

SUSTAINABLE FOOD INNOVATIONS:

PRODUCT DEVELOPMENT, PACKAGING, AND WASTE VALORIZATION

**Innovations in Sustainable Food Processing,
Functional Foods and Smart Technologies**

Edited by

**Kamlesh Prasad, PhD
Shubhra Shekhar, M. Tech.
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**Sant Longowal Institute of Engineering and Technology,
Longowal – 148106, Sangrur, Punjab, INDIA**

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Sustainable Food Innovations: Product Development, Packaging, and Waste Valorization

About the Editor

Kamlesh Prasad, PhD

Prof. Kamlesh Prasad is a distinguished academician, researcher, and food technologist with extensive experience in teaching, research, academics, administration, and scholarly publishing. He is currently serving as Professor in the Department of Food Engineering and Technology at Sant Longowal Institute of Engineering and Technology (SLIET), Longowal, Punjab, India. In addition to his academic responsibilities, he has served as Head of the Department (Food Engineering and Technology), Coordinator of the Internal Quality Assurance Cell (IQAC), Chairman of the Rajbhasha Hindi Cell, and Public Grievance Officer (PGO) of the institute. He is also the Chairman of the Conference on Future Innovations, Food Allergies, and Traditional Foods (FIFATF-2025 and FIFATF-2026).

Prof. Prasad obtained his postgraduate degree in Food Technology from the CSIR-CFTRI, Mysore. He subsequently earned his doctoral degree in Food Technology from GBPUA&T, Pant Nagar. His major areas of specialisation include fruit and vegetable processing, non-destructive quality evaluation of foods, image analysis, food process optimisation, nanotechnology applications in food systems, engineering properties of biological materials, innovative food processing technologies, and traditional foods to combat hidden hunger.

Prof. Prasad has authored and co-authored more than 200 research papers published in reputable national and international journals and conference proceedings. He has also authored several books, edited scholarly volumes, and contributed chapters to books published by leading national and international publishers. His publications have served as valuable references for researchers, students, and professionals in food science, food engineering, and postharvest technology. Also associated with several prestigious professional societies and scientific organisations, including the ASABE, IFT, AFST(I), NSI, USI, IEEE, and other national and international professional bodies. In addition to his research accomplishments, Prof. Prasad has actively contributed to academic leadership, curriculum development, student mentoring, and research capacity building.

This edited book is being published as part of the conference proceedings, reflecting his commitment to advancing research and disseminating knowledge in these critical domains.

Shubhra Shekhar, M. Tech.

Mr Shubhra Shekhar is a PhD candidate in the School of Chemical Engineering at the University of New South Wales (UNSW), Sydney, Australia. He is currently a member of the Faculty Board, holds higher-degree research student positions in engineering, has served as President of the Chemical Engineering Research Society (CERS), and is a member of the AGSE Industry PhD cohort, actively engaging with both industry and academic partners. His research focuses on non-destructive sensing and advanced characterisation methods to improve quality assurance and process understanding in modern food systems. His work brings together principles from chemical engineering, computer science, and data-driven modelling to develop innovative approaches for analysing complex food products and their behaviour.

He is a GATE achiever and has completed an M. Tech. (Food Process Engineering) from NIT, Rourkela. He received the Best Student Award from the Association of Food Scientists and Technologists, India (AFSTI), Mysuru, in 2021 and ranked top in the deemed-to-be university at graduation. He was also the All-India Topper (Elite) and received a Silver Medal for the NPTEL Course conducted by IIT Kharagpur. Got an appreciation letter from Nestle India Ltd., Moga, for his contributions in the form of recommendations. Won several prizes in academics, co-curricular and extracurricular activities. Received letters of appreciation for his contributions to several events and activities. He has successfully delegated his responsibilities as the in-charge of the Society of Food Technocrats (SOFT), the Photography Club (SVIESA), and numerous other professional committees and events. He has industrial exposure with Mondelez India Foods Private Limited, Baddi, HP; Mrs Bector's Food Specialities Limited, Greater Noida, UP; and Nestle India Limited, Moga, Punjab. He is a widely travelled person and has visited countries including Australia, Switzerland, Italy, France, Vatican City, Belgium, the Netherlands, Germany, the Czech Republic, Austria, Hungary, Singapore, Thailand, and Hong Kong. His work is published as articles in books, journals, and conference proceedings of international repute.

Harish Kumar Sharma, PhD

Harish Kumar Sharma S/o Mrs Sharda Sharma and Late Shri M. M. S. Sharma is a Professor (HAG) of Sant Longowal Institute of Engineering & Technology (SLIET) (Deemed University) (Established by: Government of India) and worked as Director, National Institute of Technology (NIT) (An Institution of National Importance), Agartala and Founder Mentor Director of Indian Institute of Information Technology (IIIT), Agartala. Professor Sharma is involved in Teaching, Research, and Administration and has published 167 papers in peer-reviewed Journals and a total of 205 papers in National/International Journals/Proceedings. He has supervised 18Ph.Ds and 44 M.Tech. students for their theses and authored/edited (10) books, (02) proceedings, and (02) manuals, published by reputed National and International Publishing Houses. He contributed 34 book chapters published by National and International Publishing Houses and visited different countries. Professor Sharma has successfully handled several projects and successfully transferred technology on a commercial scale. He has filed two patents, holds four copyrights, and provided technical assistance to various industries.

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Preface

It gives us immense pleasure to present ***Sustainable Food Innovations: Product Development, Packaging, and Waste Valorization***, an edited volume bringing together the research contributions addressing important contemporary challenges and opportunities in sustainable food processing, food product development, packaging, and resource valorization.

The food sector increasingly needs to meet growing demand for nutritious, safe, affordable, high-quality foods while using natural resources efficiently and reducing food and agricultural waste. Sustainable food innovation therefore requires approaches that integrate product development, nutritional improvement, efficient processing, waste reduction, value addition, and environmentally responsible packaging.

The book comprises fourteen chapters covering diverse themes. These include food applications for addressing celiac disease, techno-economic evaluation of wheat bran for fibre-rich food products, rice straw for sustainable packaging, utilization of underexplored banana species, food allergen reduction using cold plasma, and the nutritional and functional potential of tangerine peel waste.

Several chapters emphasize the valorization of underutilized crops and food resources. The volume includes studies on Tardi (*Dioscorea bellophylla*) starch, amla cultivars, multi-millet formulations, bitter gourd, jute leaves, asparagus bean flour, dietary-fibre recovery, and bioactive compounds from stinging nettle. These contributions show the potential of diverse plant resources and food-processing residues as sources of nutrients, functional ingredients, bioactive compounds, and value-added food products.

The book also highlights sustainable packaging and innovative processing technologies. Converting rice straw into packaging materials offers a way to create value from agricultural residue, while starch-based antimicrobial films show the potential of renewable materials for functional packaging applications. Other contributions address cold plasma treatment, drying technologies, extraction processes, and hydrothermal recovery of dietary fibre.

An important feature of this volume is its multidisciplinary approach, bringing together perspectives from food technology, food engineering, agricultural sciences, nutrition, biotechnology, materials science, and related disciplines.

We hope that “*Sustainable Food Innovations: Product Development, Packaging, and Waste Valorization*” will serve as a useful reference for researchers, academicians, postgraduate and doctoral students, food technologists, engineers, industry professionals, and other stakeholders.

We sincerely thank all the authors, reviewers, institutions, colleagues, students, and supporters whose contributions have made this volume possible.

K. Prasad, S. Shekhar, and H. K. Sharma (Editors)

Acknowledgement

The publication of *Sustainable Food Innovations: Product Development, Packaging, and Waste Valorization* has been made possible through the collective efforts, cooperation, and support of numerous individuals and institutions. As editors, we sincerely acknowledge everyone who contributed to preparing and completing this volume.

First, we express our heartfelt gratitude to all the contributing authors for sharing their research findings, knowledge, and expertise. The fourteen chapters covering sustainable food product development, agricultural and food-waste valorization, sustainable packaging, functional ingredients, food allergen management, processing technologies, nutritional enhancement, dietary-fibre recovery, and bioactive compounds form the foundation of this book.

We sincerely thank the reviewers and subject experts for their valuable time, critical evaluation, and constructive suggestions. Their scholarly inputs have helped improve the quality, scientific content, and presentation of the chapters.

We gratefully acknowledge Sant Longowal Institute of Engineering and Technology (SLIET), Longowal, for providing the institutional support and academic environment necessary for this scholarly initiative. We particularly appreciate the support of all FIFATF-2025 sponsors in bringing this edited volume to publication.

We also acknowledge the valuable contribution of the Department of Food Engineering and Technology, SLIET, Longowal, whose academic and research environment continues to encourage innovation and knowledge dissemination in food engineering and technology.

We extend our sincere thanks to the collaborating institutions and academic partners whose researchers contributed to this volume. We particularly acknowledge the association of researchers from national and international institutions.

We thank our research scholars, students, faculty members, colleagues, collaborators, and well-wishers for their valuable support, encouragement, and academic contributions. We also appreciate the efforts of all those who assisted with manuscript preparation, editing, compilation, formatting, proofreading, correspondence, and publication. Special thanks to my scholars, Gunjan Thakur and Sunil Kumar, for their efforts in shaping this book in its present form.

Finally, we express our heartfelt gratitude to our families and friends for their patience, encouragement, and continued support throughout the preparation of this book. Thanks are also extended to the administrations of the institute and the Ministry of Food Processing Industry for their support.

We sincerely hope that this volume will contribute to advancing research and innovation in sustainable food product development, resource-efficient processing, sustainable packaging, agricultural and food-waste valorization, nutritional enhancement, and the development of environmentally and economically sustainable food systems.

K. Prasad, S. Shekhar, and H. K. Sharma (Editors)

Synergistic Effect of Multi-Millet Formulation on Polyphenol Stability and Antioxidant Potential: A Mixture Design Approach

Parinitha  and Jyothi Lakshmi 

Abstract. Millets are increasingly recognized as functional foods owing to their rich polyphenols and antioxidant compounds that contribute to health-promoting effects. This study aimed to investigate the synergistic potential of multi-millet formulations in enhancing polyphenol stability and antioxidant activity through optimized blending. A simplex centroid mixture design approach was employed to combine finger millet, pearl millet, and sorghum in varying ratios. Functional responses, including total polyphenol content (TPC), total flavonoid content (TFC), DPPH radical scavenging activity, and FRAP assay, were evaluated across experimental runs. Results revealed that the optimized blend (53% finger millet, 28% pearl millet, 18% sorghum) maximized TPC (639.59 mg/100g), TFC (57.17 mg/100g), and antioxidant responses, confirming finger millet as the primary contributor. Principal component analysis indicated a positive contribution of finger millet (0.345), whereas pearl millet and sorghum exerted negative effects on variance. The synergy index ($SI > 1$) demonstrated that optimized ratios enhanced functional properties beyond the additive effects of individual millets. These findings confirm the potential of millet-based formulations to deliver improved bioactivity and nutritional integrity through strategic ratio optimization. This study provides a scientific basis for developing multi-millet functional foods with superior health benefits.

Keywords: Multi-millet formulation, Polyphenol stability, Antioxidant potential, Product optimization, Synergy Index

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1. Introduction

Millets are gaining global attention as functional and sustainable food crops because of their rich content of bioactive compounds, particularly polyphenols and antioxidants, which contribute to their health-promoting potential. These small-grained cereals are known for their antioxidant, anti-inflammatory, and neuroprotective properties, making them valuable in addressing oxidative stress-related disorders and improving overall nutritional health (Senguttuvel et al., 2024). Despite their individual nutritional merits, single millet varieties often have limitations in bioactive concentration and functional efficiency compared with blended formulations. Combining different millet species may offer synergistic interactions among their phytochemical constituents, potentially enhancing bioactive stability and overall antioxidant functionality beyond the additive effects of individual grains. Such synergistic enhancement through multi-millet formulations could contribute to the development of novel functional foods with improved nutritional quality and health benefits.

To explore this synergistic potential scientifically, mixture design models, particularly the simplex centroid approach, provide a structured way to identify optimal blend ratios. These statistical designs allow systematic evaluation of individual and interactive effects of multiple components on key response variables, such as total polyphenol content (TPC), total flavonoid content (TFC), and antioxidant activity.

The present study investigates the synergistic interactions among finger millet (*Eleusine coracana*), pearl millet (*Pennisetum glaucum*), and sorghum (*Sorghum bicolor*) using a simplex centroid mixture design. The objective was to optimize blend ratios for maximum polyphenol stability and antioxidant potential, while identifying the key contributors through principal component analysis (PCA) and synergy index evaluation. The findings aim to provide a scientific foundation for formulating millet-based functional food products with enhanced bioactivity and nutritional integrity.

synergistic enhancement in TPC, TFC, and antioxidant responses, establishing finger millet as the dominant contributor. The simplex centroid mixture design effectively identified interactive effects among components, while PCA and SI analyses confirmed true synergy ($SI > 1$). These results provide a strong scientific basis for developing millet-based functional foods that combine sustainability, nutritional quality, and enhanced bioactivity.

Acknowledgment

The first author sincerely thanks the University Grants Commission (UGC) for the fellowship, and the authors express gratitude to the Director, CSIR-CFTRI, Mysuru, for providing the necessary infrastructure and facilities.

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Innovations in Sustainable Food Processing, Functional Foods and Smart Technologies

This book presents recent research and innovative applications in sustainable food product development, packaging and waste valorization. It explores the utilization of biodegradable crops, food processing by-products and agricultural residues, development of functional and specialized food products, sustainable packaging materials, and emerging processing technologies. The chapters highlight multidisciplinary approaches integrating food science, food engineering, nutrition, biotechnology and materials science for resource-efficient, environmentally sustainable and value-added food systems. The volume serves as a useful reference for researchers, academics, students, industry professionals and Policymakers working towards innovations in sustainable food processing, functional foods and smart technologies.

KEY TOPICS COVERED

- Sustainable food product development and functional foods
- Utilization of undervalued crop and food processing by-products
- Agricultural residue conversion and waste valorization
- Sustainable and biodegradable packaging materials
- Food allergen reduction and processing technologies
- Nutritional and bioactive potential of fruits, vegetables and herbs
- Dietary fibre recovery and value-added ingredients
- Techno-economic analysis and scalability
- Innovative drying, extraction and processing methods
- Applications of smart and sustainable technologies in food systems

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