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Low-Temperature Storage of Dragon Fruit: A Key to Preserving Quality and Reducing Postharvest Losses

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Keeping dragon fruit fresh after harvest is important as growing it. While low-temperature storage effectively extends shelf life and preserves quality, temperatures below the optimum level can cause chilling injury and reduce marketability. Innovative technologies, including modified atmosphere packaging, edible coatings, natural biomolecules, and smart cold-chain systems, are paving the way for sustainable postharvest management and better-quality fruits for consumers.

Introduction

Dragon fruit (*Selenicereus* spp.), popularly known as pitaya or Kamalam, is a tropical fruit belonging to the family Cactaceae. Native to Central and South America, it is now cultivated in more than 30 countries, with Vietnam leading global production and exports. In India, its cultivation has expanded rapidly due to its adaptability to diverse agro-climatic conditions, drought tolerance, attractive market value, and increasing consumer demand. Gujarat is the leading producer, followed by Karnataka, Maharashtra, Andhra Pradesh, Telangana, Tamil Nadu, West Bengal, Odisha, and the North-Eastern states (Nangare et al., 2020).

Dragon fruit is widely recognised as an "exotic fruit" and a "superfruit" because of its attractive appearance, rich nutritional composition, and health-promoting properties. It is an excellent source of dietary fibre, vitamin C, minerals, and natural antioxidants such as phenolic compounds, flavonoids, and betalains, which contribute to improved health and protection against oxidative stress.

Despite its high nutritional and economic importance, dragon fruit is highly perishable after harvest. Physiological and biochemical changes during storage cause moisture loss, shrivelling, softening, peel discolouration, and microbial spoilage, leading to reduced quality, shorter shelf life, and significant postharvest losses.

Low-temperature storage is the most effective method for extending the shelf life of dragon fruit by reducing respiration, transpiration, senescence, and microbial growth while maintaining nutritional and sensory quality. However, storage below the optimum temperature can induce chilling injury, characterised by peel browning, pitting, membrane damage, and increased susceptibility to decay. Therefore, maintaining the optimum storage temperature is essential for preserving fruit quality, reducing postharvest losses, and ensuring better marketability.

Nutritional and Commercial Importance of Dragon Fruit

The growing popularity of dragon fruit is driven by its attractive appearance, excellent nutritional value, health benefits, and increasing commercial importance. It is rich in dietary fibre, vitamin C, essential minerals, and natural antioxidants such as phenolic compounds, flavonoids, and betalains. These bioactive compounds help protect against oxidative stress,

support immunity, improve digestion, and reduce the risk of several chronic diseases, making dragon fruit a preferred choice among health-conscious consumers.

The increasing demand for dragon fruit has enhanced its economic value. In India, cultivation is expanding rapidly due to its premium market price, adaptability to diverse climatic conditions, and government support for high-value horticultural crops. This has created better income opportunities for farmers and strengthened the fruit's potential in both domestic and export markets.

In addition to fresh consumption, dragon fruit is processed into juices, jams, jellies, beverages, yoghurt, ice cream, fruit powders, bakery products, and natural food colourants. However, fresh fruits command the highest market value because consumers prefer their attractive appearance, pleasant flavour, and superior nutritional quality.

As consumer demand continues to increase, maintaining fruit quality after harvest has become essential. Appropriate postharvest technologies, particularly low-temperature storage, help preserve freshness, extend shelf life, minimise postharvest losses, and maintain the market value of dragon fruit throughout storage, transportation, and marketing.

Low-Temperature Storage: The Science Behind Freshness

As the demand for fresh dragon fruit continues to grow, preserving its quality after harvest has become essential. Being highly perishable, dragon fruit undergoes continuous physiological and biochemical changes after harvest, leading to moisture loss, softening, shrivelling, and spoilage. Therefore, effective postharvest management is necessary to minimise losses and maintain fruit quality. Among the available technologies, low-temperature (cold) storage is the most effective method for extending shelf life and preserving freshness.

Figure 1. Cold storage of dragon fruits at optimum low temperatures

Slowing Natural Metabolism

Even after harvest, dragon fruit remains a living tissue that continues to respire and lose moisture. Cold storage slows these metabolic activities, reducing the rate of ageing and delaying senescence. As a result, the fruit retains its firmness, freshness, and overall quality for a longer period.

Reducing Moisture Loss and Decay

Low temperatures combined with 90–95% relative humidity minimise water loss, reducing shrivelling and physiological weight loss while maintaining the fruit's attractive appearance. Cold storage also suppresses the growth of fungi and bacteria, thereby reducing postharvest decay and extending storage life.

Preserving Nutritional and Sensory Quality

Refrigerated storage slows the enzymatic reactions responsible for softening, pigment degradation, and nutrient loss. Consequently, important quality attributes such as peel colour, firmness, flavour, vitamin C, betalains, phenolic compounds, antioxidant activity, and overall sensory quality are better preserved during storage.

Optimum Storage Conditions

Dragon fruit is a non-climacteric fruit, meaning it does not continue to ripen after harvest. Therefore, cold storage aims to preserve the fruit rather than promote ripening. Studies have shown that storage at 5–10°C with 90–95% relative humidity can maintain fruit quality and extend shelf life to 15–20 days. However, temperatures below the optimum range may cause chilling injury, resulting in peel browning, pitting, membrane damage, and reduced marketability (Lata et al., 2024).

Importance of the Cold Chain

The benefits of cold storage are achieved only when an uninterrupted cold chain is maintained from harvest to consumption. Pre-cooling, refrigerated storage, temperature-controlled transportation, and proper retail handling help maintain fruit quality. Any break in the cold chain accelerates respiration, moisture loss, microbial growth, and quality deterioration. Low-temperature storage is the backbone of postharvest management in dragon fruit. By slowing physiological and biochemical changes, preserving nutritional and sensory quality, and reducing postharvest losses, it enhances shelf life, improves profitability for growers, and ensures that consumers receive fresh, high-quality fruits (Jadhav, 2018).

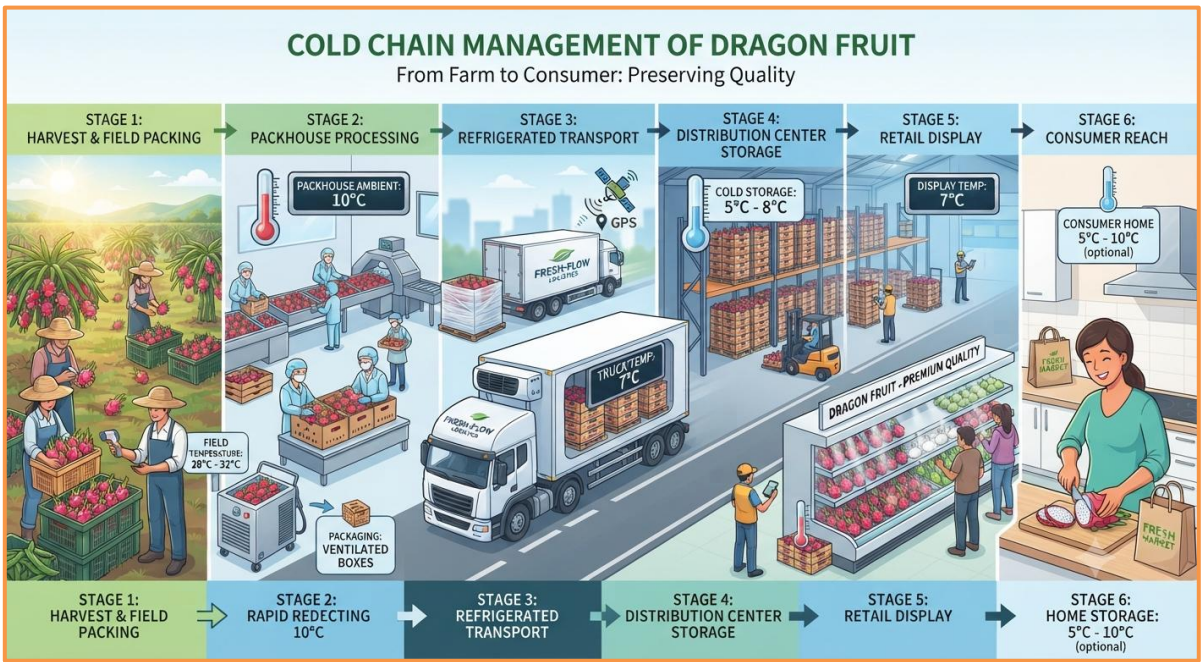

Figure 2. Cold chain management of dragon fruit in its supply chain

How Cold Storage Preserves Fruit Quality?

Low-temperature storage not only extends the shelf life of dragon fruit but also preserves its appearance, nutritional value, flavour, and marketability. By slowing physiological and biochemical changes, cold storage helps maintain the quality attributes preferred by consumers.

Reduces Weight Loss and Maintains Firmness

Cold storage reduces moisture loss through transpiration, preventing shrivelling and excessive weight loss. It also slows the breakdown of cell walls, helping the fruit retain its firmness and withstand handling and transportation more effectively.

Preserves Colour and Flavour

Appropriate storage conditions help maintain the bright peel and pulp colour by protecting betalain pigments, which are responsible for the attractive red colour and antioxidant properties of dragon fruit. Refrigeration also slows changes in total soluble solids (TSS) and titratable acidity, preserving the fruit's natural sweetness, acidity, and flavour.

Protects Nutritional Quality

Low temperatures reduce the degradation of important nutrients such as vitamin C, phenolic compounds, flavonoids, and betalains. As a result, the fruit retains higher antioxidant activity, better nutritional value, and greater resistance to oxidative stress during storage.

Improves Shelf Life and Marketability

By maintaining physical, nutritional, and sensory quality, cold storage reduces spoilage and extends the shelf life of dragon fruit. Fruits remain fresh, attractive, and suitable for transportation and marketing, providing higher returns to growers and better-quality produce to consumers.

Consumer Preference

Consumers prefer dragon fruits with bright colour, firm texture, pleasant flavour, and high nutritional value. Maintaining optimum storage conditions helps preserve these desirable qualities, ensuring fresh, premium-quality fruits reach the market**.**

Chilling Injury: The Hidden Challenge of Cold Storage

Low-temperature storage effectively extends the shelf life of dragon fruit, but storing the fruit below its optimum temperature can cause chilling injury, a physiological disorder common in tropical and subtropical fruits. Unlike microbial spoilage, chilling injury results from prolonged exposure to temperatures below the fruit's tolerance level, leading to irreversible quality deterioration.

Symptoms of Chilling Injury

Dragon fruit is sensitive to temperatures below 5°C. Early symptoms include peel browning, surface pitting, and water-soaked lesions, followed by membrane damage, electrolyte leakage, and increased accumulation of malondialdehyde (MDA), an indicator of oxidative stress. These changes reduce firmness, shorten shelf life, increase susceptibility to decay, and lower consumer acceptance (Nguyen et al., 2014).

Figure 3. Symptoms of Chilling Injury on dragon fruit surface

Economic Impact

Chilling injury reduces the market value of dragon fruit because damaged fruits are often rejected by consumers, retailers, and exporters. As a result, growers and traders experience significant postharvest and economic losses.

Preventing Chilling Injury

The most effective way to minimise chilling injury is to store dragon fruit at the optimum temperature of 5–10°C with 90–95% relative humidity. Maintaining an uninterrupted cold chain during storage, transportation, and marketing is equally important, as temperature fluctuations increase chilling stress and accelerate quality deterioration.

Emerging Eco-Friendly Solutions

Several postharvest technologies help improve tolerance to chilling stress. Modified atmosphere packaging (MAP) and edible coatings reduce moisture loss and delay quality deterioration. In recent years, natural biomolecules such as dopamine, melatonin, salicylic acid, γ-aminobutyric acid (GABA), nitric oxide donors, polyamines, hydrogen sulfide, and kojic acid have shown promising potential. These compounds enhance antioxidant defence systems, maintain membrane integrity, reduce oxidative damage, and improve resistance to chilling injury, offering sustainable alternatives for preserving the postharvest quality of dragon fruit.

Careful harvesting, proper packaging, gentle handling, and optimum storage conditions, together with these innovative technologies, provide an effective strategy for minimising chilling injury and delivering high-quality dragon fruits to consumers.

Future Technologies in Postharvest Management

Future postharvest management of dragon fruit is focused on smart, sustainable, and eco-friendly technologies to reduce losses and maintain fruit quality.

Smart Storage and AI

Smart cold storage systems equipped with IoT sensors and Artificial Intelligence (AI) can continuously monitor storage conditions, optimise temperature and humidity, predict shelf life, and improve storage efficiency.

Innovative Preservation Technologies

Technologies such as modified atmosphere packaging (MAP), edible coatings, and nanotechnology-based packaging help reduce moisture loss, delay spoilage, and maintain fruit quality during storage and transportation.

Sustainable Future

Natural biomolecules such as melatonin, dopamine, GABA, salicylic acid, and kojic acid are emerging as eco-friendly treatments to reduce chilling injury and preserve postharvest quality. Combined with energy-efficient cold-chain systems and continued research, these technologies will help minimise postharvest losses and ensure fresh, high-quality dragon fruits reach consumers.

Conclusion

Dragon fruit is an important high-value crop with excellent nutritional, health, and economic benefits. However, its perishable nature makes effective postharvest management essential to maintain quality and reduce losses. Low-temperature storage, along with proper humidity management and an efficient cold chain, plays a vital role in preserving freshness, extending shelf life, and maintaining the nutritional and sensory quality of dragon fruit. Future advancements in smart storage systems, innovative packaging, and eco-friendly technologies will further strengthen postharvest management. These approaches will help reduce losses, improve farmer profitability, and ensure the availability of fresh, high-quality dragon fruits to consumers.

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