Indian Journal of Agricultural Sciences **91** (12): 1718–22, December 2021/Article
https://doi.org/10.56093/ijas.v91i12.120790

Impact of chitosan on quality and storability of plums (*Prunus salicina*) under supermarket conditions

PUSHPENDRA KUMAR[1]* and SHRUTI SETHI[2]

ICAR-Indian Agricultural Research Institute, New Delhi 110 012, India

Received: 29 August 2018; Accepted: 04 August 2021

ABSTRACT

In the present study, effect of chitosan coating on storage quality of plum fruit (*Prunus salicina* Lindley. cv. Santa Rosa) was investigated under supermarket conditions during 2013 at ICAR-IARI. After coating the plum fruits with 2% chitosan and water, they were stored at 20±1°C and 90±2% RH for 15 days. Fruit firmness, colour characteristics (hue and chroma), respiration and ethylene evolution rate, physiological loss in weight, antioxidant activity and total phenols were measured along with the activities for pectin methylesterase and malondialdehyde content. Chitosan application resulted in better firmness of fruits, retarded ethylene evolution and respiration rates and least colour changes as compared with the control. Reduction of total phenolics and antioxidant activity were also significantly inhibited by chitosan. Furthermore, fruits coated with chitosan also exhibited a significantly lower pectin methylesterase activity throughout the storage period. Moreover, the production of malondialdehyde was significantly reduced in the coated samples. The results clearly demonstrate that dip treatment of fruits in 2% chitosan could be an effective means to enhance the shelf-life and maintain postharvest quality of Santa Rosa plums during storage.

Keywords: Chitosan, Firmness, Plum, Quality, Shelf-life

Plum (*Prunus salicina* Lindley) is one of the most important temperate and sub-tropical stone fruit, commercially produced in India. Plum fruits are regarded as healthy fruit because they are rich in vitamins, minerals, phenolic and bioactive compounds like anthocyanin (Kumar *et al.* 2016). Plum fruits are highly perishable in nature due to their inherent active metabolism and postharvest physiological activities which leads to shorter shelf-life that poses a challenge for their marketing. Moreover, the removal of protective wax coating during handling and transportation results in increased susceptibility to water loss, bruising, texture softening and sensitivity to fungal infection. Looking into the popularity and nutritional importance of this stone fruit, urgent steps are needed to control physicochemical changes, reduce fruit softening and preserve the postharvest quality of plum fruits. Several methods such as modified atmosphere packaging (MAP), low temperature storage and treatment with chemicals such as calcium, 1-MCP, polyamines, heat and ascorbic acid have been tried on plums to curb the biochemical changes during handling and storage (Valero and Serrano 2010). Recently, the use of bio-based materials is gaining momentum as a preservation method to enhance the storage life and preserve the postharvest quality of fruit as they are economical and easy to apply compared to other preservation methods (Choi *et al.* 2016). Chitosan is one such safe polymer of high molecular weight obtained from outershell of crustaceans that has excellent film forming qualities. It helps slow down respiration and regulates gas exchange through the fruit skin. Recently, chitosan is being used to preserve the quality of several fresh fruit such as blueberries (Mannozzi *et al.* 2018), guava (Silva *et al.* 2018), kiwifruit (Kaya *et al.* 2016), strawberries (Gol *et al.* 2013) and papaya (Ali *et al.* 2011). However, limited information is available on the influence of chitosan on quality of fresh plums. Thus, the objective of the present study was to examine the effects of chitosan on postharvest quality and shelf-life of plum during storage under supermarket conditions.

MATERIALS AND METHODS

Plums of Santa Rosa variety were harvested at climacteric stage of maturity in July from an orchard located at Kullu, Himachal Pradesh, India. Uniform sized fruits free from damage were packed in wooden boxes and immediately transported to Division of Food Science and Postharvest Technology, ICAR-Indian Agricultural Research Institute, New Delhi during 2013 for further studies. Chitosan coating was prepared according to the method of Han *et al.* (2004). Two gram chitosan was dissolved in 100 ml distilled water

Present address: [1]College of Horticulture and Forestry, Central Agricultural University (I), Pasighat, Arunachal Pradesh; [2]ICAR-Indian Agricultural Research Institute, New Delhi. *Corresponding author e-mail: docpkumar@rediffmail.com.

containing 0.2% acetic acid and 0.1% Tween 80 followed by homogenizing. The plum fruit were randomly divided into two groups. One group was dipped in chitosan solution (2%) and the other in distilled water dip (control) for 300 s. The fruits were allowed to air dry. Subsequently, both the sets of fruits were placed in punnets and stored at supermarket conditions (20±1°C) and 90±2% RH for further study. Triplicate samples were added in each treatment group. Observations were recorded at 3 days intervals for 15 days.

Physiological loss in weight (PLW) was measured according to Kumar *et al.* (2018) by weighing the coated and uncoated fruit with a electronic balance (Make: Precisa 310 M, Adair Dutt & Co. Pvt Ltd., Kolkata) at the beginning of storage and at all sampling days. The percentage of physiological loss in weight was calculated by using the method of Kumar *et al.* (2018) and expressed in percentage. Colour of the fruit peel was measured using Hunter Lab System (model: Miniscan XE PLUS). The value of colour was expressed as chroma index [$C=(a^2+b^2)^{1/2}$] and hue angle ($h=\tan^{-1}$ (b/a)) by using *L**, *a** and *b** values. Firmness determination of plum fruit was done using 2 mm probe of a texture analyzer (model: TA + Di, Stable micro systems, UK). Three plum fruits from each set were punctured in the mid section of each fruit at a constant speed and the maximum force developed during the puncture was recorded in Newtons. Respiration was determined as carbon dioxide production using static headspace technique. Auto gas analyzer (Model: Checkmate 9900 O_2/CO_2, PBI Dansensor, Denmark) was used to measure CO_2 evolved and expressed as CO_2 µg/kg/s. Hewlett Packard gas chromatograph (model 5890 Series II) was used to determine ethylene evolution rate (expressed as C_2H_4 ng/kg/s). Micro-structural examination of peel of chitosan coated as well as non-coated plums was carried out by using SEM (Zeiss EVO/MA10) technique and viewed on EVO/MA10 scanning electron microscope (SEM) at an accelerating voltage of 15 kV. The total phenol concentration of the coated as well non-coated plums was measured by Folin–Ciocalteu reagent method and results were expressed as g GAE/kg fresh weight basis (Kumar *et al.* 2019). Antioxidant activity (AOX) in the plums was determined by the cupric reducing antioxidant capacity (CUPRAC) method of Apak *et al.* (2004) and expressed as µmol Trolox/kg on fresh weight basis. Malondialdehyde (MDA) content in plum fruits was determined according to procedure of Kumar *et al.* (2018) and expressed as ng/kg fresh weight basis. PME activity in chitosan coated and non-coated plums was measured according to protocol of Hagerman and Austin (1986) as ng/kg/s fresh weight basis.

All data were analysed by two-way analysis of variance (ANOVA) using SAS 9.3 software and the level of significance was considered at $P<0.05$. The results are presented as means ± standard errors (SE).

RESULTS AND DISCUSSION

Colour is one of the important visual parameters to determine fruit acceptability and quality. Uncoated (control) plums recorded a rapid change in colour (chroma and hue) compared to chitosan coated plums. The plums with chitosan coating underwent slower changes in colour as indicated by the slower decrease in hue (~33%) and chroma (~27%) values. The inhibition of rapid colour changes in the plum samples coated with chitosan could be attributed to the reduction of ethylene evolution and respiration rate. It further retarded the fruit ripening and senescence process resulting in delayed colour change in terms of chroma and hue values. The results of our study are in concurrence with those of Hernandez-Munoz *et al.* (2008), Ali *et al.* (2011), Han *et al.* (2014), Silva *et al.* (2018), Mannozzi *et al.* (2018), in coated strawberry, sponge gourd, guava, papaya and fresh blueberries, respectively.

It is generally assumed that weight loss is an indicator of fruit freshness that increases during storage due to transfer of the moisture from the fruit to the surrounding environment. The weight loss continuously increased for both chitosan coated and non-coated plums during 15 days of storage under supermarket conditions. However, the weight loss of chitosan coated plums was significantly lower (~46%) than non-coated fruits during the entire storage period ($P<0.05$). The significantly lower weight loss recorded for chitosan coated plums indicated the beneficial impact of chitosan to retard moisture loss. The chitosan coating acts as an additional outer layer that covers the stomata, forming an area of high relative humidity around the fruit. This further leads to reduced water vapour transmission leading to a decrease in transpiration and in turn, a suppression in the rate of weight loss of fruits. Our results are in accordance with Han *et al.* (2004), Zhou *et al.* (2008), Silva *et al.* (2018), and Shahbazi *et al.* (2018) highlighting the ability of the chitosan edible coating formed on the fruit surface in delaying transfer of water from the produce into the environment.

Fruit firmness is a major factor governing the storage life of plums and the acceptability of the fruits by the consumers. Excessive softening of plums is a major limiting factor for storage life. We observed a continuous reduction in firmness of the fruits in both chitosan coated and non coated plums with advancement of storage period. At the termination of experiment, chitosan coated plums exhibited better firmness (~39%) than non-coated fruits (control), indicating that the positive effect of chitosan in arresting the enzymatic activities and cell wall degradation in the fruit. Further, chitosan coated plum fruits displayed a slower rate of reduction in fruit firmness than non-coated (control) ones. This preservation of fruit firmness with application of chitosan coating is similar with the investigations of Silva *et al.* (2018) and Ali *et al.* (2011) on guava and papaya, respectively.

The influence of chitosan on respiration rate of plums during storage is shown in Fig 1A. Respiration rate in non-coated plum fruits was higher in the first 6 days of storage and reached the peak on the 3rd interval. However, in chitosan coated plum fruits the respiration rate exhibited a significantly lower respiration up to 9 days storage with climacteric peak observed on 12 days of storage. Compared

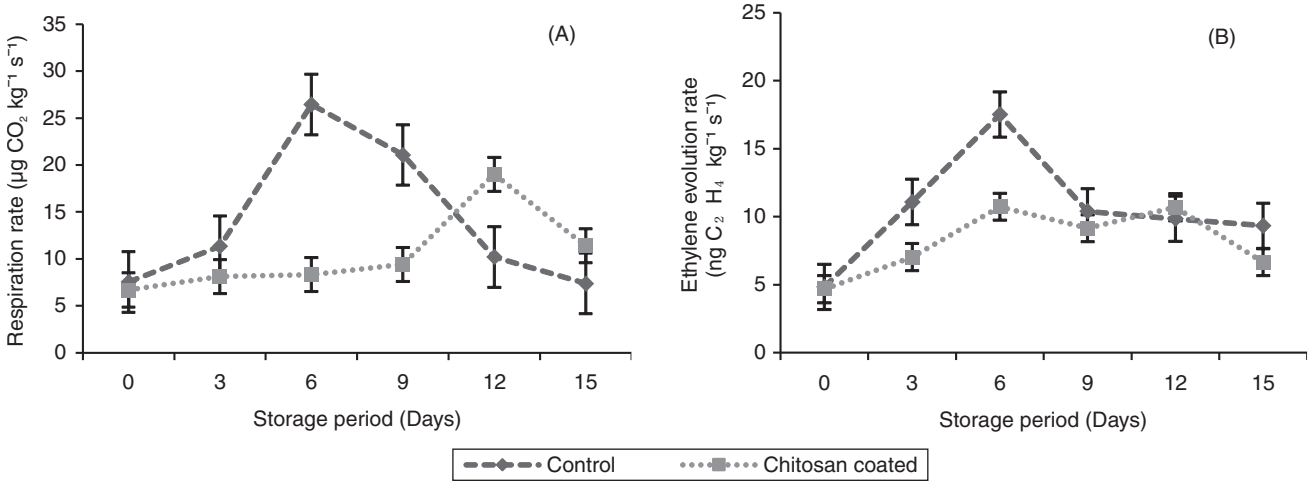

Fig 1 Impact of chitosan coating on respiration rate (A) and ethylene evolution (B) of plums at supermarket conditions (20±1ºC).

with control samples, chitosan coating lowered the carbon dioxide (CO_2) production till 9 days. At the end of 15 days, the CO_2 production in non-coated plums was 7.39 µg/kg/s while in chitosan coated plums it was 11.39 µg/kg/s. Reduction of CO_2 production in the chitosan coated fruit is attributed to the barrier properties of chitosan that restrict gas exchange between fruit and the atmosphere. Our results are in line with those of Silva *et al.* (2018) and Hernandez-Munoz *et al.* (2008) where a slow rise in CO_2 was recorded in guava and strawberry, respectively coated with chitosan.

Ethylene evolution of chitosan coated and non-coated plum fruits during storage is presented in Fig 1 B. In non-coated fruits, ethylene production was 4.84 ng/kg/s at 0 days that exhibited a sudden increase to 17.50 ng/kg/s by the 6 days, followed by a significant reduction to 9.33 ng/kg/s till 15 days. On the other hand, the chitosan coated plums exhibited a gradual increase in their ethylene production up to 12 days of storage that decreased thereafter. This may be attributed to the barrier properties of chitosan coating modifying the internal gas composition of the fruit thus, inhibiting the ripening process. These findings are in accordance with the report of Silva *et al.* (2018) and Valero *et al.* (2013) on guava and plum coated fruit, respectively.

The plum fruit membrane image of chitosan coated as well as non-coated fruits was viewed under scanning electron microscopy (SEM). The chitosan coated plum fruit are seen to have an extra outer layer that helps to retain membrane integrity better in comparison to the non-coated samples (Fig 2 A and B). The scanning electron microscopy (SEM) investigation further corroborates our results that plums coated with chitosan have reduced physico-chemical changes during storage (Tesfay *et al.* 2017).

The antioxidant activity of chitosan coated plums increased during the first 3 days of storage with a gradual decline thereafter. On the other hand, the antioxidant activity of the non-coated plums continuously declined during the entire period of storage. Such decline in antioxidant activity

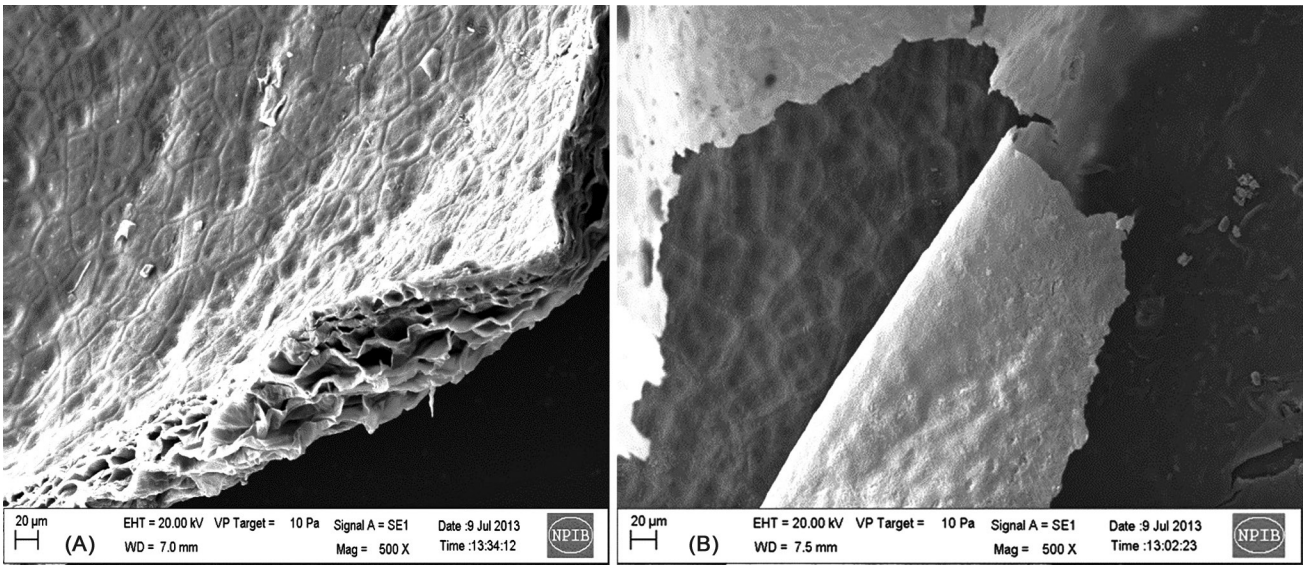

Fig 2 Scanning electron micrograph of the peel of control (A) and chitosan coated (B) plums at supermarket conditions (20±1ºC).

can be attributed suppressed respiratory activities leading to the reduction in phenolics and other related compounds which contribute to the antioxidant activity of the fruit. After 15 days of storage, the control fruit showed significantly lower antioxidant activity (~27%), while the chitosan coating resulted in a delay in this decline. Such trend shows that chitosan coating inhibited the senescence process of the coated fruits. Our results are consistent with Wang and Gao (2013) and Mannozzia *et al.* (2018).

The total phenolics content of non-coated Santa Rosa fruits recorded a slight increase during the first 6 days, thereafter showing a significant decline. However, chitosan coated plums experienced a gradual increase till 9 days that decreased gradually at the end of storage. The total phenolics content of chitosan coated plums fell drastically after 15 days of storage that may be due to the delay in senescence. The reduction of total phenols was more pronounced in control samples (water dipped) stored under ambient temperature (20±1°C). Similar findings were reported earlier by Han *et al.* (2014) on chitosan coated sponge gourd stored under supermarket conditions.

Continuous increase of malondialdehyde (MDA) content was observed in both coated and non-coated plums. On the 15 days of storage at 20±1°C, the malondialdehyde content of plums coated with chitosan was lower than non-coated fruits. It indicated that chitosan coating inhibited lipid peroxidation during storage of plum fruits. The drastic increase of malondialdehyde content in control samples resulted in softer tissues. However, chitosan coating improved the integrity of cell membrane and extended the storage life of stored fruit. Many recent studies have also reported similar observations (Shao *et al.* 2012, Shi *et al.* 2013, Khalifa *et al.* 2016). Pectin methylesterase is an important enzyme associated with softening of fruit. Pectin methylesterase activity in chitosan coated as well as non-coated (control) plums had significantly increased during storage under supermarket conditions ($P<0.05$). Application of chitosan coating on plums showed significant inhibition (~39%) in the pectin methylesterase activity during storage ($P<0.05$) that might be due to the physical barrier formed around the fruit leading to depletion of O_2 and resultant inhibition in the PME enzyme activity. Pectin methylesterase activity was significantly higher for control fruits after 15 days of storage. Lower activities of pectin methylesterase in the chitosan coated plum fruit contributed to the retention of fruit firmness during storage as also reported previously by Gol *et al.* (2013).

Chitosan treatment could be used as potential postharvest treatment for Santa Rosa plums with the objective to retard the ripening and to preserve the postharvest fruit quality. The coating was effective as a physical barrier resulting in decreased weight loss and delayed onset of respiration and ethylene peak during storage. Chitosan was also effective in delaying colour changes and inhibiting the PME and lipid peroxidation. In terms of storability, the chitosan coating could extend the plum fruit storage life with optimal postharvest quality by 15 days at 20±1°C.

REFERENCES

Ali A, Muhammad M T M, Sijam K and Siddiqui Y. 2011. Effect of chitosan coatings on the physicochemical characteristics of Eksotika II papaya (*Carica papaya* L.) fruit during cold storage. *Food Chemistry* **124**: 620–26.

Apak R, Guclu K, Ozyurek M and Karademir S E. 2004. Novel total antioxidants capacity index for dietary polyphenol and vitamins C and E using their cupric ion reducing capability in the presence of neocuprine: CUPRAC method. *Journal of Agricultural and Food Chemistry* **52**: 7970–81.

Choi W S, Singh S and Lee Y S. 2016. Characterization of edible film containing essential oils in hydroxypropyl methylcellulose and its effect on quality attributes of 'Formosa' plum (*Prunus salicina* L.). *Food Science and Technology* **70**: 213–22.

Gol N B, Patel P R and Rao T V R. 2013. Improvement of quality and shelf-life of strawberries with edible coatings enriched with chitosan. *Postharvest Biology and Technology* **85**: 185–95.

Hagerman A E and Austin P J. 1986. Continuous spectrophotometric assay for plant pectin methyl esterase. *Journal of Agricultural and Food Chemistry* **34**: 440–44.

Han C, Zhao Y, Leonard S W and Traber M G. 2004. Edible coatings to improve storability and enhance nutritional value of fresh and frozen strawberries (*Fragaria × ananassa*) and raspberries (*Rubus ideaus*). *Postharvest Biology and Technology* **33**: 67–78.

Han C, Zuo J, Wang Q, Xu L, Zhai B, Wang Z, Dong H and Gao L. 2014. Effects of chitosan coating on postharvest quality and shelf life of sponge gourd (*Luffa cylindrica*) during storage. *Scientia Horticulturae* **166**: 1–8.

Hernandez-Munoz P, Almenar E, Valle V D, Velez D and Gavara R. 2008. Effect of chitosan coating combined with postharvest calcium treatment on strawberry (*Fragaria ananassa*) quality during refrigerated storage. *Food Chemistry* **110**: 428–35.

Kaya M, Cesoniene L, Daubarasb R, Leskauskaite D and Zabulionec D. 2016. Chitosan coating of red kiwifruit (*Actinidia melanandra*) for extending of the shelf life. *International Journal of Biological Macromolecules* **85**: 355–60.

Khalifa I, Barakata H, El-Mansy H A and Soliman S A. 2016. Improving the shelf-life stability of apple and strawberry fruits applying chitosan-incorporated olive oil processing residues coating. *Food Packaging and Shelf Life* **9***:* 10–19.

Kittur F S, Saroja N S, Habibunnisa and Tharanathan R N. 2001. Polysaccharide based composite coating formulations for shelf-life extension of fresh banana and mango. *European Food Research and Technology* **213**: 306–11.

Kumar P, Sethi S, Sharma R R and Varghese E. 2016. Effect of edible coatings on eating and functional quality of Japanese plum cv. Santa Rosa. *Indian Journal of Horticulture* **73** (3): 416–22.

Kumar P, Sethi S, Sharma R R and Varghese E. 2018. Influence of edible coatings on physiological and biochemical attributes of Japanese plum (*Prunus salicina* Lindell cv. Santa Rosa). *Fruits* **73**(1): 31–38.

Kumar P, Sethi S, Sharma R R, Singh S, Saha S, Sharma V K, Sharma S K and Varghese E. 2019. Influence of altitudinal variation on the physical and biochemical characteristics of apple (*Malus x domestica*). *Indian Journal of Agricultural Sciences* **89**(1): 145–52.

Mannozzi C, Tylewicza U, Chinnicia F, Sirolia L, Rocculia P, Rosaa M D and Romania S. 2018. Effects of chitosan based coatings enriched with procyanidin by-product on quality of fresh blueberries during storage. *Food Chemistry* **251**: 18–24.

Shahbazi Y. 2018. Application of carboxymethyl cellulose and

chitosan coatings containing *Mentha spicata* essential oil in fresh strawberries. *International Journal of Biological Macromolecules* **112**: 264–72.

Shao X F, Tu K, Tu S and Tu J. 2012. Combination of heat treatment and chitosan coating delays ripening and reduces decay in GALA apple fruit. *Journal of Food Quality* **35**(2): 83–92.

Shi S, Wang W, Liu L, Wu S, Wei Y and Li W. 2013. Effect of chitosan/nano-silica coating on the physicochemical characteristics of longan fruit under ambient temperature. *Journal of Food Engineering* **118**: 125–31.

Silva W B, Silva G M C, Santanac D B, Salvadorb A R, Medeiros D B, Belghithd I, da Silva N M, Cordeiroa M H M and Misobutsia G P. 2018. Chitosan delays ripening and ROS production in guava (*Psidium guajava* L.) fruit. *Food Chemistry* **242**: 232–38.

Tesfaya S Z and Magwaza L S. 2017. Evaluating the efficacy of moringa leaf extract, chitosan and carboxymethyl cellulose as edible coatings for enhancing quality and extending postharvest life of avocado (*Persea americana* Mill.) fruit. *Food Packaging and Shelf Life,* **11**: 40–48.

Valero D, Mula-diaz H M and Zapata P J. 2013. Effect of alginate edible coating on preserving fruit quality in four plum cultivars during postharvest storage. *Postharvest Biology and Technology* **77**: 1–6.

Valero D and Serrano M. 2010. *Postharvest Biology and Technology for Preserving Fruit Quality*. CRC-Taylor & Francis, Boca Raton, USA.

Wang S W and Gao H. 2013. Effect of chitosan-based edible coating on antioxidants, antioxidant enzyme system and postharvest fruit quality of strawberries (*Fragaria* × *aranassa* Duch). *LWT - Food Science and Technology* **52**: 71–79.

Zhou R, Mo Y and Li Y. 2008. Quality and internal characteristics of huanghua pears (*Pyrus pyrifolia* Nakai, cv. Huanhhua) treated with different kinds of coating during storage. *Postharvest Biology and Technology* **49**: 171–79.