Journal of Food Engineering 102 (2011) 94–99

Contents lists available at ScienceDirect

Journal of Food Engineering

journal homepage: www.elsevier.com/locate/jfoodeng

Effect of chitosan coating on respiratory behavior and quality of stored litchi under ambient temperature

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ARTICLE INFO

Article history:
Received 20 December 2009
Received in revised form 10 August 2010
Accepted 12 August 2010
Available online 18 August 2010

Keywords:
Litchi
Chitosan
Respiration
Temperature
Quality

ABSTRACT

Litchi fruit were treated with 1% chitosan solution and stored under ambient temperature to study its change with respiration, temperature, quality etc. The respiration rate, sarcocarp temperature, the activity of polyphenol oxidase and weight loss of litchi with chitosan coating was lower than the uncoated litchi. The pericarp's temperature was lower than the ambient temperature because of litchi's transpiration. The storage time of coated litchi was 5 days longer than the uncoated. The chitosan film was characterized by Fourier transform infrared spectra and atomic force microscopy. The results showed that chitosan formed double-sides film on litchi's pericarp; one was more uniform and closely packed like a barrier, the other was rougher and better transport. Just as a plastic film, the coating can restrain the respiration, reduce moisture loss and lower the heat of respiration during storage.

1. Introduction

Litchi (*Litchi chinensis* Sonn.) is a tropical fruit with high commercial value in the international market. However, once detached from the tree, the fruit loses its qualities, such as sweet and juicy flesh and attractive bright red pericarp, within a couple of days under ambient temperatures. The short shelf life of litchi greatly limits the marketing of the fruit and has become one of the major constraints in litchi industry in China, where a huge production happens in a short season from mid-May to early July (Huang, 2002). The high rate of senescence of litchi has been attributed to the moisture loss due to heat of respiration (bio-heat) and transpiration during the storage period (Underhill and Critchley, 1993). Generally, rapid cooling after harvest and storage at low temperature are one of the most prevalent methods for maintaining the appearance and quality of litchi fruit (Narendra and Nirankar, 2008). It means that the ambient temperature is one of the most important factors affecting the litchi fruit commercial value. Harvested litchi is a living organism which breaths continuously during storage process (Huang et al., 2005). The respiration produces the bio-heat and causes the rise of temperature of fruit group, which accelerates water loss and browning (Baldwin et al., 1995; Marie et al., 2008). Therefore, there is a need for alternative novel practices to control respiration rate of the produce which automatically reduces the bio-heat and the resulting fruit temperature change during handling, distribution and retail sale.

Application of edible coatings is promising to improve the quality and extend shelf life of lightly processed produce (Krochta and De Mulder, 1997). Carbohydrates, proteins, lipids and combinations of them can be used to make edible films (Pilar et al., 2004). Chitosan (CS), a unique polysaccharide derived from deacetylation of chitin has been used in wide variety of application in the fresh-keep field owing to its good biocompatibility, biodegradability, antibacterial activity and capacities to form membrane (Balau et al., 2004; Chien et al., 2007). Due to its unique physicochemical properties, CS has been successfully used as food wraps, and maintains the quality of postharvest fruits and vegetables fruit (Devlieghere et al., 2004), and reduces the weight loss of litchi fruit (Marie et al., 2008). The coating is also safe and shows antifungal activity against several fungi (Zheng and Jiang-Feng Zhu, 2003). Previous studies indicated that CS coating had the potential to prolong storage life and control decay of many fruits, such as strawberry, peach, table grape, apple and mango (Chien et al., 2007; Dong et al., 2004; Maria et al., 2008; Romanazzi et al., 2002). Based on our present research, it is an effective method to store litchi with the coating of polysaccharide-based material especially CS (Lin and Liang, 2003; Lin et al., 2008, 2009).

Respiratory behavior of litchi is related to the fruit's character, ambient temperature and the property of the coating (Lin and Liang, 2003). There are more reports about the polyphenol oxidase (PPO) activity, desiccation, anthocyanin changes of litchi, the gas

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doi:10.1016/j.jfoodeng.2010.08.009

permeability of edible films and coatings (Bertuzzi et al., 2007; Liu et al., 2007; Tian et al., 2005), however few studies have focused on the characteristics of fruit temperature and respiratory behavior of litchi coated with CS (Lin and Liang, 2003). As far as we know, there are no details available about the relationship between respiratory behavior and the characterization of CS film which affects the change of fruit temperature and quality of litchi coated with CS during storage.

Consequently, the aim of this work was to investigate the effect of CS coating on the respiratory behavior and quality of litchi stored at ambient temperature. How the respiratory behavior effect fruit temperature (e.g. sarcocarp, pericarp and environment temperature etc.) and explaining what cause the changes of respiration and temperature. It provided a new angle of view to study the change of stored litchi. The work will be a basis of the studies on respiratory behavior and storage of litchi and subtropical zone's fruit.

2. Materials and methods

2.1. Plant material and treatment

Litchi (*Litchi chinensi* Sonn. Heli) fruit were harvested in local farms, the suburb of Nanning, Guangxi, China and transported to the research laboratory within 2 h. Fruits with uniform size, 80–90% red color, and free of physical damage, injury caused by insects, and fungal infection were used. Then they were divided randomly into groups of 100 fruit (for static state storage) or 300 fruit (for dynamic state storage). Each group had one replicate, and each treatment had three replicates. The fruit were dipped in the aqueous solution of 1.0% CS (crab shell CS, Beihai halobios Co. Ltd., Guangxi Province, China) for 1∼2 min, and then dried for 1 h. The aqueous solution of 1.0% CS was prepared with 2% acetic acid aqueous solution as solvent and 0.05–0.5% ascorbic acid as antioxidant. The fruit dipped in the acetic acid aqueous solution without CS were used as control. In static state of storage process, all fruits were placed in the modified polyethylene bag (100 fruit/bag) at room temperature with 70–80% relative humidity, while in dynamic state of storage process all fruit were packaged in plastic boxes (300 fruit/box), then wrapped with plastic bags, and finally stored in a running car for the shipping distance of 1300 km under ambient conditions (temperature 25–35 °C and humidity around 70–80%). The experiments were conducted in sequential 3 years. Similar results were obtained from three experimental periods. The data from the experiment in 2007 were presented.

2.2. The characterization of CS film

FTIR spectra were obtained on a FTIR Spectrophotometer (Nicolet Co., Nexus-470, Madison, USA). The CS powder was made as a slice with the potassium bromide to determine its FTIR spectra. The CS film was coated on litchi and dried under ambient temperature (25–35 °C). The film had two sides, one was exposed to air, which was air-dried during storage; the other was contacted with pericarp, which was moist during storage period. Their FTIR spectra were determined respectively.

The surface morphology of the films was analyzed by AFM (Asylum Research Co., MFP-3D-SA, California, USA) with a Nanoscope III, Multimode (Digital Instruments) with a 100 × 100 nm scan size and a 50 nm vertical range. Measurements were taken from several areas of the film surface using the tapping mode. The resulting data set for each sample was transformed into a 3D image. The average sample roughness was estimated with the Nanoscope 5.30r3sr3 software of the equipment.

2.3. Moisture absorption and retention testing (Sun et al., 2006)

The water-absorption ability was evaluated by the percentage of weight increase of film sample (R_a): R_a (%) = $100 \times (W_n - W_0)/W_0$, where W_0 and W_n were the weights of sample before and after putting it into a saturated $(NH_4)_2SO_4$ desiccator (87% relative humidity) in different times. After 144 h the samples were put in a saturated $CaCl_2$ desiccator (RH 36%) and recorded the weights of sample in different times. The water-retention ability was evaluated by the percentage of residual water of wet sample (R_h): R_h (%) = $100 \times (H_n/H_0)$, where H_0 and H_n were the weights of water in sample before and after putting in a saturated $CaCl_2$ desiccator (36% relative humidity). The desiccators were all put into biochemistry foster case at constant temperature 25 °C.

2.4. Respiration measurement

Respiration measurement was measured by absorbing carbon dioxide in aqueous alkali under static state (Luo, 2001).

2.5. Temperature measurement

Sarcocarp and pericarp temperature were measured with a HP34970A data collector and computer (Wang et al., 2003). The sensor was a T type thermocouple (19AWG). Before the measurement, the thermocouple was calibrated in the mixture of water and ice.

During static storage, the temperature of single fruit was measured at six test points including one at the fruit handle, one at fruit needle and the others were distributed averagely at the equator line of the fruit. The experiments were arranged in a completely randomized design, and each of them was composed of three replicates of individual fruit. The temperature of total fruit was measured at six test points including one at the upside, one at under layer and the others were distributed averagely at the equator around the bag. All test points in the package were 5 cm away from the outside. The results showed with their statistical averages. Experiments were arranged in a completely randomized pattern, and each was composed of three replicates for which 100 individual fruit were used. At the same time the environment temperature was recorded.

During dynamic storage, the temperature of total fruit was measured with a temperature and humidity recorder (Taiwan Hengxin AZ Co., AZ-8829, Taizhong, China Taiwan), The recorder was very small and was positioned in the middle of the plastic boxes (300 fruits in the box). The temperature data were recorded every 0.5 h. At the same time the environment temperature was recorded.

2.6. Enzyme assay

Fruit pericarp (2 g) was homogenized in 5 ml of 0.05 M phosphate buffer (pH 6.8) at 4 °C. The homogenate was centrifuged at $19{,}000 \times g$ for 20 min and PPO activity in the supernatant was determined with a ultraviolet–visible spectrophotometer (SHIMADZU Corporation, UV-1601, Kyoto, Japan) according to the method of Zhang and Quantick (1997), by measuring the oxidation of 4-methylcatechol. PPO activity was calculated as the increase in 0.001 unit of absorbance per min at 398 nm per mg protein.

2.7. Measurement of weight loss and GFP

Three replicates of 300 fruit were used for each treatment. Fruit were weighed regularly for weight loss.

The fruit appearance was estimated by measuring the extent of the total browned area on each fruit pericarp on the following scale