

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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**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.

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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.

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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)

Nutritional, Bioactive Compounds and Application of Tangerine Peel Waste in Food Industries

Avantika Thakur, Barinderjit Singh , and Simple Sharma 

Abstract. *Citrus reticulata*, commonly known as the tangerine, is a fruit crop with a significant portion used for raw juice production. A substantial amount of fruit, especially peel, is wasted, creating disposal issues. However, citrus peel, specifically tangerine peel, is high in bioactive compounds, essential oils, and dietary fiber, making it a potential raw material for further value-added products. This review summarises the literature on using tangerine peel to produce peel powder, including processing parameters, nutritional benefits, bioactive compounds, and potential industrial applications. Using tangerine peel as a resource minimizes waste as well as enhances economic returns to the citrus industry. Peel powder is prepared by drying and milling the peel into a fine powder, which can be incorporated into teas, bakery items, beverages, and dietary supplements as a natural flavouring and functional ingredient. Peel powder helps increase economic value for farmers, food processors, and industries. Additionally, the presence of bioactive compounds, viz., flavonoids, phenolics, terpenoids and pectin, enhances functional properties such as antimicrobial activity, antioxidant potential, and flavour retention, making them suitable for use in health foods, nutraceutical formulations, and clean label food products.

Keywords: Antioxidant activity, Bioactive compounds, Health benefits, Peel, Waste utilization

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1. Introduction

Citrus fruits are among the top primary fruit crops worldwide, and millions of tonnes are processed each year in the form of juices, concentrates, canned segments, and flavored products (FAO, 2023). At the same time, peel accounts for close to 3050% of the total fruit weight, and thus, it is the largest by-product of the citrus industry (Braddock, 1999; Khan et al., 2010). The tangerine (*Citrus reticulata*) is one of the most popular fruits, not only because it tastes good and is easy to peel but also because it has a very good nutritional profile (Li et al., 2006). As a result, it is a major contributor to this waste stream. The disposal of citrus peel waste has become a significant source of environmental pollution due to fast microbial spoilage caused by the high moisture, sugar, and essential oil content which leads to the production of unpleasant odor and increases biochemical oxygen demand (BOD) in case of unappropriated disposal (Bocco et al., 1998). Besides, this wastage attracts insects and rodents and thus, is gaining more and more processing units' disposal costs. While tangerine peel may be considered a byproduct, it is loaded with valuable chemicals. It is the outer flavedo, and the inner albedo segments are packed with dietary fiber, pectin, essential oils, flavonoids, phenolic acids, carotenoids, and a range of terpenoids, thus, the peel is not only nutritionally richer but also more biologically active than the edible pulp (Gorinstein et al., 2001; Li Han et al., 2020). These compounds have been shown to provide health benefits, including antioxidant, antimicrobial, anti-inflammatory, and cholesterol-lowering effects (Gorinstein et al., 2001; Hamdan et al., 2013; Kaur et al., 2022b; Prakash et al., 2024; Shekhar et al., 2023). Biochemically, this makes tangerine peel an attractive candidate for future functional food ingredients, nutraceutical formulations, natural preservatives, and bio-based polymer development (Putnik et al., 2017; Sharma et al., 2015). As a result of the worldwide focus on zero-waste processing, circular bioeconomy, and clean-label food production, extracting value from citrus peel is of great industrial significance. On the one hand, the conversion of the peel into high-value commodities- such as peel powder, pectin, essential oils, dietary fiber concentrates, and phytochemical extracts- helps to alleviate the environmental burden. On the other hand, it opens up new income avenues for farmers, processors, and ingredient manufacturers. Moreover, peel-

solubility and enabling targeted release in food applications. Moreover, sensory and consumer research is largely unexplored, though strong citrus aroma, bitterness, and color from peel components can significantly impact consumer acceptance. Sensory evaluations, testing consumer preference, and market segmentation studies are thus very important in defining ideal usage levels, suitable categories of food, and perceptions held by consumers of products enriched with peels. These ensure the development of standardized, safe, stable, and consumer-acceptable tangerine peel products that can be integrated into modern food systems at economically viable and scalable levels.

7. Conclusion

The peel of mandarin orange is by far the most important by-product of citrus processing packed with dietary fiber, pectin, essential oils, flavonoids, and other antioxidant phytochemicals. Such substances have the potential to create value-making ingredients suitable for functional foods, natural preservatives, nutraceuticals, and even biodegradable packaging products. In fact, with properly optimized methods-e.g., drying under control, efficient extraction, and proper standardization-the peel can be transformed into safe and top-quality ingredients matching customers' demands for health and clean-label products. Nevertheless, there are quite a few obstacles to large-scale marketing of them, such as obtaining good-quality raw materials consistently, locating pesticide residues and heavy metals, and coming up with strong techno-economic models for the economic feasibility side of things. Also, the proof of health benefits through clinical studies, especially well-designed ones, is still very much required for products that want to make functional or therapeutic claims. On the whole, scientific literature to date is very positive about the potential of mandarin peel to be a recyclable and valuable resource which in fact points to the necessity of more research and industrial openness for the commercial and societal advantages to be unlocked.

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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.

KEY TOPICS COVERED

- Sustainable food product development and functional foods
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- Food allergen reduction and processing technologies
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- 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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