

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.

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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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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)

Isolation, characterization, and utilization of Tardi (*Dioscorea bellophylla*) starch in the development of antimicrobial films incorporated with silver nanoparticles

Divyanshi Thakur  Rahul Das  and Kamlesh Prasad 

Abstract. Tuber and root crops are important food crops, mainly in tropics and subtropics. This study analyzed starch extract and flour of Tardi (*Dioscorea bellophylla*) and utilized the extracted Tardi starch (TS) to develop films incorporated with varying proportions (0.5%, 1%, 1.5%, and 2.0%) of silver nanoparticle (AgNPs) via the casting method. The results indicated that TS exhibited low fat, fiber, ash, and protein than flour but demonstrated superior solubility and swelling power. The amylose and amylopectin content were 24.56%, and 75.44%, respectively, with starch granules showed an elliptical morphology (35.212 μm). Rheological analysis revealed better pasting than Tardi flour (TF). TS had high gelatinization temperature, enthalpy, and peak viscosity, demonstrating excellent potential for industrial applications. AgNPs incorporation significantly influenced mechanical, functional, and the structural characteristics of TS films. FTIR analysis revealed slight peak shifts, while color assessment showed AgNPs films had an off-white tint. Transparency showed significant decrease as the concentration of AgNPs increased. Additionally, water vapor permeability (WVP) as well as solubility were decreased, while tensile strength (TS) improved. The films showed significant antimicrobial activity against gram-positive bacteria, making them effective for pathogen control. Given their enhanced properties, these films have potential applications as biodegradable barrier/coating on fruits and vegetables, extending shelf life as well as maintaining food safety.

Keywords: Tardi, flour, starch extract, silver nanoparticle, food coating, antimicrobial properties

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1. Introduction

Yams (*Dioscorea* spp.) belong to the Dioscoreaceae family that comprise over 650 species. Around 600 species are consumed in diverse geographical regions (Akoroda, 1993). It can be an important commodity for food security, traditional medicine, and socio-economic stability. Among tuber crops, yam ranks fourth following potato, cassava, and sweet potato. It ranks second in West Africa, after cassava. The total world production of yam in 2020 was 74.82 million tonnes, with Nigeria and Ghana being major producers (FAOSTAT, 2022). Edible starchy tubers, are culturally, economically, and nutritionally significant throughout tropical and subtropical regions (Zou et al., 2022). They contain a significant amount of carbohydrates, proteins, lipids, vitamins, and minerals. One lesser-known tuber grown in certain areas of Himachal Pradesh is "Tardi" (*Dioscorea belophylla*), a wild yam species. It grows naturally in forests at elevations from 1000 to 1800 m. It is indigenous to the western Himalayan mid-hills having a climbing vine with heart-shaped leaves that are about 5 mm thick. It has small, spherical, fruit-like structures that are not true fruits and are called "Tardolu" in the local language. Tardi tubers are brittle, milky white, and sticky inside. They are crisp and starchy when fresh. They contain several bioactive compounds that promote good health and combat diseases (Khan et al., 2024).

In recent years, biodegradable polymer materials made from renewable resources have garnered significant attention. Natural polymers are being utilized to substitute or minimize the reliance on synthetic packaging. In the food sector, this idea is gaining attention as a substitute for artificial polymeric packaging and a way to reduce the adverse consequences of synthetic packaging (Ediyilyam et al., 2021). For extending the shelf life of fresh fruits, polysaccharide-based films offer a sustainable approach. Furthermore, the development of edible films may contribute towards environmental protection by minimizing reliance on non-biodegradable polymers and enhancing the bioeconomic food sector (Martins da Costa et al., 2020). Various natural biopolymers, including starch, cellulose, fibre, pectins, gums, gluten, fatty acids, and pullulans, are often employed to produce edible films with composability characteristics. These materials are preferable because they leave no hazardous residues (Deng et al., 2025; Ghosh et al., 2025). Starch is considered an important natural polymer for

3.10.8 Antibacterial activity

The study examined the antibacterial activity of silver nanoparticle-incorporated starch films against *S. aureus* (Gram-positive bacteria). Results showed that AgNP-incorporated films, rather than control formulations, had strong antimicrobial activity. Antibacterial activity depends on starch composition, AgNP concentration, and starch content. Results showed that antimicrobial activity positively correlated with AgNPs and starch, with varying AgNP amounts (0.5%, 1%, 1.5%, and 2.0%) producing inhibition zones of 1.7, 1.8, 2.0, and 2.2 mm. According to standard protocol SN (Swiss Standard) 195, 920-ASTM E2149-01, an inhibition zone exceeding 1 mm indicates an effective antibacterial substance. Gram-positive bacterial inhibition involves disruption of the cell wall structure, resulting in the subsequent leakage of intracellular substances (Huang et al., 2017). The interactions of AgNPs with bacterial cell membranes, subsequently limiting genetic material replication (DNA) and the cell division process, resulting in reduced metabolic activity and increased formation of reactive oxygen species (ROS). These findings correlate well with a previously reported paper on chitosan/starch-silver nanoparticles (Jung et al., 2018).

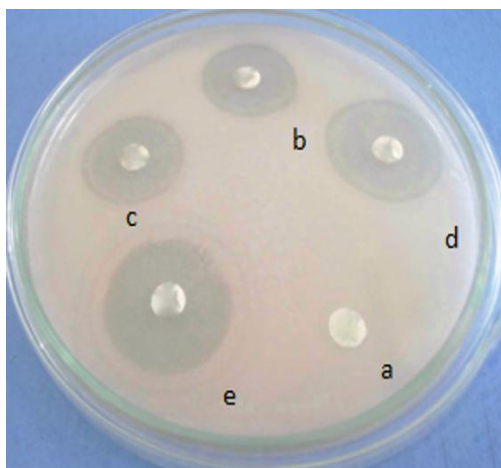


Fig. 6 Antibacterial activity of AgNPs against Gram-positive bacteria (*Staphylococcus aureus*) (a) TS film (b) TS/AgNPs-0.5% (c) TS/AgNPs-1% (d) TS/AgNPs-1.5% (e) TS/AgNPs-2% films

4. Conclusion

The research findings indicated that TF is high in protein, fat, crude fiber, and ash, whereas TS has higher carbohydrate content, primarily in starch form. TS exhibited lower amylose and high amylopectin content, making it a functional ingredient for various food applications. It showed low values for pasting parameters except for pasting time and temperature. Its superior physical and functional properties, along with a favorable color index, enhance its usability in food sector. TS starch showed significant potential to be utilized in food packaging/coatings and films to preserve freshness, protect against external factors, and improve visual appeal. Additionally, it is suitable for products like weaning meals, non-wheat noodles, and ice creams due to its low pasting parameters and high processability. In contrast, TF, with its lower retrogradation, offers benefits such as extended shelf life, improved texture, enhanced freeze-thaw stability, and better processability. These characteristics make it an essential ingredient in bakery products like bread and cakes, as well as in sauces and other processed food applications.

TS showed a type B crystallinity structure, with a higher relative crystallinity than flour, along with an elliptical shape and larger diameter. AgNP-modified Tardi starch (TS) films showed enhanced overall characteristics. Adding AgNPs reduced the films water vapor permeability and solubility while improving their mechanical strength. Furthermore, the films showed a pronounced antibacterial effect against the Gram-positive bacterium *S. aureus*, with effectiveness depending on the AgNP concentration. These results suggest strong potential for AgNP-infused TS films in advanced packaging applications, offering improved barrier properties and antimicrobial functionality. Future research can explore the optimization of AgNP concentration for maximum antibacterial efficacy, assess the films' performance against a broader range of pathogens, and investigate their environmental impact and biodegradability to ensure sustainable applications in food packaging and biomedical fields.

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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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