Commercial postharvest handling and storage technology of litchi fruit

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Abstract: Litchi is a famous subtropical fruit species in southern China. Since litchi fruit mature in hot season, the fruit deteriorate rapidly after harvest due to pericarp browning (i.e. loss of red color) and fruit decay, the postharvest life of fruit at ambient temperature is less than 3 days. This short postharvest period limits its long-distance transportation, marketing and consumption. Therefore, postharvest research becomes a key problem in the development of litchi production. This paper comprehensively introduces the causes of decay and losses of litchi fruit (i.e. the structural characteristics of fruit, the physiological and pathological causes), techniques of commercial postharvest handling and storage of litchi fruit, including differing storage characteristics of cultivars, harvest maturity and harvesting method, sorting and grading, fungicides dipping, treatments to reduce water loss, treatments to reduce pericarp browning and maintain red color of litchi fruit such as SO_2 fumigation, acid dipping or plastic packaging, quarantine treatment such as insect disinfestations, precooling, packaging, fruit storage under ambient temperature, cold storage, controlled or modified atmosphere storage, transportation and marketing.

Key words: litchi; harvesting; postharvest handling; storage; pericarp browning; fruit decay; transportation

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1 Introduction

Litchi (*Litchi chinensis Sonn.*) is an evergreen tree of the Sapindaceae family that is indigenous to the subtropics of southern China[1]. Litchi is grown commercially in many countries, including China, India, Thailand, Pakistan, Madagascar, Mauritius, Australia, South Africa and Israel which account for most of the fruit production[1,2]. China is the largest country of litchi production, and has developed rapidly in the past decade. In 1999, the planting areas of litchi in China were estimated to be 530 000 hectares with a total production of 1 260 000 tons[3,4]. Since litchi fruit mature in hot season, the fruit deteriorate rapidly after harvest due to pericarp browning (*i.e.* loss of red color) and fruit decay, the postharvest life of fruit at ambient temperature is less than 3 days. This short postharvest period limits its long-distance transportation, marketing and consumption. Therefore, postharvest research becomes a key problem in the development of litchi production[1~4]. For extending the shelf life of litchi fruit, finding a way to store it for a longer period without losing its fresh favor, preventing the browning of the red pericarp and thereby reducing the spoilage, this paper comprehensively introduces the causes of decay and losses of fruit, techniques of postharvest handling and storage, which were based on the international research results on postharvest handling and storage of litchi fruit.

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2 Causes of decay and losses of litchi fruit

2.1 Structural characteristics of litchi fruit

The edible part of litchi fruit is aril. The mature litchi pericarp consists of exocarp, mesocarp and endocarp[1,3]. The outermost exocarp has a very thin cuticle, a single epidermal layer and subepidermal schlerenchyma[1,3,5~7]. The external wall of epidermal cells is very thin[6]. There are many small projected ridges, a lot of micro-cracks with mutual connection, many lenticels with different shapes and sizes in exocarp surface[5~9]. The mesocarp is a tissue containing most of the anthocyanins. The innermost endocarp is membranous and made up of small, thin-walled, unsuberised epidermal cells[1,3,5~9]. The structure of fruit stem-end consists of vascular bundles, stellar stone-cells and ventilating tissue, which were large cell interstices and intercellular cavity[6,7]. Rapid water loss, pericarp browning and pathogens infection of litchi fruit occur during postharvest storage, which caused poor storability and

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low resistance to diseases of fruit, due to the high permeability of the cuticle to water, damage to the cuticle and projected ridges, the presence of micro-cracks and lenticels in exocarp surface, the presence of large cell interstices and intercellular cavity in fruit stem-end[3, 6, 7]. Underhill et al[9] found that micro-cracks 20~100 μm wide in the pericarp surface were present at the time of harvest but increased in density after 12 h and extended into the mesocarp, which may be involved in facilitating rapid desiccation-induced pericarp browning[10].

2 2 Physiological causes

2 2 1 Browning and loss of red color in litchi pericarp

Pericarp browning is the major postharvest problem of litchi fruit. Although the initial pericarp browning is primarily a cosmetic problem, it reduces the commercial value of the fruit[1, 3, 11]. Further browning is generally associated with the loss of eating quality[3]. Pericarp browning was mainly caused by desiccation, chilling injury, mechanical injury, heat stress, disease and senescence[1, 3, 4, 9, 11]. All these factors cause the loss of cellular compartmentation, allowing polyphenol oxidase (PPO) (located in the chloroplast and other plastids) to react with phenolics substrates (located in the vacuole), to form brown polymers[12, 13]. Peroxidase (POD) enzymes may also be involved in the oxidation of phenolics[1, 3, 4, 13].

Litchi fruit are very susceptible to water loss. Desiccation-induced browning begins on the protuberances of the pericarp and subsequently spreads across the entire surface, with browning localized in the exocarp and upper mesocarp[13]. Selective dehydration of the pericarp occurred with little movement of water between the aril and the pericarp, thus, water loss of fruit was mainly from the pericarp rather than the aril[9~11]. Eventually, the aril also loses water and the fruit become flaccid and bland[9, 10]. Browning severity and loss of red color were inversely related to the RH (from 95% to 60%), pericarp browning was positively correlated with water loss from pericarp[9~11, 14].

Chilling injury is the most serious physiological damage during cold storage. Chilling injury may occur when litchi fruit are stored at low temperatures of 0~5℃, chilling temperatures are related to cultivars and production regions[15, 16]. Chilling injury also causes the pericarp to brown. Tongdee et al[15] reported damage to fruit packed in punnets and wrapped in polyvinyl chloride (PVC) film after 30 days at 0℃ and 5℃, uniform browning was observed at 0℃, while at 5℃ there were irregular brown patches. Fruit resistance to disease descended and the fruit rapidly broke down when the chill-injured fruit were moved out from cold storage to ambient temperature[15, 16].

While the disappearance of the red pigments occurs at the same time as browning, the pericarp of litchi contains many phenols, and these are better substrates for PPO than anthocyanins[17]. However, anthocyanins, which account for the red pigmentation of the pericarp, may play an important role in browning and loss of red color in litchi pericarp[11, 18, 19]. When ortho-diphenolic compounds are oxidized to ortho-quinones by PPO, these quinones are then able to oxidize anthocyanins in a non-enzymatic reaction[20]. Jiang[21] used an in vitro system to demonstrate that PPO extracted from litchi can not oxidize an anthocyanin extract from the pericarp unless certain phenolic compounds are present. Thus, the browning of the pericarp can be attributed to the action of PPO on the colorless phenolics combined with the coupled oxidation of the red anthocyanins[3]. Zhang et al[19] found the product of the anthocyanidin degradation in litchi pericarp had a similar structure to catechol (a good substrate for PPO), which could accelerate enzymatic browning reaction by PPO. An anthocyanase, catalyzing anthocyanins hydrolysis and producing anthocyanidin, was extracted from litchi fruit pericarp. High activity of anthocyanase was observed in the pericarp. Thus, anthocyanase might contribute to the browning of litchi pericarp involved in the anthocyanase-anthocyanidin-PPO reaction[19].

The structure and color of anthocyanins are dependent on their cellular pH value. A rise in pH value converts the red flavylium cations into the colorless forms of anthocyanins (carbinol or pseudobase), which are more degradable by PPO[3, 14]. In addition, the colorless forms of anthocyanins allow expression of any brown background color. Loss of cellular compartmentation and water loss increase pericarp pH value, and this change is responsible for some of the change in color expression and subsequent degradation of the anthocyanins[3, 14, 18, 22]. The fact that red color can be regenerated by acidification indicates that anthocyanins are still present in the alternative forms. Hence, not all anthocyanins are involved in the coupled oxidation reaction[3, 22]. The importance of intracellular pH value in fixing anthocyanins and reversing the formation of colorless compounds has been recognized and applied[23~25]. However, serious pericarp browning at the later stage of storage failed to be regenerated red pericarp by acidification[22].

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2.2.2 Gas injury

Unsuitable controlled atmospheres (CA) storage or packaging may cause excessive concentration of CO_2 leading to poisoning. When CO_2 concentration exceeded 8%～10%, the ethanol content in pulp remarkably increased, ethanol flavor was very strong and the taste of pulp was off-flavors[16]. Atmosphere of 15% CO_2 resulted in off-flavors and a dull, grey pulp in 'Mauritius' ('Tai So') litchi fruit[26]. Pesis et al.[27] reported that litchi fruit packed in microperforated laminated polyethylene (PE) bags had less decay but poorer taste than fruit in macroperforated bags. CO_2 concentration in the microperforated bags were about 5% at 2℃ in fruit from the first harvest but about 13% in fruit from the last harvest. When bags were transferred to 20℃, CO_2 concentrations were as high as 26% in later harvested fruit, resulting in higher acetaldehyde and ethanol concentrations, which contributed to off-flavors.

2.3 Pathological causes

Litchi fruit are very susceptible to postharvest decay by bacteria, molds and yeasts[1,3]. Nearly 150 species of microorganisms were isolated from litchi fruit, specifically with 52 bacteria, 39 molds and 59 yeasts[16,28]. Among them, litchi downy blight (*Peronophythora litchi* Chen ex Ko *et al.*), anthracnose (*Colletotrichum gloeosporioides* Penz.) and sour-rot (*Geotrichum candidum* Link ex Pers. or *Oospora* sp.) are the most important diseases in China[4,28]. Control measures include fungicides, irradiation, heat, controlled atmospheres, and biological agents[29].

3 Different storage characteristics of cultivars

There are apparent differences on storability and resistance to diseases of litchi fruit among cultivars due to their distinctions of the structural and physiological characteristics[16,28]. Fruits of some cultivars such as 'Heiye', 'Guiwei' and 'Huaizhi', have thicker pericarp, harder aril, lower water and higher sugar in pulp and lower respiration of fruit, which are associated with strong resistance to diseases, easier storage and transportation. Whereas fruits of cvs. 'Lanzhu', 'Nuomici' and 'Sanyuehong', with thin pericarp, soft aril, high water and low sugar in pulp and vigorous respiration of fruit, tended to have low resistance to diseases, poor storage and transportation[16,28]. Therefore, selecting cultivars for better storage and transportation features is one of the important considerations for postharvest handling.

4 Maturity and harvesting

Litchi fruit should be harvested when fruit fully mature with red color pericarp and ready to eat since they do not ripen after harvest[1,3,4]. General guidelines for harvesting are difficult to prescribe because of the wide range of varieties of growth[1]. Maturity can be determined by fruit weight, pericarp color, pulp sugar, total soluble solids (TSS), titratable acidity (TA), sugar: acid ratio or TSS: TA ratio, flavor and days from anthesis[1,3,4,16,28]. Batten[30] reported that TA and TSS: TA ratio were both good indicators of flavor, however, TSS was not considered as a reliable maturity index. Chen et al.[4] and Underhill et al.[31] recommended TSS: TA ratio of 30～40 or 70 as a maturity index. The TSS: TA ratio was the greatest in 'Muzaffarpur' litchi fruit harvested 78 days after fruit set, and the optimal harvest period was 73～78 days after anthesis[32]. In practice, maturity is usually assessed on fruit color, flavor and eating quality.

Litchi fruit are harvested by breaking or cutting whole panicles, sometimes with a leafy branch, and placed in field containers, e.g. plastic crates or bamboo baskets[3]. Since mechanical damage to the fruit will increase desiccation and decay, and shorten storage life, care should be taken during harvesting[33]. Fruit should be harvested early in the day after dew dry or late in the afternoon to decrease field heat, minimize the increase of fruit temperature with the sun. Harvesting during the hottest part of the day or on rainy day should be avoided[3,16,28,33]. Shading of harvested fruit, rapid transfer of fruit from the orchard to the packinghouse and minimal delays between harvesting and cooling, all contribute to improved postharvest life and quality of fruit[3,33,34].

5 Postharvest handling

5.1 Sorting and grading

Sorting and grading of litchi fruit after harvest should be operated in shaded and well-ventilated areas or in packinghouse with low-temperature control. The panicles are split into sub-panicles, and leaves and twigs removed. Fruit that are undersized, immature, over-mature, misshapen, diseased by pathogens, damaged by insects or split are eliminated[3,33]. Fruit should be graded to ensure high quality fruit at high price, and suit different markets[3,28,33]. No international and China's national grading standards have been formulated for litchi fruit[28]. In China,

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most commonly, fruit are graded using pericarp color, fruit weight or fruit size as the basis for grading[28]. In Thailand, besides fruit size or fruit weight, grading classifications also specify freshness, length of stalk, color of pericarp, less blemishes, decay or insect damage, and percentage of loose fruit[35].

5.2 Fungicides

Fungicides dipping has been used commercially in litchi postharvest handling for inhibiting pathogen development, preventing fruit decay and extending storage life. Fungicides which had ideal results in practical storage were Benomyl, TBZ, MBC, Topsin-M, Aliette, Imazalil, Iprodione, lecithin, Prochloraz, Sportak and sulfur treatment[1, 4, 16, 28, 36, 37]. However, postharvest fungicides are not available in all growing areas to control litchi fruit diseases. Furthermore, since fungicides poses potential oncogenic risks, they are not desirable for consumers, and many countries no longer registered as postharvest chemicals[1, 33]. Thus, the alternative means such as biological control and coating application for fruit decay control are needed[16, 38～41].

5.3 Treatments to reduce water loss

Cold storage, maintaining a high relative humidity (RH), fruit coating or plastic packaging helps reduce water loss and desiccation-induced pericarp browning[1, 3]. Cold storage helps reduce water loss because it lowers the vapor pressure difference between the fruit and the dry atmosphere[3]. Litchi fruit stored at high RH (90% to 95%) also slows down water loss and reduces browning[14]. Chitosan or polysaccharide (Nature Seal) coating reduced water loss and browning in litchi compared to the control fruit[39～43]. Use of acid coating has shown some potential in maintaining color and preventing decay of litchi[43]. But wax coating was unsuccessful in preventing water loss because the coating itself cracked[9].

Fruit wax and vinyl resin plastic coating, plastic packaging such as PE film (bags), low density polyethylene (LDPE) film, polyvinylchloride (PVC) film, styrene punnets, plastic punnets with PVC film, or moulded plastic trays wrapped in plastic can reduce water loss and browning in litchi compared with unpacked fruit[1, 3]. Tongdee et al.[15] found that fruit in punnets wrapped in PVC film and stored for 40 days lost 6.4% of their weight at 10℃ and only 1.7% at 0℃. Fruit packaged in unperforated PE (0.04～0.05 mm) bags at 20℃ lost less than 2% fresh weight after 10 days, while control fruit lost 18%～30%, but the incidence of decay was higher in packaged fruit[44]. Fontes et al.[45] compared LDPE with PVC and found that while LDPE reduced water loss more in litchi fruit, condensation was higher. PVC reduced water loss without causing condensation while browning was delayed for 36 days when fruit were stored at 5℃[45].

5.4 Treatments to reduce browning and maintain red color

Techniques to reduce browning and maintain red color have included dipping the fruit in hydrochloric acid (HCl), ascorbic acid, citric acid, glutathione, polyamines (1 mmol·L^{-1} putrescine, spermidine or spermine), lecithin, sulphur dioxide (SO_2) fumigation and the treatments to reduce water loss[1, 3, 36, 46～48]. But of these, only SO_2 fumigation, acid dipping and plastic packaging have been used commercially[1, 3].

5.4.1 SO_2 fumigation

SO_2 fumigation has been the most effective practical postharvest treatment for control of pericarp browning and fruit decay in litchi[1, 3]. Fumigation is achieved by burning 100 g of 90% sulphur powder per m^3 of fruit at an ambient temperature of 28℃ for 20 min with no humidity control, although recommendations may vary slightly[1, 3, 24, 25, 35]. Sodium metabisulphite is as effective as SO_2 if followed by an acid dipping[49]. Sulphur treatment of red litchi fruit resulted in a pliable but bleached pericarp, which turned a uniform pink color after 3～5 days at 22℃[24]. If excess sulphur is used, the pericarp tends to turn yellow or pale green and fails to return to the red color[1]. Sulphite bleaching of red anthocyanins occurs as the negative ions from the sulphurous acid react with the flavylium cation and form colourless chromen-4(or 2)-sulphonic acid. This reaction is partially reversible as SO_2 is oxidized[50]. SO_2 fumigation is the most effective when whole litchi fruit sulphur residue is 200～350 mg·kg^{-1} immediately after fumigation. Sulphur residue is mainly in the pericarp and decreased rapidly in the first few days after fumigation[1, 51]. A maximum aril sulphur residue limit in Europe, Australia and Japan is 10 mg·kg^{-1}, in China is 50 mg·kg^{-1}, but in the USA, sulfur is only registered for postharvest use on grapes[1, 52, 53]. Progress has been made in decreasing SO_2 residue in the aril to 1～30 mg·kg^{-1}[3, 35, 51, 53]. However, due to SO_2 fumigation resulted in an aftertaste and with the increasing limitation on SO_2 use, the alternative methods such as heat treatment and acid dipping for reducing pericarp browning and red color retention of litchi fruit are needed[1, 3, 23～25, 48, 54, 55].

5.4.2 Acid dipping

Litchi pericarp color faded during storage, possibly

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as a result of an increase in the pH value of the cell sap[14, 24, 25, 49]. Red color in litchi pericarp can be regenerated by acid dipping due to converting the anthocyanin pigment back to the red flavylium ion, which predominates at low pH value[1, 3, 22, 24]. Zauberman, et al [24] reported that the bleaching pericarp caused by SO_2 fumigation can be restored red color by dipping fruit in dilute HCl. Blanching litchi fruit in water at 98℃ for 30 s followed by hydrocooling in water at pH 0 for 5 min resulted in a pliable, red pericarp and no aftertaste[55]. Vapor heat treatment for 2 s followed by low pH dipping (pH 0) resulted in red fruit even after storage at 1℃ for 28 days[56]. Hot water brushing, where fruit are sprayed with hot water while being brushed in a revolving drum, followed by HCl and fungicide dipping, has been shown to maintain a uniform red color for at least 35 days, without apparent deterioration in external or internal quality, or taste[48].

5.5 Insect disinfestations

Disinfestations, particularly against fruit fly, are required by many importing countries, especially the USA and Japan[57, 58]. Heat, cold, and gamma irradiation are acceptable methods for insect disinfestations of litchi fruit[52, 58, 59]. Hot water treatment (HWT) of litchi fruit at 49℃ for 20 min proposed as insect disinfestations[51, 52, 59]. Follett, et al. [59] reported that hot water immersion at 49℃ for 20 min used to control fruit fly in litchi was also effective against Cryptophlebia spp. A vapor heat treatment (VHT) at 45℃ for 30 min was sufficient to kill Queensland fruit fly (Bactrocera) without adversely affecting eating quality of litchi fruit[57]. Japan requires that litchi fruit thermally treated until the pulp temperature of fruit reaches 46.2℃ and remains there for 20 min, followed by cooling until the fruit reaches 2℃ and is maintained there for 42 h to disinfest fruit fly[1, 3, 33]. Cold storage of litchi fruit at 1℃ for 12 days or 1.1℃ for 15 days has been accepted as method for insect disinfestations[52, 58]. However, cold storage and heat treatments increase pericarp browning[48, 51, 52, 57~59]. SO_2 fumigation, alone or with an acid dipping, used in conjunction with these disinfestations treatments effectively reduced pericarp browning[1, 48, 51, 52, 57]. Irradiation is a promising and effective disinfestation treatment for litchi fruit. McLauchlan et al [60] reported that gamma irradiation at doses of 75 or 300 Gy kills the eggs and larvae of Queensland fruit fly without affecting the physical, chemical or organoleptic properties of the fruit.

6 Precooling

Litchi fruit that are quickly cooled after harvest, and remained at 5℃ are less subject to moisture loss (and subsequent pericarp browning), decay and deterioration[61]. Room cooling (3~5℃ air temperature and 80%~90% RH) took 13 h to decrease the temperature of litchi fruit from 27℃ to 3℃. Forced-air cooling (2.5 cm static pressure difference, 3~5℃ air temperature and 80%~90% RH) took 60~70 min to achieve the same result[61~63]. Forced-air cooling can dry out litchi fruit exposed directly to coolroom air, unless the coolroom operates at 95% RH. Cooling time can be extended if fruit are packaged in plastic bags, it takes up to 2 days to get pulp temperature of packaged fruit down to 5℃ with room cooling, and takes at least 12 h to cool litchi fruit with forced-air[61]. Therefore, precooling of litchi fruit should be done before the fruit are packaged into plastic bags, which is quicker and reduces the likelihood of condensation inside the plastic bag once the fruit are packaged[61]. Hydrocooling is a faster cooling technique than forced-air cooling, it takes up to 10~20 min to get pulp temperature of 3~5℃[61~63]. Hydrocooling keeps fruit moist and simple systems can be set up relatively cheaply, and has been used successfully on litchi fruit. Hydrocoolers use water to cool the fruit. The water can be cooled using either mechanical refrigeration or ice. The water is sprayed/showered over the fruit or fruit is dipped into a cold water bath[61]. Decay may be a serious problem if the hydrocooled fruit are packaged wet, excessive moisture should be drained from the fruit using fans to speed up drying before packaging[61~63]. Although vacuum cooling of litchi fruit is rapid which can decrease the pulp temperature of 'Huaizhi' litchi fruit from 29.8℃ to 12.3℃ within 30 min[28], the fruit lose more water and brown easily[4]. The application of pre-wetting fruit with water prior to vacuum cooling can reduce weight loss and increase cooling rate[33]. However, vacuum cooling is not yet commercially used because of the high cost of vacuum cooler.

7 Packaging

Litchi fruit are packaged in plastic crates or fiberboard cartons or polystyrene boxes lined with PE for export or long distance transportation. In Asia, bamboo baskets are widely used as packages for local markets, but they are easily crushed causing damage to the fruit during storage and transportation[1, 3, 33].

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8 Storage

8.1 Ambient temperature storage

Storage at ambient temperature mainly relies on fungicides dipping and packaging with plastic film (bags), which can control pericarp browning and fruit decay. Litchi fruit may be stored for 7～10 days at 20～30℃[28, 36]. However, the technology of storage at ambient temperature for litchi fruit is not yet commercially used.

8.2 Cold storage

Litchi fruit are usually treated with fungicides and stored at 3～5℃[4, 28, 29]. Recommendations for cold storage temperatures vary widely, with minimum temperature recommendations ranging from 0℃ to 7℃, depending on cultivars, production areas and the length of storage[1, 3, 16, 36]. Swarts et al.[1] recommended that litchi fruit should be stored at 0～1℃ for up to 30 days. Kadam et al.[1] recommended temperatures of 5℃ for 2 weeks of storage and temperatures of 7℃ for 3～4 weeks of storage, and Tongdee et al.[15] recommending 7℃ for up to 30 days. Pericarp browning induced by chilling injury of fruit packaged in PE case and wrapped in PE film was most rapid at 0℃, followed by 2℃ and 5℃. Zhang et al.[64] found that fruit conditioned at 5℃ for 5 days before transfer to 1℃ had less browning than those stored at 1℃ or 5℃. Therefore, the optimum storage temperature for different cultivars and different production areas should be further investigated[16].

Although litchi fruit can maintain a good color after one month of storage, the rather short shelf life of cold-stored litchi fruit due to rapid pericarp browning at ambient temperature has been one of the major obstacles for marketing. Moving out from cold storage with gradual rising of temperature or keeping fruit with plastic packaging could extend fruit shelf life up to 24～48 h[28].

8.3 Controlled and modified atmospheres storage

Kader[65] recommended 3%～5% O_2 and 3%～5% CO_2 at 5～12℃ as litchi fruit controlled atmospheres (CA) storage conditions. Atmospheres of 3%～5% O_2 and 3%～7.5% CO_2 prolonged storage life and quality of the fruit, reduced pericarp browning, slowed the rate of loss of ascorbic acid, total soluble solids and titratable acidity and reduced decay[14, 26, 66]. In addition, Jiang et al.[14] found that atmospheres of 3%～5% O_2 and 3%～5% CO_2 resulted in less water loss than air controls, despite the fact that both were kept at 90% RH. However, CA storage is not used commercially at present[1].

Scott et al.[44] measured 17.2%～18.9% O_2 and 2.1%～4.8% CO_2 after 6 days at 20℃ in punnets wrapped in PVC, suggesting that the beneficial effects were a result of minimizing moisture loss rather than modification of the atmosphere. Indications are that a combination of reduced moisture loss with atmospheric modification will/would be most effective in reducing pericarp browning and controlling decay[14]. Ragnoi[67] found that 'Hong Huai' litchi fruit packaged in sealed 150 gauge PE film bags containing 2 kg of fruit and sulphur dioxide pads could be kept in good condition at 2℃ for up to 2 weeks, while fruit that were stored without packaging were discolored and unmarketable. Modified atmosphere packaging is used to a limited extent[1, 3].

9 Transportation and marketing

Transportation of litchi fruit can be done by land, sea and air, depending on the market. Fruit sold in local markets are usually transported by truck to the distribution centers or wholesale markets. In Thailand, most vehicles used in transporting fruit to local markets are not refrigerated[3]. In China, ice is widely used in litchi fruit short distance transportation for 1～3 days in non-refrigerated vehicles. Fruit are packaged into a PE bag (0.04 to 0.05 mm thick), then sealed and placed in a polystyrene box. Finally, ice is placed on top of the PE bag (ratio of ice∶fruit is 1∶3～1∶4) and the polystyrene box then sealed[4]. However, darkening of the pericarp (chilling injury) occurs if litchi fruit contact the ice[3]. In China, litchi fruit are usually transported from the south to the north by refrigerated trucks. Fruit exported to overseas markets are usually shipped by sea in refrigerated containers because the cost of shipment is cheap and the loading capacity is larger compared with land and air transport[33]. An alternative means for fruit exported to overseas markets is air transportation. However, most of exporters do not prefer air transportation due to expensive airfreight and limited loading capacity.

10 Conclusions

World production of litchi fruit will rapidly increase in next few years, particularly in China. Postharvest handling of litchi fruit is still the main problem in litchi industry. Pericarp browning and fruit decay are the most important postharvest factors affecting storage life and quality of litchi fruit. Consequently, storage conditions and postharvest treatments are selected with the objectives of reducing these

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problems. Rapid cooling and storage of litchi fruit at low temperature can reduce water loss and control/suppress decay organisms. Cold-chain system for litchi fruit during postharvest handling, storage, transportation and marketing remains the most promising means of reducing pericarp browning and fruit decay, and maintaining the red color and aril quality. Techniques such as fungicides dipping and SO_2 fumigation to reduce pericarp browning, control postharvest diseases and decay, and extend storage life of litchi fruit have been used commercially. However, with increasing resistance to the use of chemicals, finding alternative means of browning and decay control is needed.

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荔枝果实采后商品化处理和贮藏技术

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摘 要: 荔枝是我国南方著名的主要亚热带果树, 但其果实成熟于高温季节, 采后由于果皮褐变(即失去红色)和果实腐烂而使果实迅速劣变, 常温下的采后寿命少于 3 d, 这种短的采后寿命严格限制荔枝的长距离贮运、销售和消费。因此, 荔枝采后技术研究成为荔枝生产的关键问题。该文全面地介绍了荔枝果实采后腐烂和损失的原因(即荔枝果实的结构特性、生理和病理原因), 荔枝果实采后商品化处理和贮藏技术, 包括不同品种的耐贮运性、采收成熟度和采收方法、选别和分级、杀菌剂浸泡、减少失水处理、减少果皮褐变和保持果实红色处理(如熏硫处理、酸浸或塑料包装)、检疫杀虫处理、预冷、包装、贮藏(常温贮藏、低温贮藏、气调贮藏、自发气调贮藏)、运输和销售。

关键词: 荔枝; 采收; 采后处理; 贮藏; 果皮褐变; 果实腐烂; 运输

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