

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.
Harish Kumar Sharma, PhD**



**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.

Harish Kumar Sharma, PhD

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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)

Physico-chemical and phytochemical characterization of amla (*Emblica officinalis*) cultivars: Identifying a suitable genotype for juice extraction

Sumaiya Fatima[✉] and Vivek Kumar[✉]

Abstract. Indian gooseberry (*Emblica officinalis*), commonly known as amla, is a fruit of considerable nutritional and therapeutic significance in Ayurveda. It is an excellent source of vitamin C, minerals, and diverse phytochemicals contributing to its functional and health-promoting properties. Multiple amla cultivars are cultivated across India and vary in their morphological and biochemical characteristics. The present investigation aimed to evaluate seven prominent cultivars, Balwant, Banarasi, Chakaiya, Desi, NA-6, NA-7, and NA-10, for their potential in juice extraction. Comprehensive characterization of physical parameters of fruit (average fruit weight, flesh content, seed proportion, juice yield, pomace content, moisture, and total solids), physico-chemical attributes (pH, total soluble solids, titratable acidity, and reducing sugars), and phytochemical constituents of juice (ascorbic acid, total phenolic content, DPPH scavenging activity and tannin content). Banarasi cultivar exhibited the highest average weight, flesh content, and juice yield; however, it recorded the lowest seed and pomace content. Conversely, Desi recorded the lowest juice yield and the highest seed and pomace content. No significant changes were observed among cultivars in physico-chemical properties. Ascorbic acid and TPC ranged from 393.49 to 698.63 mg/100 mL and 238.28 to 582.10 mg GAE/L, respectively, with Desi having the highest values, followed by Chakaiya and Banarasi. DPPH scavenging activity and tannin content varied from 48.29 to 68.63% and 1.39 to 1.48%, respectively. Multivariate analysis also highlighted differences among the cultivars. Finally, considering superior juice yield and appreciably high phytochemical content, Banarasi was selected as the most suitable cultivar for amla juice extraction.

Keywords: Amla juice, Juice yield, Ascorbic acid, Principal component analysis

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1. Introduction

Indian gooseberry (*Emblica officinalis*), also called Amla, is known for its excellent therapeutic and nutritional properties. It is even considered one of the most important fruits in the traditional Indian medicinal system of Ayurveda (Khalid Muzaffar et al., 2022). It has opulent amounts of vitamin C, phenolics, flavonoids, minerals, and dietary fibre, which impart potential antioxidant, anti-inflammatory and immunomodulatory properties (Fatima and Kumar, 2025). Different amla cultivars are grown across diverse agro-climatic regions in India, each with distinct morphological, physico-chemical, and phytochemical attributes (Tewari et al., 2019). These distinct innate quality attributes not only affect their nutritional and sensory profiles but also influence their applicability for different processing, storage, and product development. Therefore, understanding the physico-chemical and phytochemical profiles of various cultivars is crucial to assess their compatibility in nutraceuticals, functional beverages, and value-added food formulations. The physical properties of amla fruits directly affect their handling, mechanical stability, and overall compatibility with industrial operations such as washing, drying, transportation, and packaging. Besides, variations in the physical properties among the different cultivars provide meaningful insights about the advantages in commercial utilization for that specific cultivar. Additionally, assessing the physico-chemical attributes of different cultivars is essential for establishing their sensory acceptability, flavour profile, stability during processing and storage, and so on. These parameters directly influence the processing and preservation techniques used for value-added food formulations prepared from amla fruits (Krishna and Prasad, 2025). Furthermore, determining phytochemical composition is crucial for understanding the nutritional, functional, and therapeutic value of the various cultivars. Variations in these attributes inform the selection of amla cultivars for developing functional products using amla fruit. Only a few studies have examined the physical and chemical characteristics of selected amla cultivars (Goyal et al., 2007). However, a comprehensive evaluation covering the physical, physico-chemical, and phytochemical attributes of widely cultivated commercial amla cultivars is needed, focusing on their suitability for potential utilization and processing. Such consolidated information is essential for understanding cultivar-specific suitability for processing, designing appropriate machinery for handling and value-added operations, and selecting ideal varieties for industrial applications. Therefore, this study systematically investigated the physical, physico-chemical, and phytochemical characteristics of major commercial amla cultivars.

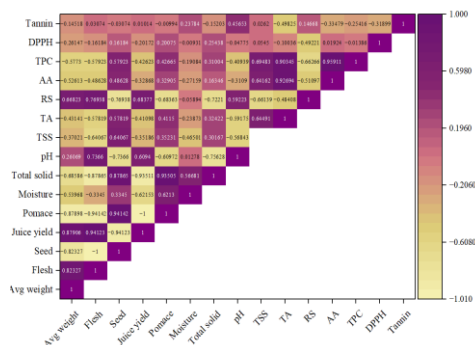


Fig. 4 Correlation between various attributes of different amla cultivars

4. Conclusion

The present study comprehensively evaluated the physical, physico-chemical, and phytochemical characteristics of seven commercially important amla cultivars. Considerable varietal differences were observed across all measured attributes. Among the physical properties, *Banarasi* exhibited higher flesh percentages and juice yield, while *Desi* recorded the lowest values, reflecting clear differences in processing suitability. Physicochemical analysis showed that pH remained low across all cultivars, confirming the inherently acidic nature of amla, whereas TSS and titratable acidity varied notably, with *Banarasi*, *NA-6*, and *NA-7* showing a comparatively higher sweetness–acidity balance. Phytochemical profiling demonstrated that *Desi* possessed the highest ascorbic acid and total phenolic content, indicating strong antioxidant potential, while cultivars such as *Chakaiya* and *Banarasi* showed comparable levels of bioactive compounds. Furthermore, PCA revealed a strong positive correlation among average fruit weight, flesh, juice yield, ascorbic acid, total phenolic content, and titratable acidity. In addition, *Banarasi* and *Chakaiya* cultivars were grouped together, highlighting their similar attributes. Overall, the integrated assessment of physical, physico-chemical, and phytochemical attributes shows that cultivars like *Banarasi*, *Chakaiya*, and *Balwant* have superior potential for commercial utilisation, owing to their favourable fruit size and juice yield, while the *Desi* cultivar, characterised by its high antioxidant richness, is more appropriate for nutraceutical applications. Overall, given its higher juice

yield and notably elevated phytochemical levels, Banarasi emerged as the most suitable cultivar for amla juice extraction.

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SUSTAINABLE FOOD INNOVATIONS:

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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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