

Value Addition in Citrus and Valorisation of Waste for Secondary Agriculture and Profit Optimization

Citrus fruits are among the most important horticultural commodities worldwide because of their nutritional, medicinal, and industrial significance. India is a leading producer of mandarin, sweet orange, lemon, and acid lime; however, substantial post-harvest losses occur due to inadequate storage, limited processing infrastructure, and poor value-addition practices. Citrus fruits are highly valued because of their refreshing flavour, rich nutritional composition, antioxidant properties, and therapeutic importance. They are important sources of vitamin C, flavonoids, carotenoids, sugars, dietary fiber, organic acids, and several bioactive compounds that contribute to human health. Citrus fruits are highly suitable for secondary agriculture because nearly every component of the fruit can be converted into value-added products. Approximately 40–45% of citrus fruits are utilized for juice extraction, while the remaining 55% is generated as waste in the form of peel, pulp, pomace, and seeds. Traditionally, these by-products were discarded, causing environmental pollution and economic losses.

Keywords: Citrus fruits; Citrus value chain; Profit optimization; Secondary agriculture

IN recent years, citrus waste valorization has emerged as an important component of secondary agriculture and circular bioeconomy models, focusing on the conversion of processing residues into high-value products. Advanced green extraction technologies such as microwave-assisted extraction, ultrasound-assisted extraction, supercritical fluid extraction, membrane filtration, and freeze drying have significantly improved recovery efficiency, product quality, and environmental sustainability. Research findings from the ICAR-Central Citrus Research Institute have further highlighted the potential of immature dropped citrus fruits as rich sources of hesperidin and diosmin for nutraceutical applications.

Secondary agriculture and citrus value chain:

Secondary agriculture plays an important role in strengthening the agricultural economy by transforming raw produce into processed and industrial products. Value addition increases the commercial value of citrus fruits by converting them into ready-to-serve beverages, concentrates, candies, essential oils, pectin, nutraceuticals, and functional foods. Such activities also promote export opportunities and sustainable utilization of agricultural waste. Despite the immense potential of citrus processing, several challenges continue to affect the growth of

the sector. In addition, extraction technologies for high-value compounds are not widely available, and a large quantity of citrus waste remains underutilized.

Nutritional and functional importance of citrus:

Citrus fruits are rich sources of bioactive compounds with nutritional and therapeutic importance. They contain vitamin C, flavonoids, carotenoids, limonoids, terpenes, pectin, dietary fiber, sugars, and organic acids. These compounds contribute significantly to antioxidant activity, immune enhancement, cardiovascular protection, antimicrobial action, and prevention of chronic diseases. More than 500 natural compounds have been identified in citrus fruits, including flavonoids, carotenoids, coumarins, volatile compounds, limonoids, and phenolic substances.

In India, citrus fruits have conventionally been processed into common food products like squashes, jams, and jellies. These products are still very popular because people are familiar with them, they are easy to make, and they are widely accepted by consumers. Ready-to-serve (RTS) drinks made from mandarin orange or acid lime juice are among the most common citrus products available in the market. People like them because they are refreshing and rich in vitamin C. Citrus squashes made from sweet orange or lime juice concentrates are also widely consumed, especially during the summer season. Marmalade, a thick spread made from citrus juice and peel (mainly orange), is commonly eaten as a breakfast spread in urban areas. Jams and jellies prepared from lemon,



Fizzy Citrus drink



Lemon Squash



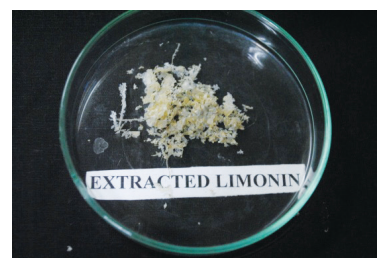
Orange Squash



Mandarin (Peel)
Marmalade



Orange Seeds



Extracted Limonin

lime, or orange are also popular because of their good taste and texture, especially among young consumers. Apart from these, citrus syrups and candied peels are also becoming popular. These are made by treating citrus peels with sugar after removing their bitterness. They are now being used in bakery products, ice creams, and traditional sweets. These traditional citrus products form the foundation of India's citrus processing industry and provide a good base for developing new and innovative products in the future.

Citrus processing and value addition

Citrus processing is an important component of secondary agriculture because it increases shelf life, improves marketability, and enables diversification of products. A wide range of citrus-based products are produced by processing industries. Citrus beverages include juices, ready-to-serve drinks, and carbonated beverages. Citrus concentrates prepared through evaporation and membrane technologies have long shelf life and high export potential. Citrus peel powder and dried slices are used as dehydrated products, while peel oils, pectin, limonin, and dietary fiber serve as industrial ingredients and nutraceuticals.

Fizzy citrus drinks: Carbonated citrus beverages have gained popularity because of their refreshing taste and commercial appeal. Lime and mandarin fizzy drinks are prepared through juice extraction, chilling, carbonation, bottling, and sealing operations.



Fizzy drink (Mandarin)

Citrus juice concentrates:

Citrus juice concentrates are important industrial products because of their long shelf life, ease of transportation, and export potential. Traditionally, juice concentrates were prepared through flash evaporation and freeze drying. However, modern membrane technologies such as ultrafiltration, reverse osmosis, and osmotic distillation have become increasingly popular because they preserve flavour, aroma, and nutritional quality better than conventional thermal methods. Using these technologies, juice concentrates of Khasi mandarin, Kachai lemon, Nagpur mandarin, and Sweet orange were developed



Orange Juice Concentrate

with total soluble solids ranging between 51–52.5°Brix.

Citrus waste utilization: Citrus processing industries generate large quantities of peel, pomace, pulp, and seeds, which can be effectively utilized for development of value-added products. Citrus waste is a rich source of pectin, flavonoids, essential oils, limonoids, dietary fiber, and seed oil.

Pectin extracted from citrus peel is widely used in jam, jelly, confectionery, and pharmaceutical industries because of its gelling properties. Pectin extracted from Khasi mandarin peel exhibited higher methoxyl content and jelly grade compared to Kachai lemon peel.



Citrus Peel Pectin



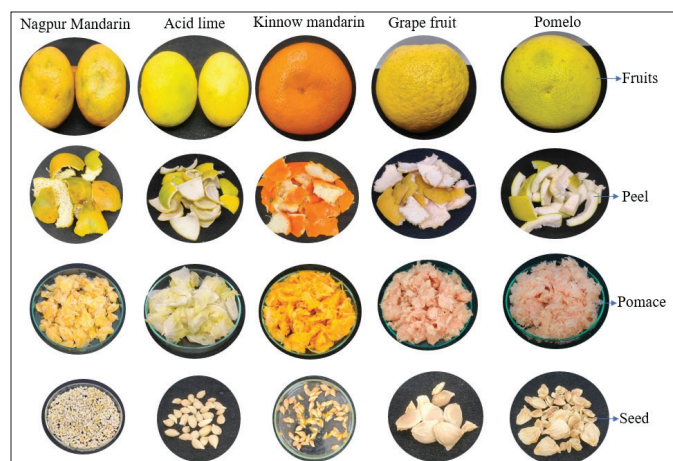
Cold Press Oil



Hydrodistilled Oil

Citrus peel oil contains valuable aromatic compounds such as limonene, pinene, sabinene, terpineol, and ocimene, which are extensively used in food, cosmetic, fragrance, and pharmaceutical industries.

In recent years, citrus waste valorisation has gained attention as a sustainable strategy for waste management



and resource recovery. Citrus residues are now recognized as valuable biomass containing industrially important compounds such as pectin, limonene, flavonoids, and antioxidants. These compounds have applications in food, pharmaceutical, cosmetic, and nutraceutical industries. Despite growing research interest, several gaps remain in the effective utilization of citrus waste. Most studies focus on the extraction of individual compounds rather than integrated valorisation approaches capable of utilizing the entire biomass.

Citrus processing waste (Peel, pomace and seeds)

Characterization of citrus waste: The characterization of citrus waste directly influences processing decisions and product development strategies. High pectin content supports its utilization in food stabilizers and edible films, while elevated sugar content favors bioethanol production through fermentation. Waste rich in essential oils is suitable for extraction of flavoring agents and antimicrobial compounds. Similarly, high cellulose and hemicellulose content can support biogas, compost, or biochar production. Thus, detailed characterization enables efficient selection of extraction technologies and enhances economic feasibility in integrated biorefinery systems.

Farmers upliftment through citrus waste utilization

Citrus waste valorization can have a meaningful impact on farmers and the broader economy by converting an underused agricultural byproduct into a source of additional income, employment, and industrial raw material. In citrus-growing regions, peels, pulp, seeds, and pomace are often discarded after juice extraction or market processing, creating disposal costs and environmental burdens. By developing collection, processing, and extraction systems for these residues, farmers and local processors can benefit from an added revenue stream through the sale of waste biomass to food, nutraceutical, cosmetic, and bioenergy industries.

At the macroeconomic level, citrus waste valorization supports import substitution and industrial innovation by providing domestic sources of pectin, essential oils, antioxidants, dietary fiber, and biodegradable materials. These value-added products can reduce dependence on imported inputs and improve the competitiveness of food and packaging industries. The approach also contributes to waste minimization, lower pollution, and more efficient resource use, which reduces environmental management costs for municipalities and processors.

Environmental and social implications

Citrus waste valorisation provides important environmental benefits by reducing agro-industrial waste and promoting sustainable resource utilization. The valorisation of citrus waste also contributes to social and economic development, particularly in rural and citrus-producing regions. Processing industries based on citrus waste can generate employment opportunities in collection, transportation, extraction, and product manufacturing sectors. Technology transfer and adoption of sustainable processing methods can further strengthen agro-based economies and encourage industrial innovation.

Citrus flavonoids and nutraceuticals

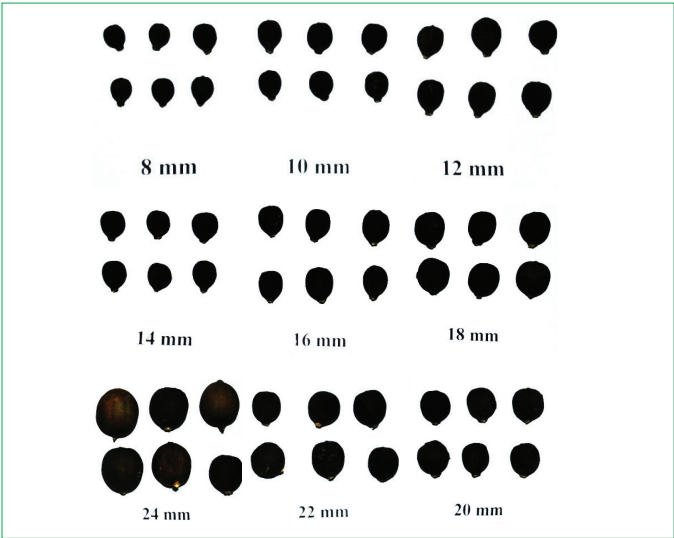
The global nutraceutical market has expanded rapidly due to increasing consumer awareness regarding health-promoting foods and natural bioactive compounds. Citrus fruits and their by-products are important sources of nutraceutical ingredients such as flavonoids, vitamin C, and dietary fiber. India’s nutraceutical market has also shown remarkable growth and is projected to reach nearly \$18 billion by 2026. Commercial citrus nutraceuticals include vitamin C supplements, citrus fiber, citrus extracts, and bioflavonoid preparations rich in hesperidin and naringin. These products are widely used in pharmaceuticals, dietary supplements, and functional foods.

Research findings on citrus dropped fruits

Immature dropped fruits generated during citrus cultivation are generally discarded as waste. However, recent studies conducted at ICAR-Central Citrus Research Institute revealed that these fruits contain high concentrations of flavonoids such as hesperidin, narirutin, diosmin, didymin, and neoponcirin. The results demonstrated that immature Nagpur mandarin fruits

Table. Flavonoid content of immature Nagpur mandarin fruits

Sr. No	Sample Size (mm)	Hesperidin (%)	Narirutin/Isonariging (%)	Diosmin (%)	Didymin Neoponcirin (%)
1	8	24.30	0.143	0.28	0.281
2	10	26.63	0.118	0.17	0.331
3	12	28.74	0.134	0.18	0.384
4	14	27.67	0.147	0.13	0.354
5	16	21.03	0.212	0.14	0.459
6	18	15.49	0.098	0.07	0.369
7	20	11.47	0.191	0.07	0.685
8	22	8.095	0.26	0.0	0.417
9	24	7.777	0.325	0.0	0.342



Immature Dropped Fruits of Nagpur Mandarin

contain very high levels of hesperidin, particularly at smaller fruit sizes.

Future Scope of Citrus Value Addition

The future of citrus value addition lies in the development of innovative functional foods, nutraceuticals, and eco-friendly processing technologies. Increasing research attention is being directed toward development of probiotic citrus beverages, fortified juices, citrus peel-based nutritional bars, antimicrobial compounds for packaging applications, and extraction of bioactive compounds. Advances in membrane technology, green extraction methods, biotechnology, and waste-to-wealth approaches are expected to further enhance the profitability and sustainability of citrus processing industries. Utilization of citrus by-products for development of high-value ingredients will not only reduce environmental pollution but also create additional employment opportunities and support sustainable agro-industrial growth.

SUMMARY

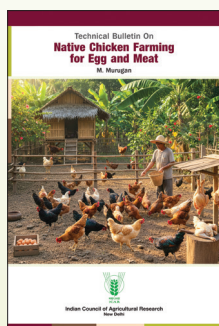
Citrus value addition plays a significant role in

strengthening secondary agriculture and improving farmer income. Processing technologies enable diversification of citrus products into beverages, concentrates, confectionery products, nutraceuticals, and industrial ingredients. Efficient utilization of citrus waste provides opportunities for extraction of pectin, flavonoids, limonoids, dietary fiber, and essential oils. Research findings indicate that immature dropped fruits are promising sources of valuable flavonoids such as hesperidin and diosmin. The expanding nutraceutical market further increases the commercial importance of citrus bioactive compounds. Promotion of agro-processing industries, technological innovations, and sustainable waste utilization strategies can transform the citrus sector into a profitable and environmentally sustainable agro-industrial system.

For further correspondence, contact:

¹Dr. Dinesh Kumar, Head, Food Science and Post Harvest Technology, ICAR-Indian Agricultural Research Institute, New Delhi 110 012, India. Email: dineshscn@gmail.com; ²ICAR-Central Citrus Research Institute, Amravati Road, Nagpur 440 033, Maharashtra, India.

Technical Bulletin on Native Chicken Farming for Egg and Meat



This publication provides a comprehensive understanding of native chicken farming, including its production and marketing systems. The subject matter is sequentially presented, covering the introduction, native chicken stocks concept, stock selection, rearing systems and housing models, feeding basics meat and egg production, biosecurity principles, health management, economics and capacity building.

TECHNICAL ASPECTS

Pages: vi + 110; Price: ₹ 500.00, US\$ 80.00; Postage: ₹100

ISBN No.: 978-81-7164-311-0

For obtaining copies, please contact:

Business Unit

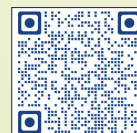
ICAR-Directorate of Knowledge Management in Agriculture

Krishi Anusandhan Bhawan – I, Pusa, New Delhi 110012

Tel: 011-25843657; email: businessuniticar@gmail.com

website: www.icar.gov.in

SCAN QR Code



Attention Indian Horticulture readers: • All disputes are subject to the exclusive jurisdiction of competent courts and forums in Delhi/New Delhi only. • The Council does not assume any responsibility for opinions offered by the authors in the articles and no material in any form can be reproduced without permission of the Council. • The Council is not responsible for any delay, whatsoever, in publication/delivery of the periodicals to the subscribers due to unforeseen circumstances or postal delay. • Readers are recommended to make appropriate enquiries before sending money, incurring expenses or entering into commitments in relation to any advertisement appearing in this publication. The Council does not vouch for any claims made by the advertisers of products and services. The publisher and the editor of the publication shall not be held liable for any consequences in the event of such claims not being honoured by the advertisers.