24-046

Extraction of natural food color from *Bixa orellana* (Annatto) and its application in food

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ABSTRACT

Archaeological evidence suggests that dye, obtained from animals, plants or minerals are used for coloring of food and non food materials. This has been practiced in India and the Middle East for over 5,000 years. Mainly these colors are obtained from the plant kingdom; mostly from roots, bark, leaves, flowers, fruits and wood. Annatto is a natural dye that can be used as a dye for dyeing textile fibers such as cotton, wool, and silk. The Bixin pigment is extracted from *Bixa orellana* that can be used for the production of red color in the food industry. It is non-carcinogenic in nature. Due to its huge carotenoid content its antioxidant activity is high. Recently, there has been an international interest in natural dyes due to the ban on the use of synthetic dyes in many countries. Since annatto (*Bixa orellana*) seeds are non-toxic, their use as a source of natural dyes has increased. It also play a vital role in flavor generation. It can be applied as a coloring agent in different food products like baked foods, butter, cheese and margarine etc.

Keywords – *Bixa orellana*, Annatto, Bixin, natural food color, anti carcinogenic,

ETBFT-24-049

Exploring The Potential Of 3d Printing for Eco-Friendly Seafood Alternatives

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ABSTRACT

The development of 3D printing technology has had a big impact on the food industry and has opened up new opportunities for sustainable substitutes, especially for seafood. As worries about overfishing, the devastation of marine ecosystems, and the environmental effects of traditional seafood production increase, 3D printing offers a creative way to create substitutes that closely mimic actual seafood. The review paper analyzes the use of 3D printing to produce seafood substitutes, emphasizing how this technology can replicate the nutritional value, flavor, and texture of real seafood. It also evaluates important substances like algae, seaweed, and plant-based proteins to determine how well they can replicate the complex qualities of seafood. The difficulties in achieving the required texture, scaling up production, and ensuring cost-effectiveness while preserving customer satisfaction are also taken into account. 3D printed food offers vegan sustainable and nutritious options, creating diverse textures and flavors that mimic animal products. It encourages environmentally beneficial behaviour, reduces waste and improves accessibility, which makes plant-based diets more efficient and creative. It is also investigated whether these substitutes may be modified to meet particular dietary requirements, including being vegan or free of allergens, which makes 3D printing a practical and sustainable way to produce food in the future.

Keyword: Seafood Analogs; Sustainable Development; 3D Printing; Eco-Friendly; Cost-Effectiveness

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Exploring the role of rice protein in modulating the gelation and structural integrity of rice flour hydrogels

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Hydrogels are three-dimensional solid networks created by physically or chemically cross-linked hydrophilic polymeric structures that can retain significant amounts of water or other biological liquids within their matrix. This study aims to examine the effect of rice protein on the quality parameters of hydrogels derived from rice flour (RF)- rice protein (RP). Initially, different proportions of RP were combined with RF, and properties (color, techno-functional, and pasting profile) were analyzed. The minimum concentration for gelling was determined from the Least Gelation Concentration (LGC) and hydrogels were developed through large-scale deformation based on this concentration. The hydrogel was characterized by examining its textural properties including hardness, cohesiveness, and springiness as well as structural features like FTIR, XRD, and SEM analyses. The findings indicated that composite flours with higher RP concentrations exhibited a more pronounced yellow hue. Elevating RP concentration resulted in a reduction in peak, breakdown, final, and setback viscosities while increasing pasting temperature, indicating protein-starch interactions that preserve granule integrity and delay gelatinization. While RF produced gel at 10%w/v concentration due to the limited gelling ability of RP, the hydrogels attained LGC at 16 %w/v. The hardness, springiness, and gumminess of composite gels significantly diminished with the increase in rice protein concentration. FTIR analysis verified a direct interaction between rice starch and rice protein without covalent bond formation. The XRD showed A+V type semi-crystallinity for hydrogels and the percentage of crystallinity decreased with the subsequent addition of RP which confirmed the FTIR results. SEM analysis revealed a transition from a heterogeneous network with large, irregular pores to a compact honeycomb-like structure at higher RP levels. The results support that incorporating rice protein into rice flour-based hydrogels enhances structural integrity and functional properties, offering promising potential for various food applications.

Keywords: Rice protein, rice flour, hydrogel, texture, structure

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Effect of sanitation methods on microbial loads of different raw salad ingredients

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ABSTRACT:

Fresh raw produce like Lettuce, Apple, Celery are majorly used as salad components. The fresh fruits and leafy vegetables are the potential to cause foodborne outbreaks due to microbes present on the surface and florets of the leafy vegetables. Rinsing raw fruits or vegetables under running tap water does not ensure the total removal of microbes from their surfaces. Thus, in order to eliminate or reduce the microbial load, the effect of sanitation was studied. Sanitation solution was calculated in ppm (parts per million) in different concentrations and tests were performed based on contact time of the vegetables in each different concentration like 100ppm, 50ppm and nil sanitation i.e. only tap water for 1 min, 3min and 5 mins. The widely used industrial sanitation solution – Sodium hypochlorite was selected ideally for use. Samples from each test was collected and microbiological test was performed for *E.coli*, *Yeast and Moulds*, *Salmonella* and *Total viable count*. From microbiological studies, results inferred after the fifth day from sampling were inferred that maximum contact time and maximum concentration of sanitization solution gives best results for all fruits/vegetables. Sensory analysis was performed to check for the influence of the sanitization solution with respect to contact time on the food item. Bitterness if observed during sensory evaluation, 100ppm with 3 mins contact time was considered an optimum combination.

Key Words: Sanitation methods, Microbial loads, Salad Ingredients, Foodborne outbreaks, Sodium hypochlorite.

ETBFT-24-053

Development of dietary fibre-rich extruded rice analogues using microcrystalline cellulose

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Abstract

Rice is a staple food consumed widely, but it is often criticized for its low dietary fibre content. Most of its dietary fibre is removed during milling, making it more susceptible to digestive enzymes and thus more easily digestible. This study aimed to produce fibre-rich rice analogues (RA) utilizing extrusion technology by incorporating microcrystalline cellulose (MCC) at concentrations from 1% to 5%. Fiber-rich RA was prepared by mixing rice flour with MCC at these concentrations, followed by extrusion. The produced rice analogues were dried and analysed for physical properties (colour, texture), cooking properties, techno-functional properties (water absorption capacity (WAC), emulsion capacity (EC), emulsion stability (ES)), *in vitro* starch digestibility, X-ray diffraction (XRD), and scanning electron microscopy (SEM). The samples were found to be lighter with the incorporation of MCC, without significant alterations in textural properties. Cooking time was found to decrease, making the RA suitable for instant preparation. Techno-functional properties like WAC, EC, and ES were enhanced by 5%, 12.6%, and 12% respectively with 5% MCC incorporation. XRD analysis revealed an increase in V-type crystallinity. This enhanced V-type crystallinity led to the formation of more resistant starch from 11.73% to 19.52%, making the RA slowly digestible and reducing the glycaemic index. SEM analysis revealed smaller pore formation due to the interference of MCC in starch gelatinization, which contributed to the reduction in cooking time. The increased resistant starch in the developed RA is expected to aid gut cleansing and promote probiotic bacteria growth. Findings from the study showed that MCC can be incorporated up to 5% without negatively affecting the technological properties of the rice analogues, thus ensuring convenient usage. Hence, MCC can be used as a functional ingredient to improve the fibre content of extruded RA, offering metabolic health benefits.

Keywords: Rice analogues, insoluble dietary fibre, microcrystalline cellulose, resistant starch, estimated glycaemic index

ETBFT-24-059

Internet of Fruit Things (ioft): A Smart iot-Based Real-Time Approach for Monitoring Fruit Health

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Abstract— The Internet of Things (IoT) has revolutionized modern technology by enabling the development and deployment of smart devices. These smart devices are the important nodes of IoT architecture to address real-world challenges. Today, we are surrounded by a variety of smart technologies. The most popular of those includes smart homes, smart cars, smart televisions, and smartwatches etc. All of these enhance convenience and efficiency in human daily life. Despite the technological advancements in wireless sensing node technology, there is still a huge challenge in health and food security. Existing technologies are not completely efficient in determining the health and quality of perishable plant products like fruits and vegetables. It is resulting in massive post-harvest losses. According to recent investigation the global fruit and vegetable production is around 675 million metric tons annually, of which nearly 0.3 billion metric tons are wasted. In India, the annual production adds up to 86.602 million metric tons with around 5.6 million metric tons wasted due to spoilage. Fruits and vegetables cause the biggest waste here. It is contributing as high as 18% of the total production, amounting to around ₹13,300 crore being discarded yearly. In a government-supported study conducted in 2022, it was estimated that between 5% and 13% of fruits and vegetables were lost in India solely due to post-harvest inefficiencies. To minimize this problem, we present here a real-time IoT-based fruit health monitoring system (RTIFHMS) designed to eliminate fruit waste while continuously monitoring its quality. It includes a NodeMCU ESP8266 microcontroller, the moisture sensor to measure moisture levels. This present work also includes gas sensors, which measure odors produced from fruits, and hence spoilage. These sensors connect to the cloud-based IoT platforms, like ThingSpeak and Blynk. This concept facilitates real-time monitoring and early warnings about fruit spoilage. The aim of this solution is food preservation, the reduction of losses. Finally this present work Internet of Fruit Things (IoFT) can maintain more efficient supply chains in the agricultural sector.

Keywords— Internet of Things (IoT), Internet of Fruit Things (IoFT), smart devices, real-time IoT-based fruit health monitoring system (RTIFHMS).

ETBFT-24-060

Development of Gluten-Free Functional Cookies Fortified with Encapsulated Papaya Leaf Extract: Nutritional, Sensory, and Stability Analysis

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Abstract

The article explores the development of a plant-based, functional cookie snack by replacing rice flour in the formulation with a functional ingredient (sodium alginate-pectin system encapsulating papaya leaf extract (PLE)). The study evaluates the nutritional and physical properties of the baked cookies, along with the stability of the encapsulated PLE's nutritional parameters. Gluten-free cookies made solely with rice flour were used as the control, while cookies fortified with 0.4% and 1% encapsulated papaya leaf extract (ALEXPB) were compared. Among these, cookies fortified with 1% ALEXPB emerged as the preferred option in sensory evaluations, demonstrating that fortification did not negatively impact sensory acceptance. These cookies exhibited the highest levels of soluble protein (56.21%), total phenolic content (49.48 mg GAE/g), total flavonoid content (217.22 mg QE/g), and antioxidant activity (31.86%). Various analyses—including morphological, structural, thermal, sensory, and in-vitro digestion characterizations—confirmed the compatibility of ALEXPB with the cookie formulation. Furthermore, microbial studies conducted over 90 days of storage revealed lower total plate counts and reduced yeast and mold colonies in the 1% ALEXPB-fortified cookies compared to the control. This suggests improved microbial stability. The results indicate that cookies fortified with ALEXPB are a promising option for a gluten-free, antioxidant-rich snack. Incorporating papaya leaf extract, an abundant yet underutilized plant resource, into the cookie formulation provides significant functional benefits, primarily due to its antioxidant properties.

Keywords: Encapsulation; Functional cookies; Papaya-leaf extract; Sodium-alginate

ETBFT-24-066

Nutrishe: a sustainable approach towards women's health

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Abstract:

This project focuses on the development of a nutrient-rich beverage specifically designed to address common health issues faced by women in their daily life. The innovative formulation combines natural, nutrient ingredients to create a holistic and sustainable health drink. This beverage harnesses the nutritional power of carefully selected botanicals known for their high nutrient content and health benefits. The primary components are rich in essential vitamins and minerals, including iron, calcium, and other vital nutrients that contribute to overall well-being. The primary aim of this project is to provide an accessible, natural solution for enhancing women's health, promoting vitality, and preventing nutrient deficiencies. Through rigorous analysis and testing, this product that not only meets nutritional needs but also aligns with sustainable practices. This nutrient drink represents a significant step towards improving women's health on a broad scale, offering a convenient and effective way to incorporate essential nutrients into daily diets. Our research and development efforts underscore the importance of holistic health solutions that are both effective and environmentally responsible.

Keywords:

Sustainable; holistic; formulation; vitality; innovative

ETBFT-24-067

Paper Title: A comprehensive review on extraction and application of okra mucilage

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Abstract:

Abelmoschus esculentus, commonly known as okra, is a widely cultivated plant belonging to the Malvaceae family. It holds significant nutritional, pharmaceutical, and industrial value, particularly due to its rich content of bioactive compounds. One of its most notable components is okra mucilage (OM), a polysaccharide-rich substance primarily composed of D-galactose, L-rhamnose, and galacturonic acid. In addition to polysaccharides, OM contains proteins, vitamins, and essential minerals, making it a valuable natural resource. Due to its unique physicochemical properties, okra mucilage has garnered increasing scientific interest for its applications in food, pharmaceuticals, and biotechnology. OM is widely recognized for its ability to enhance texture, stability, and nutritional value in food formulations, while its bioactive properties contribute to health benefits such as improved insulin sensitivity, anti-cancer potential, blood pressure regulation, and antimicrobial effects. The physicochemical properties of okra mucilage, including its solubility in warm water, gelling ability, and bioadhesiveness, make it a promising candidate for use as a natural excipient in drug formulations, ensuring stability and controlled release mechanisms. This review provides an extensive evaluation of okra mucilage, emphasizing its functional benefits, extraction methodologies, and industrial applications.

Keywords:

Okra Mucilage (OM); Malvacea Family; Bioactive Compounds; Extraction Methodologies; Food Application; Pharmaceutical Application

“Let food be thy medicine and medicine be thy food.”

---Hippocrates

Thank You