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POSTHARVEST CALCIUM SALT TREATMENT OF FRESH JUJUBE FRUIT AND ITS EFFECTS ON BIOCHEMICAL CHARACTERISTICS AND QUALITY AFTER COLD STORAGE

Farid MORADINEZHAD*, Mehdi GHESMATI, Mehdi KHAYYAT
University of Birjand
Amir Abad Campus, College of Agriculture, Department of Horticultural Science, 331, Birjand, Iran

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ABSTRACT

Jujube fruit quickly undergoes spoilage and normally has a short shelf life. Therefore, the effect of immersion treatment in different calcium salts on qualitative and biochemical characteristics of fresh jujube fruit was evaluated. Treatments included control (distilled water) and solutions of calcium chloride, calcium nitrate, and calcium sulfate at a concentration of 0.5 and 1%. Fruits were immersed in water or calcium salt solution for 5 min, air-dried and then cold stored at 4 °C for 50 days. The results showed that such treatment did not affect significantly the pulp color and the anthocyanin concentration in the fruit. However, the soluble solids in the treated fruits significantly decreased compared with the control. Interestingly, all levels of calcium salts, except 0.5% calcium nitrate, preserved the total antioxidant capacity in comparison with the control. Concentrations of 1% calcium nitrate, chloride, and sulfate significantly increased crispness compared with the control. The taste of fruit treated with calcium sulfate significantly deteriorated compared with the control and other treatments. In general, 1% calcium nitrate and 1% calcium chloride applied before storage preserved or strengthened the jujube fruit qualities after storage compared with control. It can be concluded that such treatment is recommended for practical application.

Key words: *Ziziphus jujube*, calcium chloride, calcium nitrate, calcium sulfate, antioxidant

INTRODUCTION

Chinese jujube (Chinese date) (*Ziziphus jujuba* Mill) belongs to the Rhamnaceae family. The jujube fruit juice is very rich in vitamins, especially vitamin C, and is used in the preparation of various types of beverages (Liang et al. 1998). Jujube is one of the most five valuable fruits in China that has been used for long in herbal medicine (Chen et al. 2017).

The amount of postharvest losses of horticultural plants in developing countries is about 40–50% or even higher (Kader 2005). Therefore, it is important to look for such postharvest treatment that will help in the improvement of product quality and reducing losses. Some of the commonly used and proved methods include ultraviolet radiation for protecting fruit against pathogenic fungal infections (Guo et al. 2015), the use of polyamines to counteract the destructive effects of ethylene and extend the shelf life of fruit (Sharma et al. 2017), storage in a controlled/modified atmosphere, and dipping fruit and vegetables in different protective solutions (Moradinezhad et al. 2013).

Proper plant nutrition is essential for regular growth, higher yield, and better quality of fruit. Usually, the soil constitutes the basis of good nutritional status for plants, but sometimes, despite the fact that the elements are present in the proper amount in the soil, absorption of elements is disrupted (Lanauskas et al. 2006). This is especially important in terms of calcium, which is crucial for the firmness of the fruit tissue and, because of that,

*Corresponding author:
e-mail: fmoradinezhad@birjand.ac.ir

for the quality and shelf life of the product (Fallahi et al. 1997). Pre-harvest foliar spray or dipping of harvested fruit in calcium salt solutions is one of the methods used to integrate the production systems, to improve the fruit properties, and to minimize the use of fungicides. A common method of using soil fertilization with calcium for increasing the concentration of calcium in fruit has often little importance. The foliar application is the most effective way to increase the amount of calcium in the fruit as proven by previous studies. The external use of calcium significantly increases the concentration of calcium in the fruit juice and affects some of the changes related to maturity (Poovaiah 1986). This can be done by pre-harvest spray or postharvest immersion (Tzoutzoukou & Bouranis 1997). Calcium plays a key role in the cell wall and plasma membrane stability. In calcium deficiency, respiration rate increases, which ultimately reduces the shelf life of fruit. Therefore, the increase of calcium content in fruits can improve the quality of fruits, reduce the losses, and increase their shelf life (Salem & Khoreiby 1991).

Jujube fruit tends to spoil rapidly; therefore, its shelf life is very short due to shrinking and softening at room temperature and the fruit turns into dark brown color after 5–7 days (Moradinezhad et al. 2018; Padmaja & Bosco 2014). Using methods that can maintain the freshness of jujube and quality of fruit required for export seems to be necessary. Literature reviews show the positive effects of postharvest dipping treatments in calcium salts of different fruits (Biggs et al. 1997; Moradinezhad & Khayyat 2014; Moradinezhad & Jahani 2016, 2017). Our recent studies regarding calcium salt foliar spray on jujube showed that calcium chloride and calcium nitrate significantly affected the qualitative and quantitative properties of the fruit (Ghesmati et al. 2017; Zeraatgar et al. 2018). However, in some cases, immersing the fruit in calcium solution after harvest is preferable to foliar application and such information is not available for Chinese jujube. Therefore, the purpose of this study was to investigate the effect of fruit coating with various calcium salts after harvest on qualitative, biochemical, and organoleptic characteristics of jujube fruit after storage.

MATERIALS AND METHODS

In order to investigate the effect of fruit dipping in calcium salts (calcium chloride, nitrate, and sulfate) on physicochemical properties and quality of fresh jujube fruit, the experiment using a randomized complete block design with four replications was conducted at the Faculty of Agriculture, University of Birjand, Birjand, Iran. Fresh jujube fruits Iranian ecotype at crisp maturity (white-red) stage (Moradinezhad et al. 2016) were harvested from a commercial orchard in the mid of July and then transferred to the laboratory. Treatments included dipping in: distilled water (control), calcium chloride, nitrate, and sulfate at concentrations of 0.5 and 1%. Healthy and uniform fruits were selected in terms of color and size and then dipped in calcium salt solutions for 5 min. Thereafter, the fruits (200 g per bag, about 40 fruits) were air-dried, placed in nanoplastic bags (Deco, Italy), sealed, and stored in a refrigerator at 4 ± 1 °C and relative humidity 85 ± 5% for 50 days. The physicochemical and organoleptic characteristics of fresh fruit were evaluated at the end of the storage period. Ten samples were collected from each replicate for chemical assessments including soluble solid content (SSC), titratable acidity (TA), and total anthocyanin content.

Physicochemical and quality assessment

Color components of fruit pulp

Color components (L* – brightness, a* – redness and greens, and b* – yellowness and blue color) of fruit pulp were measured using a colorimeter (TES, 135-TAIWAN). Eight fruits were used to measure color in each replicate. The different color indexes (hue and chroma) were also calculated according to the following equations (Pathare et al. 2013).

(1) Hue = arc tang $\frac{b}{a}$

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

Soluble solid content

The SSC of fruit juice was measured at room temperature 20 °C using a hand-held refractometer (RF10, 0–32%, Brix, Extech Co., USA). Data were recorded in terms of Brix.

Titratable acidity

TA was performed using 5 ml of juice by adding 2–3 drops of phenolphthalein as a marker and titration with 0.1 N sodium hydroxide. The emergence of the pink color revealed the end of the titration (AOAC, 1980). The acidity was expressed as a percentage of malic acid.

Total anthocyanin content

The pH difference method was used to determine the anthocyanin content of the juice with use4 of potassium chloride and sodium acetate buffers (Swain 1965). The total anthocyanin (mg·dm^{-3}) content was measured based on the following equation:

(3) Anthocyanin (mg·dm^{-3}) = $\frac{(A \times MW \times DF \times 100)}{(f \times d)}$;

$A = (A_{max} - A_{700nm})$ pH 1 – $(A_{max} - A_{700nm})$ pH 4.5,

where A denotes absorption, A_{max} – absorption at 510 nm, A_{700nm} – absorption at 700 nm, MW denotes the molecular weight of pelargonidin 3-glucoside: 529 g·mol^{-1}.

Total antioxidant capacity

Ten milliliters of 96% ethanol was added to 2 g of fresh jujube fruit. The top of the solution was separated and re-extracted by adding 10 ml of 70% ethanol to the previous sediments. The extract was centrifuged at 4500 rpm for 15 min. The antioxidant activity using radical-free 2,2-diphenyl-1-picrylhydrazyl (DPPH) method was done with slight modifications according to Li et al. (2005). For this purpose, 0.5 ml of ethanolic extract was added to 2 ml of an ethanolic solution of 0.25 mM radical-free DPPH and placed in the dark for 2 h; the absorbance of the solution at 517 nm was measured by a spectrophotometer and the results were expressed as % DPPH radical inhibition using the following formula:

(4) % DPPH radical inhibition (%) =

$$[1 - \left(\frac{\text{Absorption of sample}}{\text{Absorption of control}}\right)] \times 100$$

Weight loss

To measure the weight loss, the packages (fruits plus nano pack) were weighed initially and at the end of the storage time, the weight loss percentage was calculated using the following equation.

(5) Weight loss (%) = (initial weight – final weight)/(initial weight) × 100

Organoleptic assessment (crispness and taste)

To evaluate the crispness and taste, the five-point hedonic test was used with a score 1–5 (5 – very good, 4 – good, 3 – acceptable, 2 – bad, and 1 – very bad) by seven trained panelists.

Statistical analysis

The statistical analysis of the obtained data was done using the SAS program v. 9.4 (SAS Institute Inc.) and the mean comparison done by the LSD test at the probability level of 1 and 5%.

RESULTS AND DISCUSSION

Color of fruit pulp

The immersion of jujube fruits in different solutions of calcium salts had no significant effect on the color parameters of the fruit pulp (data not shown).

Soluble solid content

The SSC decreased significantly at the end of the storage period as a result of postharvest calcium salt treatment (Fig. 1A). The highest soluble solid values (17.2%) were found in control sample and the lowest (15.1%) in 1% calcium chloride treatment. However, there was no significant difference between calcium nitrate (0.5%) and different levels of calcium sulfate.

There are conflicting results about the effect of various calcium salts on soluble solids of various fruits. Li et al. (2014) stated that calcium chloride treatment of jujube fruit did not affect SSC, which is not consistent with the results of this experiment. Shafiee et al. (2010) reported that strawberry fruit dipped in a solution of calcium chloride preserved the SSC in comparison with the control. Moradinezhad et al. (2013) found that at the end of the storage period, the SSC of control in pomegranate fruit was higher than in calcium-treated fruit. It has also been shown that the soluble solids concentration increases with longer storage time. However, dipping tomato fruit in calcium solution decreased the SSC (Pila et al. 2010). Similarly, previous studies have been reported the reduction of SSC in strawberry (Aguayo et al. 2006) and in tomato (Paliyath et al. 2008) as a result of dipping in calcium chloride. Reductions of SSC in calcium chloride-treated fruit may be due to decreased respiration and metabolism in the fruit tissue (Pila et al. 2010).

It is noteworthy that lesser respiration rate slows metabolic processes in the fruit and decreases the SSC as a result of a reduction in the conversion of carbohydrates to sugar (Rohani et al. 1997).

Titratable acidity

The postharvest application of calcium nitrate increased TA, especially at a concentration of 1% (Fig. 1B), while calcium chloride or calcium sulfate did not affect TA in fruit. Fallahi et al. (1997) showed that postharvest application of calcium nitrate increased the TA in apple fruit. They also stated that TA reduction in the control may be due to a decrease in the citric acid content. Similarly, gooseberry fruits immersed in 1% calcium nitrate had higher TA than the control (Kumar Loudhi 2014). Increase of TA in tomato fruit treated with 1% calcium ascorbate during storage has been reported by Bahramian et al. (2016). Moradinezhad and Jahani (2016) in the study of postharvest effects of different calcium treatments on apricot fruit stated that 2% calcium chloride increased the TA of the fruit at the end of the shelf life, which contradicts with our results on jujube. Safa et al. (2015) in a study on sweet cherry fruit showed that immersion of fruits before storage in a solution of 70 mM of calcium chloride preserved the TA during the storage time compared with the control. The use of calcium chloride may lower the metabolism of fruit by reducing the production of ethylene and the rate of respiration that reduces the TA. According to previous research (Ding et al. 1998), TA reduction due to biochemical changes in organic fruit compounds is possible during the respiration process. Calcium nitrate has been able to maintain the TA of treated plum fruit and prevent it from being lost, as the role of calcium in delaying the fruit ripening and reducing the ethylene production and the respiratory rate has been proven (Valero et al. 2002).

Total antioxidant capacity

The effect of dipping in calcium salts on the increase of antioxidants was significant at both concentrations of calcium chloride and calcium sulfate and at 1% of calcium nitrate (Fig. 1C) compared with the control. The lowest antioxidant content was observed in control samples and the highest in fruits treated with 1% calcium nitrate and 1% calcium sulfate.

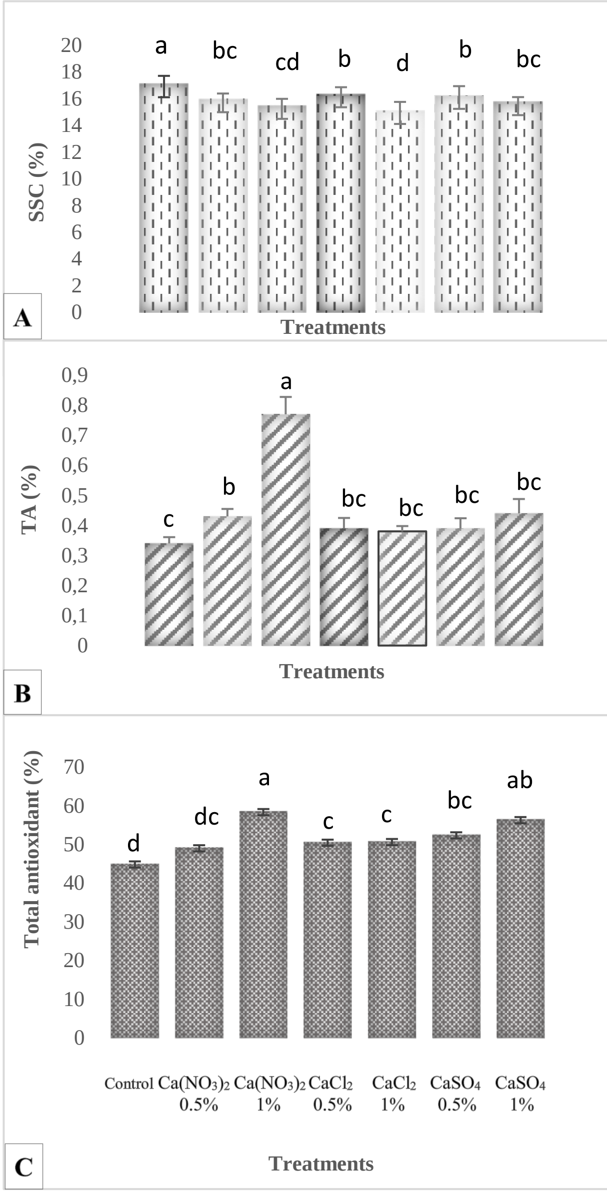

Fig. 1. Effect of postharvest calcium salt treatment on (A) soluble solid content, (B) TA, and (C) total antioxidant of fresh jujube fruit after 50 days of cold storage at 4 °C

Madani et al. (2016) and Bagheri et al. (2015) showed that postharvest treatment with 2% calcium chloride increased the antioxidant levels in papaya and persimmon fruit, during storage compared with control. The antioxidant activities are likely to vary during different stages such as harvesting time, storage practices, the time between fruit harvesting and consumption (Tareen et al. 2012). The antioxidant capacity of fruits and vegetables includes enzymatic compounds, such as catalase enzymes, ascorbate peroxidase, and superoxide dismutase, and non-enzymatic compounds, as vitamin C, phenolic compounds, and carotenoids (Xiaoe et al. 1998).

Different factors (stresses and senescence) produce free radicals. Fruit cells use antioxidants to remove these free radicals. Therefore, treatments, which delayed senescence and reduced respiration and stress, maintained the antioxidants content of cells (Asghari & Babalar 2010). Reduction of the antioxidants during storage has been reported as a result of the senescence process (Vangdal & Slimestad 2006). Therefore, the use of treatment with calcium chloride that delays the senescence can be effective in maintaining antioxidant capacity (Aghdam et al. 2013). Calcium stimulates tissue resistance to damage by antioxidant activity; therefore, preharvest and postharvest treatments of fruits and vegetables with calcium can be recommended for the storage (Paliyath et al. 2008). Calcium strengthens cell walls, reduces respiration, maintains cellular structure, reduces the senescence process, and prevents the reduction of antioxidants during storage.

Total anthocyanin content and weight loss

Different calcium salts applied for jujube fruit did not have a significant effect on the amount of anthocyanin content and weight loss (data not shown).

Crispness index

Immersion of jujube fruits in 1% of calcium salt solutions had increased the value of crispness index compared with control (Fig. 2A). The highest value index was obtained using 1% calcium chloride.

The maintaining of crispness with dipping in calcium solution was reported in plum (Lurie 1998) and peach fruits (Manganaris et al. 2007). Akhtar et al. (2010) found that immersion of loquat fruit in 2 or 3% calcium chloride maintains the firmness of the fruit tissue and consequently increases the crispness to the end of the storage period.

Fruit taste

The results showed that immersion of jujube fruit in calcium sulfate solutions decreased the taste scores of the fruit compared with the control during 50 days of storage (Fig. 2B). The best taste was assessed in control samples, whereas the use of calcium chloride and calcium nitrate reduced the taste scores.

Hamzehzad et al. (2010) stated that immersion of peach fruit in a solution of calcium chloride reduced the taste values of the fruit. Treating apricot fruits with calcium chloride at the concentration 1, 3, and 5% caused panelists to prefer control fruit or those dipped in 1% calcium chloride (Antunes et al. 2003). Contrary to the above, Moradinezhad and Jahani (2016) reported that apricot fruits treated with 2% calcium chloride had better taste than control.

Immersion of jujube fruits in the calcium solution before storage reduced the SSC compared with the control at the end of the storage period.

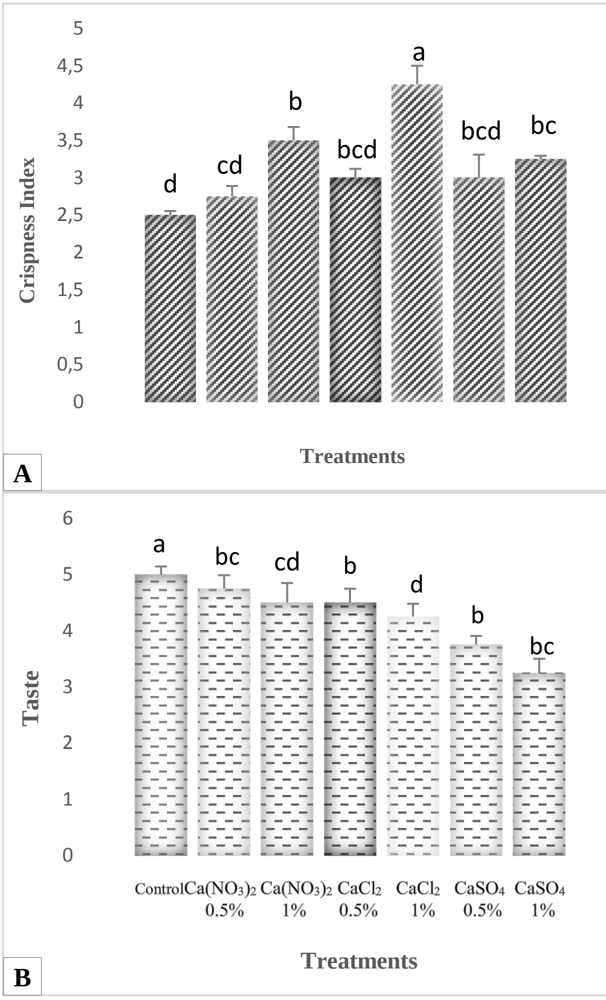

Fig. 2. Effect of postharvest calcium salt treatment on (A) crispness index and (B) taste of fresh jujube fruit after 50 days of cold storage at 4 °C

Therefore, reducing the taste of the fruit due to the reduction of soluble solids seems logical because the conversion of carbohydrates to sugar increased the SSC (Rohani et al. 1997) and leads to fruit taste improvement. Therefore, the higher scores of taste in control samples are likely due to the greater soluble solids.

CONCLUSION

This study revealed that immersion of jujube fruit in 1% calcium nitrate before cold storage preserves the biochemical and organoleptic traits and improves the overall acceptability of the fruit.

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