

SUSTAINABLE FOOD INNOVATIONS:

PRODUCT DEVELOPMENT, PACKAGING, AND WASTE VALORIZATION

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

Edited by

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

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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 melon, 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)

Influence of extraction techniques on the bioactive profile of stinging nettle (*Urtica dioica*) and potential applications

Amisha Gurung and H. K. Sharma 

Abstract. *Urtica dioica*, known as stinging nettle, is well-known for its valuable nutrients and bioactive compounds. The aerial part (leaves and stem) is rich in phenolic acids and flavonoids, while the root contains phytosterols. UD has been studied for its biological and therapeutic activities. Additionally, the bioactive profile makes it an excellent functional food ingredient. Bioactive compound recovery may vary depending on the technique used. Modern techniques improve bioactive compound recovery and reduce extraction time and solvent use. Based on recent studies, UD extract can modulate oxidative stress and inflammatory mediators; however, its efficiency may depend on plant part, extraction parameters, and technique. Many researchers have developed functional food products incorporating UD flour. Overall, UD is a good source of valuable compounds, and detailed studies on bioaccessibility and clinical research are needed to establish it as a functional and nutraceutical product. However, the available information is quite dispersed and needs a comprehensive study to bridge the gap between bioactive compounds, therapeutic potential and application in food systems. Therefore, this chapter examines the nutritional and bioactive composition of *U. dioica* leaves based on various extraction techniques and the potential application of leaf extract as a therapeutic agent.

Keywords: *Urtica dioica*, bioactive compounds, extraction technique, functional ingredient.

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1. Introduction

Urtica dioica, which is generally referred to as stinging nettle, is from *Urticaceae* family. The aerial part of the plant is covered with tiny needle-like structures called trichomes. Each trichome releases neurotransmitters like histamine and acetylcholine when touched (Devkota et al., 2022). There is increasing interest in plant research because of their rich bioactive profile and health benefits. Plants have been used for ages to treat and prevent diseases because they contain significant nutrients and active compounds (phenolic acids, flavonoids, vitamins, and minerals). Due to the growing demand for natural products, researchers are focusing on finding the potential uses of therapeutic plants. Because of its rich nutritional profile, researchers have incorporated *U. dioica* into food systems. Leaf extract, leaf powder, seed flour etc., have been used to improve the nutritional characteristics of food products such as cake, bread, pasta, cookies, and milk-based products (Mohammadi et al., 2016). Researchers have also explored using *U. dioica* leaf extract in packaging systems. The leaves are often consumed as a side dish or in soup, stew etc. It is a powerhouse of many active compounds like phenols, flavonoids, sterols, fatty acids and vitamins, which provide significant health benefits like antioxidant, anti-hypertensive, anti-analgesic, anti-inflammatory and cardiovascular-related activity (Devkota et al., 2022). In some cultural practices, the leaves and stems of stinging nettle are topically applied to relieve joint pain (Randall et al., 1999). In recent decades, research has reported recovering valuable compounds from *U. dioica* leaves using both conventional and modern techniques. Repajić et al. (2021) reported the presence of benzoic acid, cinnamic acid, flavonols, flavones, isoflavones, coumarins, etc., with chlorophyll as the most abundant natural pigment in the leaves and stalks of *U. dioica*. Different extraction techniques (UAE, MAE and conventional extraction) and concentrations of solvents (ethanol, methanol, water) were varied to extract bioactive compounds from *U. dioica*. 60% methanol (v/v) with UAE resulted in the highest antioxidant activities (Naqash et al., 2025). The presence of valuable compounds also contributes to the therapeutic potential of *U. dioica*. Researchers have identified phenolic acids, flavonoids, and tannins that have shown antioxidant effects (Naqash et al., 2025).

increasing UD concentration, significant decrease in yeast, mold and Enterobacteriaceae counts was observed during storage (14 days), suggesting the potential of UD in contributing towards microbial stability and extended shelf life. Fish is highly susceptible to spoilage; therefore, research is required to overcome the challenges faced during the storage or transportation of fish. To control fish spoilage by psychotrophic bacteria such as *Pseudomonas* and *Shewanella*, ethanolic extract of oregano and UD was used. Results indicated that the UD extract had better antimicrobial activity for both bacterial strains. UD nano-emulsion (1-4%) has been employed to increase the shelf life of fish meat. Storage study (14 days) of fish with 4% UD nano-emulsion resulted in optimal quality (Sterniša et al., 2020).

6. Conclusion

Urtica dioica has a significant content of nutrients and valuable compounds for application in the food nutraceutical industry. Concisely, UD leaf contains phytochemicals, such as phenolic acids, flavonoids, carotenoids, mineral and vitamins, which contributes to its bioactivity or health benefits. Advancement in extraction technologies, results in efficient recovery of bioactive compounds. However, variation in bioactive compounds in UD is related to processing condition, extraction techniques and solvents. Among conventional techniques, Soxhlet extraction provided highest recovery of bioactive compounds. Whereas, in modern extraction techniques, MAE was successful to recover maximum bioactive compounds present in UD. Further, health benefits of UD are widely reported, with evidence from in-vivo and in-vitro studies. UD leaf flour, extract and seed flour has been used to develop functional bakery, dairy, extruded and meat products. All the results indicate that use of UD enhances the biological and functional properties of the food product.

Future research may focus on the acceptability of UD food products. Scalability and regulatory considerations are also needed before the commercialization of product. Overall, the present study demonstrates the potential of UD as a functional formulation due to its rich polyphenolic profile, while detailed clinical study is required to validate the application of UD in food and pharmaceutical sectors. The extraction of different bioactive compounds and their application for the different functional benefits also require the attention of the researchers.

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SUSTAINABLE FOOD INNOVATIONS:

PRODUCT DEVELOPMENT, PACKAGING, AND WASTE VALORIZATION

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.

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