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Effect of chitosan coating on postharvest life and quality of plum during storage at low temperature

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ABSTRACT

The effect of chitosan coating on the storage life and quality of 'Santa Rosa' plum was investigated. The plum fruits were treated with 2% chitosan coating and stored at 1 ± 1 °C under 90 ± 5% RH. During storage, observations on weight loss, fruit firmness, colour, rates of respiration and ethylene evolution, biochemical and quality attributes were recorded at weekly interval. Our experiment yielded that chitosan had a significant effect in maintaining fruit firmness (~78%), retarding weight loss (~52%), respiration and ethylene evolution rates and delaying the colour change as compared to non-coated fruits. Furthermore, at the end of 35 days of storage at low temperature, a significant reduction in pectin methylesterase activity (~44%) and malondialdehyde production (~21%) was observed. Similarly, anthocyanin content (~24%) was significantly retarded in chitosan-coated 'Santa Rosa' plums. Thus, postharvest application of chitosan as an edible coating can effectively maintain the quality and extend the storage life of plum up to 35 days under low temperature storage condition.

1. Introduction

The elevated rate of ripening results in rapid softening of plums, which results in a very short storage life at ambient temperature (Menniti et al., 2004). Depending on the genotype, the plum fruits may have a storage life of only about two to six weeks even if stored at 0 °C (Abdi et al., 1997). Although cold storage at 0–2 °C is beneficial in extending the postharvest life of plums but it may lead to the development of chilling injury symptoms manifested by flesh translucency and internal breakdown which leads to loss of quality and reduction in consumer acceptability (Manganaris et al., 2007). To retard ripening, prevent physiological disorders, delay the physico-chemical changes and enhance the postharvest life of plums, various treatments such as modified atmosphere packaging, edible coatings, low temperature storage and treatment with chemical agents such as 1-methylcyclopropene, nitric oxide, salicylic acid and chlorine dioxide have been attempted (Chen and Zhu, 2011; Sharma and Sharma, 2016). Among various postharvest management strategies, the application of edible coatings has been reported to be very promising (Kumar et al., 2016; Soradech et al., 2017). These eco-friendly surface coatings control gas and moisture transfer and curb oxidation processes thus retarding fruit senescence (Tharanathan, 2003). The natural wax coating on the surface of plum fruits gets damaged during handling and transportation, resulting in damage to the fruits. The application of edible coatings can play a significant role to replace the natural bloom and prevent losses during the postharvest handling.

Among several coatings used for extending shelf life of fresh fruits, chitosan, a non-toxic polysaccharide, has been attempted in guava (Hong et al., 2012), table grape (Gao et al., 2013; Romanazzi et al., 2002), strawberry (Wang and Gao, 2013; Han et al., 2004), litchi (Jiang et al., 2005), longan (Jiang and Li, 2001), peach (Li and Yu, 2000), mango (Kittur et al., 2001) etc. with successful results, owing to its excellent film-forming and biochemical properties (Muzzarelli et al., 2012; Han et al., 2014). The chitosan coating regulates gas exchange, slows down respiration (Jiang and Li, 2001) and activates defence mechanisms against a wide range of microorganisms (Aider, 2010). However, during our review, we found that only scanty literature is available on the effect of chitosan coating on the shelf life and quality of plums during low temperature storage. Therefore, we planned to work on its use in plums with the objective to evaluate the potential effects of chitosan coating on the postharvest life and quality attributes of 'Santa Rosa' plum during low temperature storage.

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2. Materials and methods

2.1. Raw materials

For conducting the experiment, physiologically mature fruits were harvested from an orchard in Kullu, Himachal Pradesh, India and brought to the laboratory situated in Delhi immediately after harvest. Plums were selected on basis of colour and freedom from infection and damage.

2.2. Coating formulation

Preparation of chitosan coating was done as per the method of Han et al. (2004). Two percent chitosan was dissolved in distilled water containing 0.2% glacial acetic acid to which 0.1% Tween 80 was added and then the mixture was homogenized.The pH of chitosan coating solution was maintained at 5.0 with 1 M sodium hydroxide.

2.3. Coating of plums

The sorted and graded fruits were divided into six lots of 10 kg each, of which, fruits of three lots were dipped in 2% chitosan solution and remaining three lots were dipped in distilled water (control or non-coated) for 5 min. After air drying, the plums were packed in plastic punnets and stored under 1 ± 1 °C at 90 ± 5% RH.

2.4. Scanning electron microscopy (SEM)

The scanning electron microscope Zeiss EVO/MA10, available at Division of Entomology, Indian Agricultural Research Institute, New Delhi, India, was used for viewing the surface microstructure of peel from chitosan-coated and non-coated plums. The micrographs were viewed at an accelerating voltage of 15 kV. Samples were coated with 24 μ of palladium and comparable magnifications of plum peel of coated and non-coated fruits were photographed.

2.5. Observations recorded and methodology

The observations on various physico-chemical parameters were recorded at 7 days intervals for a period of 35 days. For all determinations, three fruits from each lot of chitosan-coated as well as non-coated were randomly selected with three replicates. The details of methodology are as follows.

2.5.1. Weight loss

Weight loss of plums during storage was measured using an electronic balance (Make: Precisa 310 M, Adair Dutt & Co. Pvt Ltd., Calcutta) at every 7 days of sampling and expressed in percentage as follows:

$$WL = IW - \frac{FW}{IW}\text{x}100$$

where, WL is the weight loss (%), IW, is the initial weight (g) of plums and FW is the final weight (g) of plum on sampling date.

2.5.2. Peel colour and fruit firmness

Peel colour of plum fruits was evaluated with a Hunter Lab System (model: Miniscan XE PLUS). The value of colour was expressed as chroma and hue angle by using corresponding L^*, a^* and b^* values as per the following formula:

$$Chroma = \sqrt{a^2 + b^2}$$

$$Hue = \tan^{-1}(b/a)$$

Three readings were taken at different locations on each fruits. Fruit firmness was measured using a texture analyzer (model: TA + Di, Stable micro systems, UK) using compression test and expressed in Newtons (N).

2.5.3. Respiration and ethylene evolution rate

Respiration rate (ml CO_2 $kg^{-1}h^{-1}$) of the non-coated and chitosan coated plums was determined using auto gas analyzer (Model: Checkmate 9900 O_2/CO_2, PBI Dansensor, Denmark) where as ethylene evolution rate (μL $kg^{-1}h^{-1}$) of the samples was determined by injecting headspace gas into Hewlett Packard gas chromatograph (model 5890 Series II) (Kumar et al., 2016).

2.5.4. Determination of soluble solids content, titratable acidity and ascorbic acid

Soluble solids content of plums was estimated using a hand refractometer (ATAGO make; 0–50 °B) and expressed as degree Brix (°B) at 20 °C. The titratable acidity and ascorbic acid content of the non-coated and chitosan-coated plums was estimated by titration with 0.1 N sodium hydroxide (NaOH) and 2,6-dichlorophenol indophenol, respectively (Ranganna, 1999).

2.5.5. Determination of anthocyanin, total phenolic, malondialdehyde (MDA) content and antioxidant (AOX) and pectin methylesterase (PME) activity

The anthocyanin content in the chitosan-coated and non-coated plums was determined by using pH differential method and expressed as milligrams of cyanidin-3-glucoside equivalent per kilogram of fresh weight (Wrolstad et al., 2005). Folin–Ciocalteu reagent method was used to determine the total phenol content of plums as mg gallic acid equivalent/100 g (Han et al., 2014). Total AOX activity of the 'Santa Rosa' plums was measured by the cupric reducing antioxidant capacity method of Apak et al. (2004). The MDA content was measured using thiobarbituric acid by the method of Eum et al. (2009) and expressed as μmol g^{-1}. The PME activity in non-coated and coated plums as per the method ascribed by Hagerman and Austin (1986) and represented μmol $g^{-1}min^{-1}$fresh fruit weight)

2.6. Statistical analysis

Two-way analysis of variance was performed on the data sets using SAS 9.3 software and significant effects ($p < 0.05$) were noted. Significant difference amongst the means was determined by Duncan's Multiple Range Test (DMRT).

3. Results and discussions

3.1. Weight loss and fruit firmness

Coating the plums with chitosan was effective in creating a physical barrier to water loss (Fig. 2A). A 52% reduction in weight loss was observed in chitosan-coated plums than non-coated plums demonstrating that the chitosan coating successfully retarded moisture loss from plums and maintained their freshness during storage for longer time. An increase in weight loss during storage was observed that may be due to increase in moisture loss from the fruits caused by the respiration and transpiration processes (Zhu et al., 2008). The chitosan coating smoothened the pericarp surface and coated the stomata (as evidenced by the electron micrographs shown in Fig. 1) resulting in reduced respiration and transpiration rates through the pores. Similar phenomena of moisture loss reduction due to blocking of pores and stomata have been earlier reported by Dong et al. (2004) in litchi. Our results are also in tune with those reported by Hong et al. (2012) who reported that moisture loss in guava fruits was significantly reduced by application of chitosan coating.

Fruit firmness, an important quality attribute for determining market value and shelf life of the fruit (Ozturk et al., 2012), was found to decline during storage of plums. The phenomena of loss of firmness