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Advances in Packaging of Litchi Fruit to Maintain the Quality

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Authors' contributions

This work was carried out in collaboration among all authors. Author SKP developed the concept and wrote the first draft of the manuscript. Author AP collected relevant literature, developed table and figures and assisted in manuscript preparation. Author ESM assisted in manuscript preparation and performed critical proof-reading and author NL assisted in the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Litchi is distinctly a delicate, delicious summer delight, juicy, flavoured and attractive bright red colour fruit having good source of minerals and vitamins. India and China account for about 91 percent of the world's litchi production but it is mainly marketed locally. Despite its wide popularity and demand in domestic and international market, transporting the fruit to distant markets has remained a challenge due to its highly perishable nature. Postharvest interventions therefore become indispensable to preserve litchi fruit quality for longer duration. One among such interventions is packaging that directly influences transpiration losses and respiratory metabolism in litchi fruit. Packaging plays the all important roles of containment, protection, convenience, and communication. Previously, gunny bags, bamboo basket, wooden boxes were used for packaging, but are now being rapidly replaced by corrugated fibre board (CFB) boxes for the versatility they bring. Modified atmosphere packaging (MAP) of litchi in combination with postharvest treatments

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offers promising solutions to preserve litchi fruit quality. Intelligent packaging through use of sensors, wireless sensor networks, radio-frequency identification device (RFID) etc show the way ahead for future packaging solutions. Nonetheless, innovation in litchi packaging will require careful considerations of all factors that lead to quick fruit deterioration and generation of waste.

Keywords: Litchi chinensis; packaging; postharvest; MAP; fruit quality.

1. INTRODUCTION

Litchi is brightly coloured strawberry shaped fruits having thin leathery skin and sweet musky aroma. It is a rich source of vitamins and minerals as well as a powerful antioxidant. Litchis contain Vitamin K, Vitamin B6, and more Vitamin C (more than citrus fruit), Niacin, Riboflavin, Thiamin and Folate. Minerals abundant in the Litchi fruits include Magnesium, Iron, Calcium, Copper, Phosphorous and Potassium. They are also purported to have some anti-inflammatory properties, aid in gastrointestinal health, and have as much fiber as an apple [1]. Litchi is now grown commercially in many countries and production in India, Australia, China, Israel, South Africa and Thailand has expanded markedly in recent years. Increased production has made significant contributions to economic development in these countries, especially those in South-East Asia. India is the second largest producer of litchi in the world after China with an area and production of 92.34 thousand ha and 686450 tonnes, respectively during 2017-18 [2]. In India, Bihar, West Bengal, Jharkhand and Assam accounts for more than 60% of the total litchi production in the country. Postharvest losses in fresh fruits and vegetables remain unacceptably high despite globally recognised solutions for reducing food loss along the supply chain. Studies commissioned by the Food and Agricultural Organisation of the United Nations estimates that about 45% of fresh fruits and vegetables constitute food loss in the postharvest chain [3]. The reasons for these huge losses are manifold including lack of awareness about postharvest handling of fruits and vegetables, use of traditional packaging, abusive use of packages by labour, poor infrastructure for storage of horticulture produce, and absence of cold chain for perishable produce among others [4].

Freshness or harvest quality maintenance of litchi has been one of the biggest challenges in the litchi supply chain [5]. Consumers want produce to be fresh, typified by the quality at harvest. However, fresh handling and marketing of litchi is severely impaired by pericarp browning, a phenomenon whereby detached fruit rapidly turns from red to dark brown. A steady process of moisture loss from fruit is the most important reason for pericarp browning, and important factors that aggravate pericarp browning include high temperature, low humidity, atmospheric composition, surface air movement etc [6]. In addition, internal fruit physiological conditions such as very high respiratory metabolism and high susceptibility to water/ transpiration loss also predispose the fruit to quick deterioration. Moisture loss from fruits is facilitated by poor skin resistance to water vapour movement, air current, warm temperature, low RH and temperature gradient between the air and fruits. Browning can occur when as little as 2% of the pericarp moisture is lost after harvest [7]. Micro-cracking also causes pericarp browning. Micro-cracking of the pericarp occurs at the initial stage of fruit development due to the rapid expansion of the aril [8]. According to Joubert and Monelise [9], the expanding aril exerts an increased stress or turgor pressure against the pre-grown pericarp. Drought is another significant contributor to pericarp cracking during fruit development, which leads to the loss of pericarp extensibility [10]. In addition, micro cracking can be induced by handling or packaging line operations [11]. Therefore, maintaining attractive red colour of pericarp along with freedom from decay and insect pest become the primary objective of every stakeholder in the litchi supply chain.

2. PACKAGING

Packaging is one of the most important steps in the complicated journey of fruits and vegetables from growers to consumers. The Packaging Institute International defines packaging as the enclosure of products, items or packages in a wrapped pouch, bag, box, cup, tray, can, tube, bottle, or other container form to perform one or more of the following functions: Containment, protection, preservation, communication, utility and performance. Therefore, packaging not only contains and protects during handling, storage, transportation, and distribution, but also serves as a symbol of value-addition and assurance of quality [12].

Several types of package are commonly used in the fresh produce industry, and include packages fabricated from paper and paper products (compressed cardboard, corrugated cardboard or fibreboard), wood and wood products, and plastics. Wooden crates and boxes have been the traditional mode of packaging. Currently, plastic crates and fibreboard boxes are commonly used by growers and traders. However, due to the cost involved, plastic crates are used for distribution in the local market. For transportation to distant markets cheaper disposable packages are preferred. Polymers or plastics exhibit many desirable features like transparency, softness, heat-seal ability, and good strength to weight ratio with high tear and tensile strength. Efficient mechanical properties, good barrier to oxygen, and low cost make up the reasons for the extensive use of polymers for packaging. The introduction of corrugated boxes has revolutionized the packaging industry, improved returns to the producers, and opened up export markets. The choice of each type depends on the utility, capacity to enhance value to produce, and cost factor.

2.1 Functions of Packaging

According to the Codex Alimentarius Commission packaging is done to preserve quality and freshness, add appeal to consumers and to facilitate storage and distribution. The fundamental essence in ideal packing should envisage communication, legal information (viz. Weight, size, contents, use etc), bar coding, appeal, reliability, consistent quality in time delivery and value for money. The functions of packaging are well defined and inter-related: Containment, protection, convenience, and communication [13].

2.1.1 Containment

The most basic function of packaging is that of containment which allows for convenience in handling and storage, reduces losses and makes large-scale transportation and marketing possible. Containment also plays the important role of containing the right amount/size of produce or product that can lead to healthy eating habit.

2.1.2 Protection

Packaging keeps food products in a limited volume, prevents it to leak or break-up, and protects it against possible contaminations and changes [14]. Packaging protects the contents from physical or mechanical injuries, cuts, tears, bruises, etc. Packaging acts as a barrier between the contents and the environment. It protects the contents from outside environmental effects like micro-organisms, gases, odours, temperature abuse, dust, vibrations, compressions, and shocks. Interestingly, packaging also protects the outside environment from the contents.

2.1.3 Convenience

Packaging leads to convenience in storage, transportation, and distribution of horticultural produce. Food packaging allows for consumers to enjoy food they want, at their convenience. This holds greater meaning in the present era of increasing inter-dependence among nations for food and services. Over the years, modernization and industrialization have resulted in ever-increasing single-person-households and percentage of women in the workforce. This has resulted in drastic lifestyle changes with increasing demand for convenience food which include pre-prepared foods, fresh-cut, and minimally processed fruits and vegetables.

2.1.4 Communication

Food packaging communicates important information about contained product and its nutritional content, together with guidelines about preparation. Packaging improves sales, and makes advertising and large-scale distribution possible. Packaging can act as a symbol of value addition and quality assurance. It communicates the quality of the content and the satisfaction a product offers. Packages communicate to the consumers about the nutritional value of contents and how best they can be made use of. Nutritional information on packages can help consumers make informed, healthful choices, thereby improving sales [15].

2.2 Packaging Requirements for Litchi

Litchi is a non climacteric fruit therefore; it is harvested at full ripening to obtain quality fruit of specific variety. Maturity Standards based on physico-chemical parameters (flattening of skin protuberanes, change of colour, TSS: acid ratio of pulp, etc) and heat unit submission (<1400 hrs for early, 1400-1600 hrs for mid season and > 1600 hrs for late cultivars) have also been delimited. However, the prevailing marketing trend governs the time of harvest as early crop fetches better price [16]. Packaging, in general,

plays an important role in protecting the fresh produce and delaying the process of deterioration. Packaging makes this possible by creating conditions that reduce internal fruit metabolism. Efforts to develop packaging regime for litchi must therefore ensure reduction in quick loss of moisture and respiratory metabolism. World-over litchi fruit is either packed as individual fruits (detached from pedicel) or as whole fruit bunches. Packing detached fruits into bags or boxes, or bamboo baskets are more common and popular in Asian countries, while in India litchi is packed as whole bunches. For long distance transportation litchis are packed in wooden boxes lined with craft paper or fibre board cartons or polystyrene boxes lined with polyethylene bags. Some of the packaging systems popularly used in India for preserving harvested litchi fruit are discussed with merit and demerit are as follows:

2.2.1 Natural materials for packaging

In many developing markets, baskets and containers made of natural materials such as bamboo, straw, palm leaves; gunny bags etc. constitute commonly used packages. Natural fibres such as jute, sisal, coconut coir, etc, are also used to prepare sacks or bags, either woven to a closed texture or as nets. Natural materials are normally low in cost - both raw material and labour involved, and also offer the advantage of re-usability. However, natural materials lack rigidity and bend out of shape when stacked for long distances. Besides, they don`t come in uniform shape and pose difficulty in loading, and often have sharp edges which usually cause cuts and puncture damages. They also cause pressure damage when tightly filled and leads to huge postharvest losses. [17] Bryant also observed that injury due to impact caused darkening of the protuberance tip, cracking of the pericarp and skin colour deterioration. Such type of packaging may be suitable for local markets or carrying up to pack house.

2.2.2 Wooden box packaging

Wooden containers of 18-22 kg capacity are still being commonly used in the form of reusable boxes or crates in major part of India. They not only offer the benefits of strength and reusability, wooden boxes when made to a standard size stack well on trucks or storage rooms. Wooden boxes are now gradually being replaced by less expensive alternatives. The disadvantages of wooden containers are:

- They are not environment friendly as their usage leads to felling of trees.
- Obtaining uniformity of weight is a problem
- They are heavy and costly to transport
- They may cause compression and vibration injuries if contents are over- or under-packed.
- They often have sharp edges, splinters, and nails etc, which can easily cause damage to contents. These leads to the excess moisture loss from the litchi fruits. Litchi moisture loss has been shown to result in increased conductivity of pericarp tissues and loss of membrane integrity [18].

Despite these, wooden boxes are still popularly used to pack litchi by growers and distributers due to the physical strength they offer. But for export and air transportation such packaging is not economical and practical.

2.2.3 Plastic crates

Plastic crates are usually made of high density polyethylene(HDPE) or PP by injection molding. Polyethylene has higher impact strength and a low degradation by ultra-violet radiation while polypropylene has a better scratch resistance. The performance of both materials can be improved by adding antioxidants and UV protectants (for sunlight protection). The advantages of plastic crates are:

- As these crates are strong and rigid they can be used for many journeys, making the cost per journey relatively low
- Different sizes and shapes are available
- They can be easily cleaned and disinfected
- They are strong and weather resistant and because of this they can be used in humid areas

These crates are either of stackable, stack-nest or collapsible in design. Collapsible plastic crates are the most expensive crates followed by stack-nest and then the stacking crates. The collapsible crates reduce the storage space requirement and transport cost of empty containers. The normal capacity varies between 20 – 40 kgs. The use of plastic crates for distant market transportation has increased less mechanical damage to fruits during transportation and handling.

2.2.4 Cardboard (fibreboard) packaging

Nowadays, the use of cardboard boxes has increased which is made from solid or corrugated

fibreboard. Containers closing with either fold-over or telescopic (i.e. separate) tops are called boxes or cases, while shallower and open topped ones are called trays. Corrugated fibre board CFB) boxes are supplied in collapsed form and are usually set up by the user. Cardboard boxes are available in a wide range of sizes, designs, and strength. It is light and clean, and can readily and easily be printed upon with nutritional information, weight, amount, etc. Because of its relatively low cost and versatility CFB boxes remain the dominant package container for litchi. It has been found in one study at ICAR-National Research Centre on Litchi (NRC on Litchi), Muzaffarpur that CFB boxes were very effective in significantly reducing mechanical and pathological losses, whereas browning and fresh weight loss (FWL) was reduced by about 50%. Compression causes tip darkening; severe loads in particular cause puncture, shape distortion and skin cracking of fruits [19]. Most CFB boxes are made of three or more layers of paperboard manufactured by the Kraft process. They are nowadays laminated to protect from exposure to moisture but still easily damaged by careless handling and stacking. CFB boxes inside individual non-woven polypropylene bags created a modified atmospheric condition that reduced the respiration rate as well as provided a barrier to water loss. Litchi fruits stored with or without stalks in CFB boxes, cushioned with green cassia (*Cassia al et al*.) leaves recorded the best postharvest quality throughout the storage [20]. Fruits in the CFB packaging also produced lesser ethylene than those in conventional wooden box packaging [19]. Litchi fruit cv. Shahi harvested early in the morning (up to 6.00 AM) and kept in perforated polymer bags and packed in CFB box (2 Kg) recorded least physiological loss in weight (6.8%), browning index, respiration rate (116.2 mL CO_2 $kg^{-1}h^{-1}$) and maximum anthocyanin content 28.36 mg $100g^{-1}$ peel) as well as marketable fruits (74%) after 5 days of storage at ambient condition [21]. Some popular CFB boxes of different capacities being promoted by ICAR-National Research Centre on Litchi, Muzaffarpur, Bihar are given below:

2.2.5 Thermocol packaging

Thermocol packaging is another packaging technology developed and popularised by ICAR-National Research Centre on Litchi, Muzaffarpur, Bihar. Thermocol boxes are utilized for insulation of content from temperature abuse on the outside. The temperature inside the box is also brought down by introduction of ice-packs and such lower temperature can be maintained over extended period of time due to the

Table 1. Capacity and dimension for litchi packaging

Capacity	Dimension (L x B x H)	No. of ply	Picture
Consumer pack (2 kg)	26 cm x 18 cm x 13 cm	3	
2 kg pack for reefer van	30 cm x 20 cm x 10 cm	5	
4 kg Consumer pack	40 cm x 18 cm x 20 cm	5	
Pack for cool chain transport (6 Kg)	40 cm x 30 cm x 15 cm	5	

Fig. 1. Thermocol packaging

temperature insulation provided by thermocol covering. Although this technique is comparatively costlier than other packaging material, it offers feasibility for transport of litchi fruits to distant markets. Packaging of litchi in foam plastic box with ice inside is commercially used in China on large scale which can maintain freshness of litchi by 7-10 days under ambient conditions [22].

2.2.6 Poly bag packaging

Different types of flexible plastic films like LDPE (Low Density Polyethylene), PVC (Poly Vinyl Chloride), PP (Polypropylene) and cellulose acetate films are used for packaging of horticultural produce. These films are mostly used as pouches with holes punched at regular intervals to allow respiration. They are available in a wide range of thicknesses and grades and can be engineered to control the environmental gases inside the pouch. LDPE is the most widely used material. Plastic bags reduce moisture loss from stored fruit over a broad temperature range. In Asian countries such as China and Thailand, litchis are usually packed into polyethylene bag (0.02-0.05 mm thick) and placed in polystyrene boxes while ice is placed on top of the sealed bag [16]. The influence of various packaging materials on litchi (*Litchi chinensis* Sonn.) fruits stored under cold conditions revealed that packaging materials coupled with cold conditions increased the shelf life of litchi to 16 days. Polyethylene and polyvinylchloride were found to be most efficient. Wrapping fruits with polyethylene reduced spoilage (12.76%), while unpacked fruits experienced maximum spoilage (25.99%). Physiological weight loss was also reduced to minimum (3.10%) in fruits packed in polyvinyl chloride as compared to the control (8.98%) [23].

2.2.7 Punnet box packaging

Present day punnets are generally made in a variety of dimensions of semi-rigid, transparent, light weight Polyethylene terphthalate (PET) with lockable lids, or of clamshell design, and with vents. The packets of 500-700 g are used by organised retailers to sale in super market under controlled atmospheric conditions. These packaging permits visual examination by consumers and discouraging physical contact with the merchandise at point of sale [24]. The packing of litchi fruits in ventilated punnet boxes and overlapping with semi permeable or Poly vinyl chloride (PVC) films/ bags create a modified atmospheric condition leading reduced respiration rate of fruits besides providing a barrier to water loss. This practice has been found to enhance the shelf life of litchi fruits by 5-7 days at ambient condition (35-38^{o}C) and by 15 to 18 days at low temperature (5-7^{o}C) at ICAR-NRC on Litchi, Muzaffarpur, Bihar [25].

2.2.8 Modified atmosphere packaging

Modified atmosphere packaging may be described as the use of an atmosphere composition surrounding the product which is different from that of normal air, usually consisting of reduced oxygen and increased carbon dioxide concentrations combined with a low temperature, maximizes the product shelf-life. Storing fruits in plastic films creates modified

atmospheric conditions around the produce inside the package allowing lower degree of control of gases and can interplay with physiological processes of commodity resulting in reduced rate of respiration, transpiration and other metabolic processes of fruits [26]. The modified atmosphere conditions within the film packages can significantly reduce the rates of ripening and senescence primarily by reducing the synthesis and perception of ethylene [27,28].

The effects of different treatments, including controlled atmosphere, high relative humidity, anti-browning agents, low temperature and surface coating on the quality of litchi fruit during storage, were evaluated in several studies [29,30,31]. Low storage temperature and modified atmosphere packaging (MAP) are common postharvest technology used to extend the shelf life of many whole and fresh-cut fruit, as they reduce the respiration rate, surface damage and browning [32]. In litchi fruit this technology reduced pericarp browning [33], controlled postharvest diseases and maintained a high humid environment for the retention of fruit at low temperatures [34]. Modified atmosphere packaging, like in several horticultural crops, has been beneficially exploited to extend shelf life and maintain freshness and quality of litchi fruit (Table 2).

Active packaging is a new concept that has arisen as a response to continuous consumer demand and market trend. This technique concerns with the substances that adsorb/absorb CO_2, O_2, flavour/ odours, moisture, ethylene and those microbes that release CO_2, antimicrobial agents and antioxidants [35]. The O_2, CO_2, ethylene scavengers and microbial agents are placed inside the packaging system, so as to effectively improve the packaging environment. Plasticized protein coating on polypropylene films works as antimicrobial agent when incorporated with nisin and whey protein isolate, the films with bacteriocins absorber can be used as an active packaging film [36,37].

2.2.9 Intelligent packaging and smart packaging

Intelligent packaging is a system that provides reliable and correct information regarding the condition of the contained food product, the environment, or the integrity of packaging. Intelligent packaging contains a component that enables the monitoring of the condition of packaged food or the environment surrounding the food during storage and transport. Thus, intelligent packaging is an extension of the communication function of packaging, and communicates to the user useful information based on ability to sense, record, or detect changes (desirable and/or undesirable) in the product or environment. These facilitate decision making to extend shelf-life, enhance safety, improve quality, provide information and warn about possible problems [38].

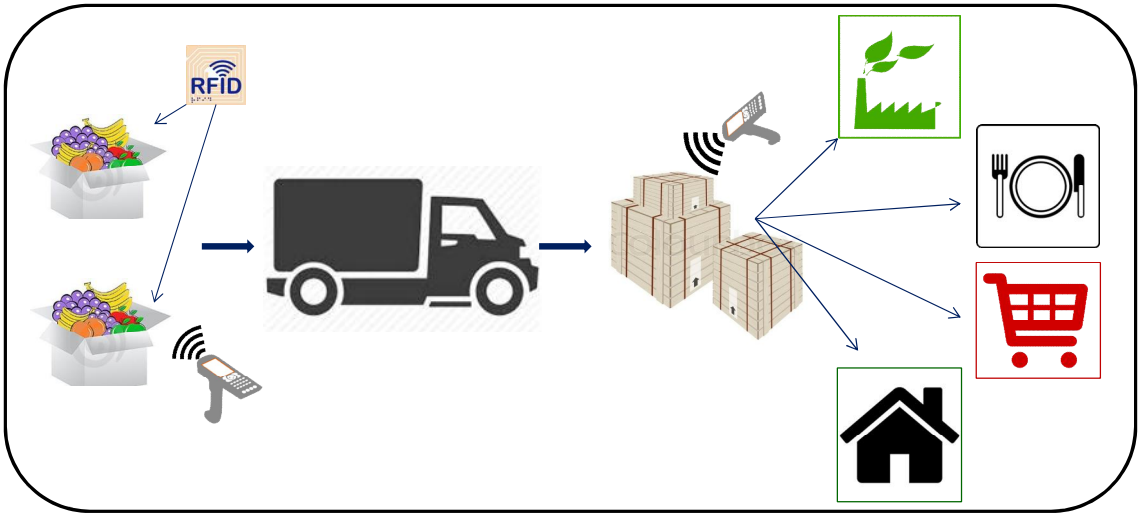

Fig. 2. Schematic representation of intelligent packaging through integration of RFID and sensors (adapted from [4])

Table 2. Atmosphere modification for control of pericarp browning and quality retention in litchi

Atmosphere modification						Effect on browning
CA/MA/MAP	**Cultivar (s)**	**O_2 (%)**	**CO_2 (%)**	**Combination treatment (s)**	**Storage condition**	
BOPP, PVC	Shahi	5	5	EDTA treatment	10, 15, 20°C	Weight loss & Browning ↓ Retention of good colour
PF	Mauritius	-	-	-	13°C	Weight loss ↓; Anthocyanins ↔
BOPP	Mauritius & McLean`s Red	~17-18	~4-5	1-MCP	2°C	PPO, POD & Browning ↓ ; Colour ↔ Better effect in McLean`s Red
BOPP	McLean`s Red	16	6	Anti-microbial agents	3°C	Browning & PPO ↓
BOPP	McLean`s Red	-	-	Hot water dip	2°C	Water loss ↓, colour↔
BOPP	Mauritius	17	6	-	2°C	Weight loss ↓; colour ↔
CA	Heiye	5	5	-	3°C	Anthocyanin decomposition ↓ Browning and decay ↓
PE	Hong Huay	-	-	-	5°C	Bright colour ↔
CA	Huaizhi	3-5	3-5	0.1% TBZ	1°C, 90%RH	Weight loss & disease incidence ↓ Bright colour ↔; Ascorbic acid ↑
CA	Mauritius	4	7.5	Hydrocooling	5°C, 90-95% RH	Pericarp colour and firmness ↔ Decay↓
PE	Hong Huay	-	-	Hydro-cooling	5°C	Weight loss & pericarp browning ↓

↓: Decrease; ↑: Increase; ↔: Stabilize; CA: Controlled Atmosphere; MA: Modified Atmosphere; MAP: Modified Atmosphere Packaging; POD: Peroxidase, PPO: Polyphenol Oxidase; BOPP: Bioriented Polypropylene; PE: Polyethylene; PF: Propa Fresh™ PFAM; PVC: Polyvinyl Chloride; EDTA: Ethylenediaminetetraacetic Acid

3. CONCLUSION

Litchi is very delicate and perishable in nature. Pericarp browning, a physiological disorder, is major limitation in storage and marketing. Harvesting at proper stage of maturity and very careful handling is very essential operation. The package must be capable of protecting the product from the transport hazards; preventing the microbial and insect damage; minimising the physiological and biochemical changes and losses in weight. Considering the long-term needs of eco-systems and to achieve an overall economy, other alternatives available like corrugated fibre board boxes, corrugated polypropylene board boxes, plastic trays / crates / wooden sacks, moulded pulp trays/thermoformed plastic trays and stretched film and shrink wrapping would have to be looked into.

4. FUTURE DIRECTIVES

Quick deterioration of litchi fruit after harvest is a multi-factor phenomenon involving genetic influence, growing conditions, water loss and desiccation, enzyme activity, fruit senescence, fungal infection, and heat injury. Packaging technologies including MAP, CAP, and active packaging need to be adopted for quality preservation and extension of shelf life of litchi fruit. Many novel techniques and systems have become available for real-time measurement of produce within the package and its environment. Non-destructive techniques and technologies that allows for sensing and communication quality parameters without having to open the package are promising. Therefore, innovation in packaging solutions must take into consideration the combination of treatments that prevent or reduce moisture loss and desiccation, reduce oxidative damage and activity of oxidative enzymes, delay fruit metabolism and senescence, and control decay pathogens. The marketing condition and market distance should also be taken in to consideration while designing/ developing packets.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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