

Postharvest management and value addition of dragon fruit (*Hylocereus* spp.) in India

Dragon fruit (Kamalam) is gaining global recognition as a super crop due to its easy cultivation, high stress tolerance, and nutraceutical benefits. With its potential to thrive on degraded lands in India, large-scale farming is expanding rapidly, anticipating a production surge over 50,000 ha in next three years. While ensuring its success, effective plantation, harvesting and postharvest practices are essential, especially considering its short shelf-life of 5–7 days. Key postharvest disorders such as splitting, mechanical and chilling injury, moisture loss, and decay must be addressed promptly to minimize losses. Additionally, managing by-product wastes, such as peel and bulk stem segments for industrial applications is crucial for profitable agriculture. The current postharvest practices discussed need to be strictly implemented for fresh dragon fruit, as a major portion undergoes fresh consumption in the country. To address seasonal gluts and extend shelf-life, valorised products from dragon fruit pulp and peel developed by ICAR–NIASM are emphasized. The article concludes by stressing the importance of postharvest research, infrastructure development, market standards and policy formulation to support increased production, exports, and improve the livelihoods of poor and marginal farmers on degraded lands.

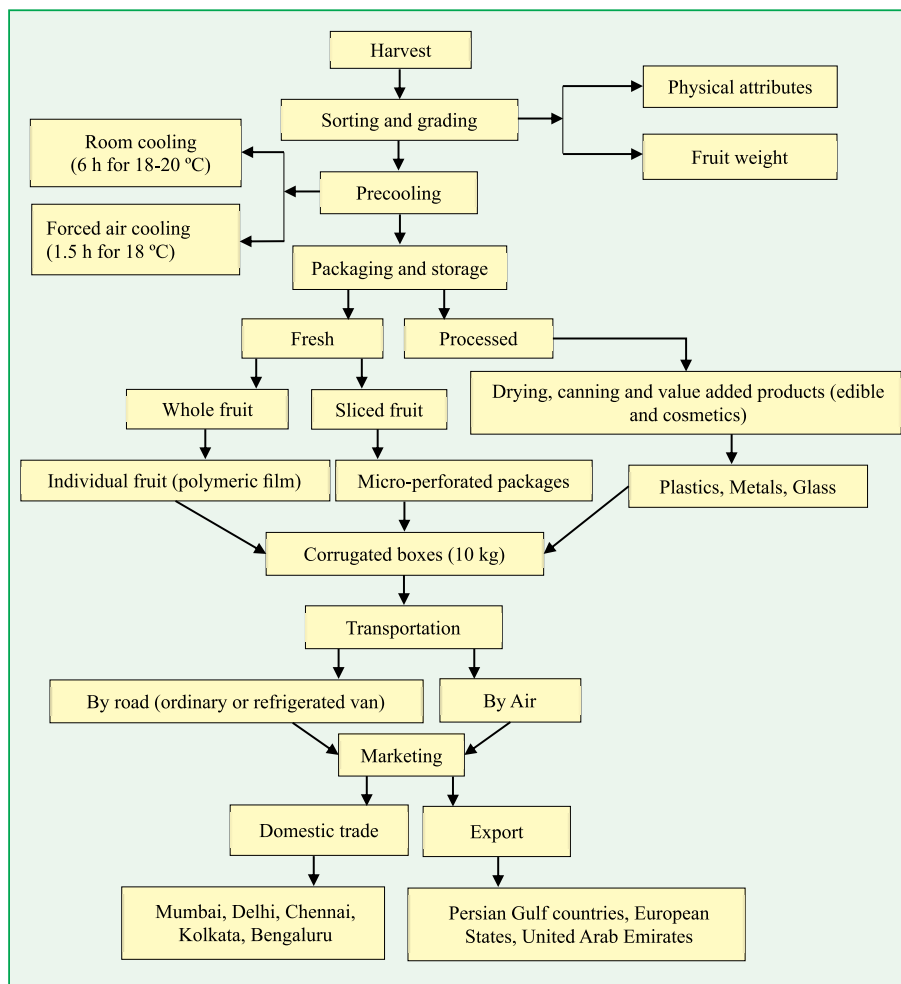
CLIMATE change-induced abiotic stresses threaten natural resources, agricultural productivity, and food security globally. To address these challenges, adopting climate-resilient technologies, especially for diversifying crops in India's degraded lands (120 million ha) is essential. Recently, dragon fruit (*Kamalam* or *Pitya* or *Pitahaya*), a fruit of exotic tropical climbing semi-epiphytic vine cacti, has gained global recognition as a super crop in such harsh ecosystems. It offers huge potential of crop diversification, particularly in neglected underutilized barren degraded lands of India. A farmer of these regions has now started large-scale commercial farming, and is expected to rise exponentially over 50,000 ha in the next three years (MoA&FW, Government of India, 2023). This led to a steep increase in production in Gujarat, Maharashtra, Karnataka, Andhra Pradesh, West Bengal, Telangana, Tamil Nadu, Odisha, Gujarat and Andaman and Nicobar Islands, as well as in many north-eastern states. The fruit comes in several varieties, each with distinct shapes, sizes, and colours, but classified into three types i.e. *Hylocereus undatus* (pink peel with white flesh), *Hylocereus polyrhizus* (pink peel with red flesh or pink flesh), and *Selenicereus megalanthus* (yellow peel with white flesh).

Being a fruit of perishable nature and short shelf life (5–7 days), minimizing postharvest losses is crucial, necessitating exploration of value-addition to continuously increase production and redirect surplus for processing.

The challenges include optimizing harvesting, processing, and postharvest management practices, along with developing regional-specific cultivation protocols, including processing-friendly varieties. This will also be useful in resolving facts related to its adaptability, consumer acceptability, and marketability. The article discusses the current status of pre- and postharvest practices for fresh dragon fruit, emphasizing the development of value-added products for longer shelf life in India. Implementing these techniques can help mitigate marketing problems during seasonal oversupply. Dragon fruit postharvest management involves two key strategies: (i) emphasizing fresh consumption and (ii) promoting offseason consumption through value-addition to extend shelf-life. A schematic flowchart depicts the major post-harvest practices for fresh dragon fruit and its processed products. The subsequent sections explain relevant information about postharvest handling in the Indian context.

Postharvest management practices for fresh dragon fruit

Fruit maturity indices and quality characteristics: Dragon fruit, a non-climacteric fruit, should be harvested at full maturity, marked by maximum sugar levels and acidity for optimal quality and flavour. It contains small black seeds (2.70–14.7%), bright red/yellow skin (36.7–37.6%), and



Major postharvest practices and marketing for dragon fruit

white/coloured flesh (47.4–73.8%). An ideal harvest index suggests total soluble solids (TSS) to titratable acidity (TA) ratio of 40. Key maturity indicators include days after anthesis (DAA) and red peel colour intensity, with colour break occurring 25–32 days from flowering. A shift from vibrant green to full red skin signals maturity. Optimal harvest maturity is at 35–38 DAA for domestic and 32–34 DAA for international markets. In India, dragon fruit is generally harvested at physiological maturity within 30–35 DAA.

Harvesting: In India, the fruiting peak extends from the second fortnight of July to September, occasionally stretching into December. Harvesting is conducted manually 8–10 times throughout the season. Fruit weight varies from 150 to 800 g, influenced by crop age, location, and management practices. The process, managed by a skilled labours team using tools like garden knives, scissors, or pruning shears, starts in the morning, with breaks of 1.5–2 hr in the afternoon. Twisting during

picking is avoided to minimize damage. Harvested fruits are collected, placed in plastic crates, and transported to collection centres; farmyards, or via mini tractor, minivan, or pick-up.

Sorting and grading: Harvested fruit are manually sorted by farm labourers to eliminate diseased, insect-infested, cracked, and damaged items. Rejected fruit are collected separately for disposal. The graded fruit undergoes a cleaning process to remove adhering dirt and enhance its appearance. Grading is typically based on weight, size, and colour to meet quality standards. In India, although there is no official classification, domestic produce is informally categorized into three grades: A (>400 g), B (200–400 g), and C (200 g) for marketing purposes. Different nations have their own standards. Globally, the FAO/WHO Codex Alimentarius Commission's Codex standard for dragon fruit (2007) is adopted, categorizing based on unit weight and physical qualities.

Packaging: Cleaned and graded fruits are packed into plastic crates, fibreboard boxes, or cartons on the same day for efficient local market delivery. Carton sizes, materials, and fruit quantity vary between domestic and international markets. In India,

dragon fruit is typically packed in 10 kg cartons, preferred for both domestic and export markets, including Gulf countries. Some farmers opt for 15–20 kg cartons, commonly used in APMC markets for various fruit crops. Packaging, usually done in the afternoon, involves stacking fruits in two to three layers, separated by a cardboard barrier. A 10 kg carton carries 18–28 fruit (350–500 g), while a 15–20 kg carton contains 40–55 fruit. For the export purpose each individual fruit is covered with polymeric film before placing into cartons.

Precooling: It can be performed either immediately after harvesting or preliminary farm level sorting and grading for removal of 'field heat'. Commercial farms often transport freshly harvested fruit promptly to precooling facilities to meet storage and export requirements. It is vital to note that precooling works best for dragon fruit



Harvesting and transport to collection centres



Grading (a) and packaging for domestic (b) and Gulf markets (c)



Pretreatments and storage of minimally processed/fresh cut dragon fruit

when the temperature stays between 5–8°C for 24 hr. Commonly used methods include room cooling, which takes about 6 hr to reduce core temperatures from 29 to 20°C and more efficient forced air cooling, which typically takes 1.5 hr to lower fruit core temperature from 26.5°C to 18°C.

Pre-treatments and storage: This operation, currently optional due to fresh consumption and market demand, becomes crucial during glut seasonal production and dragon fruit processing. The dragon fruit shelf-life diminishes within a week of harvest due to factors such as increased weight loss, faster respiration rate, accelerated ripening, and shrivelling. Further, key postharvest disorders, including splitting, mechanical injury, chilling injury, and decay, drastically reduce shelf-life and storage quality if timely care is neglected. Hence, different physical and chemical pre-treatments, viz. heating, chemicals, edible coating, and modified atmosphere (MA) are employed to extend storage period, enhance marketability, and improve profitability. Exogenous application of postharvest chemical treatments like chitosan, forchlorfenuron (CPPU), salicylic acid (SA), methyl jasmonate (MJ), 1-methylcyclopropene (1-MCP), and gum arabic has been documented to prolong shelf-life and storage quality. The advocated gas composition for MA of whole dragon fruit is 2–4% O₂ and 6–8% CO₂ at temperature ranged from 5–10°C with different packaging materials such as low density polyethylene/polypropylene/high density polyethylene (LDPE/PP/HDPE) prolonging the storage life to 21–27 days.

For cold storage, the recommended temperature for *Hylocereus undatus* and *Hylocereus polyrhizus* species is 10°C, and for yellow pitaya (*Selenicereus megalanthus*), it is 6°C, with 85–90% relative humidity (RH). Many commercial farms find storage at 10°C with 93% RH optimal for preserving quality, resulting in a longer storage life of up to 15–17 days. However, if the temperature is too low, the

fruit softens and may be damaged, while exceeding the optimal range causes the spine to turn yellow and lose freshness. Minimally processed or fresh-cut dragon fruit can be stored at 4–6°C for 10–14 days without altering qualitative attributes, using preformatted foam trays or plastic punnets wrapped in polyvinyl chloride (PVC) film.

Transportation: The fruits, packed in plastic crates, fibreboard boxes, and cartons with paper cushions, are often supplied by roads to various wholesale and retail markets for domestic consumption in nearby towns and metro cities such as Mumbai, Delhi, Chennai, Kolkata, Bengaluru, and Pune. This delivery typically takes place in the evening or the following morning to prevent excessive heat release during transport. The highest grade is usually directed to supermarkets, while the lower grade is distributed to fruit stall stands along the roadside. Refrigerated vans or ordinary tempos (small trucks) are often used to transport packaged produce to these local markets. Recently, a few progressive farmers' groups in Maharashtra, Gujarat, and Karnataka have begun exporting dragon fruit via airways to Gulf countries, European states, and the United Arab Emirates.

Processing and valorised products of dragon fruit

Different parts of the dragon fruit, including the pulp, peel, seeds, flower buds, dried flowers, and stems, provide significant nutritional benefits such as vitamins, minerals, dietary fibres, and antioxidants. The pulp, low in calories, is rich in vitamin C, phytoalbumins, calcium, phosphorus, and soluble fibres; red and pink pulp serve as colouring agents. Despite comprising almost one-third of the fruit weight, the peel is often discarded post-consumption, overlooking its potential antioxidative, antibacterial, anti-aging, and detoxification benefits. The different parts of dragon fruit can be processed into dried form, canning, and value-added products for longer shelf-life and off-season availability.

Flowers buds and young stems are used in soups, salads, and consumed as vegetables. Dehydrated flowers make an antioxidant-rich tea. Matured stems, being lignocellulosic material, have potential for animal feed, biofuel feedstocks, and fibre production. Peeled fruit slices are eaten as fresh/frozen cut, consuming seeds together. Fruit pulp is used in various products such as juice, jam, jelly, marmalade, RTS, beverages, nectar, squash, red wine, ketchup, spread, ice cream, sherbet, dried powder, and preserves. Spray-dried dragon pulp powder has economic potential due to its lower weight and volume, longer shelf-life, easier handling, storage, transport, and export. Dragon fruit powder, made from the whole fruit, can be a natural colouring agent and dietary supplement. Freeze-dried extract powder is used for smoothies, syrup, tea, and food ingredients. Oils are extracted from dragon fruit seeds, also used in various food products like syrup, ice cream, sherbet, confectionery, yogurt, and pastries. Peel extracts are used for natural food colouring, pectin, cosmetic embellishments, and more. Thus, it can be inferred that, dragon fruit and its derivatives have a wide range of applications in diverse Indian cuisine.

Considering the multi-health benefits, ICAR–National Institute of Abiotic Stress Management, Baramati (Pune),



Pulp juice



Canned pulp cubes



Pulp jam



Spray dried pulp powder



Peel candy



Peel jelly

Valorised products of pulp and peel of dragon fruit developed by ICAR-NIASM

optimized and developed processes for producing valorised products from peel/pulp, such as pulp juice, pulp jam, peel candy, and peel jelly on an experimental basis. Utilizing these value-added products of edible and non-edible part will be a revolutionary step for the long-term growth of fruit processing industries and establishing a market value chain. However, such products are rarely available in the market, necessitating more research for development and promotion to enhance trading opportunities globally. Focusing on developing small-scale processing units and mechanizing processing lines

postharvest practices and processing methodologies to transform dragon fruit into valorised products could serve as turning points for enhancing the livelihood, income, and socio-economic status of poor and marginal farmers on water-scarce degraded lands.

For further interaction, please write to:

Dr G C Wakchaure, ICAR-National Institute of Abiotic Stress Management, Baramati, Pune, Maharashtra 413 115.

*Corresponding author: goraksha.wakchaure@gmail.com

for comprehensive utilization could reduce production costs, increase profits, and improve the quality of the final product, making it more accessible to the majority of the population. In addition to adopting the aforementioned pre- and postharvest practices, processing and value-addition techniques, there is a need to establish standard cultivation protocols, postharvest infrastructure, quality standards, marketing facilities, export procedures, accreditation, and certification for profitable dragon fruit farming and entrepreneurship. This requires a strong policy framework involving collaboration between State Departments, the Central Government, and public and private funding institutions. India's strategic geographic location is highly suitable for marketing fresh dragon fruits and its processed products globally.

In conclusion, selecting and implementing appropriate

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Telefax: 011-2584 3657; E-mail: bmicar@gmail.com