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Effect of calcium lactate in combination with hot water treatment on the nutritional quality of persimmon fruit during cold storage

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ABSTRACT

Quality reduction and quick softening, occurring after harvest, limit shelf-life of persimmon fruit. In the present research, the effects of hot water and calcium lactate treatments on maintaining the firmness and preserving the quality of persimmon fruit during cold storage were investigated. 'Karaj' persimmon was harvested at commercial maturity stage and treated with hot water at three levels of 25 °C for 25 min, 45 °C for 30 min and 50 °C for 20 min, and calcium lactate at three levels of 0, 0.5 and 1%, and their combinations. The treated fruits were then stored at 1 °C with a relative humidity of ≥80%. At 20 and 40 days of the storage, fruits were removed from the refrigerator and some traits were evaluated three days after storage under shelf-life conditions. The evaluated traits were calcium content, firmness, weight loss, soluble tannin content, carotenoid, ascorbic acid, antioxidant capacity, total soluble solids and titratable acidity. The results showed that the amount of calcium in fruit tissue increased only in calcium lactate treatment, and hot water treatment showed a small effect on the trait. The combination of calcium lactate and hot water treatments caused higher effect on maintaining the firmness, controlling weight loss and preserving the quality of fruit when compared to applying each treatment alone. Furthermore, the treatments maintained antioxidant properties of the fruits during cold storage by maintaining the amount of soluble tannin, carotenoid and ascorbic acid contents. Thus, combined treatment of hot water and calcium lactate can be used to enhance antioxidant properties and preserve nutritional quality of persimmon fruits during postharvest storage.

1. Introduction

Persimmon (*Diospyros kaki* Thunb.) is an important subtropical fruit appreciated by consumers due to its excellent qualitative attributes and bioactive compounds such as condensed tannins, polyphenols, carotenoids and vitamins (Bibi et al., 2007; Bubba et al., 2009). Persimmon is highly perishable climacteric fruit that may deteriorate quickly when stored at ambient temperature (Zheng et al., 2005). Therefore, low temperature is the most effective method to slow the ripening process as well as decay development of this fruit. However, this fruit is sensitive to chilling injury during cold storage (Besada et al., 2008). External browning and softening are two of the main chilling injury symptoms observed in persimmon fruit, however its susceptibility to chilling injury depends mainly on the cultivar and storage temperature (Besada et al., 2008; Khademi et al., 2012). Thus, it is necessary to develop a suitable technology to reduce chilling injury and maintain overall quality of the persimmon fruit during cold storage.

Recently, heat treatments have gained much attention for use as an environmentally friendly technology for the maintenance of postharvest quality of many horticultural crops. Previous studies have shown that hot water treatment is effective in reducing chilling injury in persimmon (Besada et al., 2008; Burmeister et al., 1997; Khademi et al., 2014), maintaining fruit quality in Thai lime (Kaewsuksaenga et al., 2015), delaying the normal ripening and senescence in strawberry (Civello et al., 1997) and controlling postharvest diseases in peach (Jemric et al., 2011). Huan et al. (2017) reported that hot air and hot water treatments maintained fruit quality, decreased reactive oxygen species (ROS) levels and enhanced the antioxidant ability of fruit under cold storage. However, hot water treatment was more effective than hot air treatment in alleviating internal browning symptom in peach fruit. In persimmon fruit, Khademi et al. (2012) showed that hot water treatment alleviated flesh browning during cross from packing line, which was related to enhancing the activity of catalase and ascorbate peroxidase and reducing the activity of peroxidases. Moreover, persimmon fruits treated with hot water and 1-MCP maintained higher firmness resulting from lower activities of pectin methylesterase and polygalacturonase, which were concurrent with higher catalase and lower peroxidase activities (Khademi et al., 2014). In

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another study on the effect of hot water treatment at different times and temperatures on persimmon fruit cv. 'Karaj', the results showed that hot water treatments at 45 °C for 20–30 min, and 50 °C for 15–20 min were the most effective ones in the maintenance of fruit quality during cold storage without any adverse effects on the appearance of the fruits (Khademi et al., 2015).

Calcium, as an essential macronutrient, plays a vital role in regulating major physiological processes in plants. Pre and postharvest treatments with different calcium salts such as calcium lactate, calcium chloride, calcium phosphate, calcium propionate and calcium gluconate have been effective in reducing physiological disorders of fruits and vegetables. Among these salts, calcium chloride has been widely used to maintain textural attributes and postharvest quality of several fruits (Aguayo et al., 2008; Manganaris et al., 2005; Silveira et al., 2011; Wang et al., 2014). However, it has been reported that 2.5% Ca chloride solution imparted an undesirable bitter taste to cantaloupe cylinders, which was avoided by using calcium lactate at the same concentration (Luna-Guzman and Barrett, 2000). Hanson et al. (1993) also found an unacceptable salty taste in blackberries dipped in 2 and 4% Ca chloride. Calcium lactate is suggested as a good alternative calcium source because it provides better textural features (Manganaris et al., 2005) and avoids the bitterness or off-flavors associated with the chloride salt (Luna-Guzman and Barrett, 2000). Rico et al. (2007) showed that use of a calcium lactate wash at a warm temperature (50 °C) was more effective in preventing the softening of fresh sliced carrots during storage.

To the best of our knowledge, little information is available about the combined effects of hot water and calcium lactate treatments on persimmon fruit. Thus, the objective of the present study was to investigate the effects of hot water treatment combined with calcium lactate treatment on alleviating chilling injury and maintaining quality and antioxidant capacity of persimmon fruit during cold storage.

2. Materials and methods

2.1. Fruit source, treatments and storage conditions

Persimmon fruits (cv. 'Karaj') were first harvested at physiological maturity stage from a commercial orchard in Karaj city of Iran, then immediately transported to the postharvest laboratory at University of Zanjan, and selected for uniformity of size, shape, color and free from disease, pest or mechanical damage. On the day of harvest, a sample of 21 fruits were separated from the selected fruits, and directly analyzed at harvest. The remaining fruits were randomly divided into nine groups, each containing 42 fruits, and were subjected to the following treatments: 1) H25 °C- Ca 0% (fruits were dipped in water at 25 °C for 30 min); 2) H25 °C- Ca 0.5% (fruits were dipped in 0.5% calcium lactate at 25 °C for 30 min); 3) H25 °C- Ca 1% (fruits were dipped in 1% calcium lactate at 25 °C for 30 min); 4) H45 °C- Ca 0% (fruits were dipped in water at 45 °C for 30 min); 5) H45 °C- Ca 0.5% (fruits were dipped in 0.5% calcium lactate at 45 °C for 30 min); 6) H45 °C- Ca 1% (fruits were dipped in 1% calcium lactate at 45 °C for 30 min); 7) H50 °C- Ca 0% (fruits were dipped in water at 50 °C for 20 min); 8) H50 °C- Ca 0.5% (fruits were dipped in 0.5% calcium lactate at 50 °C for 20 min); and 9) H50 °C- Ca 1% (fruits were dipped in 1% calcium lactate at 50 °C for 20 min). After applying the treatments, all fruits were dried for approximately 1 h at ambient temperature, and then stored at 1 °C with 80–90% relative humidity up to the 40 days. Samples of 21 fruits from each treatment as three replications were removed after 20 and 40 days of cold storage and held at 20 °C for 3 days to simulate shelf conditions, and finally the qualitative characteristics were assessed.

2.2. Fruit assessment

For determination of calcium content, dry tissue (2 g) was burned in a muffle furnace at 500° C for 2 h to obtain the ash. The ash was then digested in 4 ml HCl: distilled water (1:1 v/v) and filtered through 'Whatman 40' paper. The obtained filtrate was diluted to 50 ml by distilled water. The content of Ca was analyzed by inductively coupled plasma emission spectroscopy (ICP-OES) in a 'Horiba Jobin Yvon ACTIVA' spectrometer, and the results were expressed as mg/100gFW (Zhi et al., 2017).

Fruit firmness was determined using an Effegi, FT 327 penetrometer equipped with an 8 mm tip at 3 equatorial points, and the results were expressed as kg/cm^2 (Khademi et al., 2015).

Persimmon fruit samples were weighed before and after the storage to calculate weight loss (%) during storage by using the formula of [(weight of fruits before the storage − weight of fruits after the storage)/weight of fruits before storage] × 100.

The soluble tannin content was determined by Folin-Denis method (Taira, 1996). To do so, 1 g of fruit sample was homogenized with 10 ml of 80% methanol using a mortar for 5 min. The homogenate was centrifuged at 10000 rpm at 4 °C for 10 min, and then for 1 ml of extract, 7 ml distilled water was added in a test tube, followed by adding 1 ml of Folin-Denis reagent for color development. After 5 min, 1 ml saturated sodium carbonate solution was added and absorbance was measured at 760 nm within 1 h by using spectrophotometer. The amount of tannin content was estimated against standard tannic acid, expressed as mg of tannic acid equivalents per 100 g of the sample.

For measurement of total carotenoid content, 1 g of fruit sample was homogenized in precooled mortar with 5 ml hexane and acetone (60:40) solution. The upper organic layer was transferred into a test tube on ice and the remaining aqueous layer re-extracted with 5 ml of the same solution repeatedly and transfer the organic layer to the same tube until the aqueous layer becomes colorless. The absorbance of the organic extract was measured spectrophotometrically at 450 nm and the amount of total carotenoid content was calculated according to Wang et al. (2005).

Ascorbic acid content was determined by the 2,6-dichlorophenol indophenol (DCPIP) titration methods as described by Bolek and Obuz (2014) with slight modifications. The amount of 2 g of fruit pulp was extracted with 10 ml of 3% metaphosphoric acid, and the obtained extract was centrifuged at 10000 rpm at 4 °C for 20 min. The resulted supernatant was titrated against 2,6 dichloro phenol indophenol (DCPIP) dye until the appearance of faint pink color. The ascorbic acid content was expressed as mg/100 g fresh weight.

Antioxidant activity was evaluated by measuring the scavenging activity of the examined extracts on the 2,2-diphenylhydrazil (DPPH) radical as described by Aghdam et al. (2013) with some modifications. 10 µl of supernatant (prepared as mentioned above for tannin content assay) was filled up to 1900 µl DPPH solution (100 mM). After 30 min incubation period at room temperature in dark place, the absorbance of the resulting solution was measured spectrophotometrically at 515 nm and the percentage of reduction in DPPH was calculated according to the following equation:

$$DPPH_{SC}\ (\%) = (1 - (A_{sam}/A_{con})) \times 100$$

Where $DPPH_{SC}$ is the inhibitory percentage, A_{sam} is the absorbance of the test sample, and A_{con} is the absorbance of DPPH solution without extracts.

Fruit samples were pooled and juiced to determine soluble solids content (SSC) and titratable acidity (TA). SSC was determined by using a hand refractometer (RF40), and TA was measured by titrating of fruit juice with 0.1 N NaOH up to pH 8.2; using 10 ml of juice diluted to 100 ml with distilled water (Khademi et al., 2015).

2.3. Statistical analysis

A randomized design with three replicates per treatment was used in this experiment. To determine the effects of hot water, calcium lactate and storage time on each dependent variable, a three-way analysis of variance was carried out using SAS software (version 9.2). Mean