Fundamental and Applied Agriculture
Vol. 4(3), pp. 890–897: 2019
doi: 10.5455/faa.45660

Horticulture
ORIGINAL ARTICLE

Pre-storage calcium salts treatment maintained postharvest quality and bioactive compounds of fresh jujube fruit

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ARTICLE INFORMATION

Article History
Submitted: 26 Apr 2019
Revised: 10 May 2019
Accepted: 19 May 2019
First online: 10 Jul 2019

Academic Editor
Mohammad Golam Mostofa
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ABSTRACT

Jujube fruit is quickly damaged and it has a short shelf life in ambient temperature mainly due to senescence and flesh browning. The effects of postharvest calcium salts on quality attributes and physico-chemical characteristics of fresh jujube fruit were investigated with four replications. Fresh jujube fruits at crisp mature (whitish red) stage were picked from a local commercial jujube orchard during early in August in Birjand. Uniform fruits were then selected and immersed in solutions of different calcium sources (calcium chloride, calcium nitrate and calcium sulfate) at two concentrations (0.5 and 1%) or distilled water as control for 5 minutes, air-dried and then stored in cold storage for 50 days. The physico-chemical and sensory quality attributes of fresh fruit were evaluated at the end of storage time. The results showed that weight loss and pH was not influenced by the calcium salt solutions, whereas immersion of jujube fruits in different concentrations of calcium salts had a significant effect on the firmness of the fruit tissue. Calcium salts treatment significantly reduced fruit decay and shrinkage. In addition, postharvest dipping in calcium chloride and calcium nitrate solutions preserved nutritional value (ascorbic acid and total phenolic content) and maintained the sensory quality of fresh jujube fruit. Postharvest calcium salts application preserved the bioactive compounds, quality and improve the overall acceptability of jujube fruit, especially at a concentration of 1% of both salts. However, to determine the proper concentration of calcium salts and the time of dipping treatment for practical applications further studies are required.

Keywords: Ascorbic acid, calcium chloride, calcium nitrate, calcium sulfate, postharvest dipping

Cite this article: Moradinezhad F, Ghesmati M, Khayat M. 2019. Pre-storage calcium salts treatment maintained postharvest quality and bioactive compounds of fresh jujube fruit. Fundamental and Applied Agriculture 4(3): 890–897. doi: 10.5455/faa.45660

1 Introduction

Jujube (*Zizyphus jujuba* Mill) is a member of Rhamnaceae family. Jujube trees are widely grown in South Khorasan province of Iran, which is the most important production area since long ago (Zeraatgar et al., 2017). Jujube is rich in vitamins and bioactive substances, such as flavonoids that have a pharmacological impact on human health, and hence, it has been consumed as one of the herbal medicines for many years in Asia, China and Middle-East (Chen et al., 2017). However, fresh jujube fruit has a short shelf life about 3 days at ambient temperature, characterized by flesh browning, shrinkage and reduced eating

quality (Moradinezhad et al., 2018). Fresh jujubes rot easily and lose water during transportation and storage because of respiration and other physiological actions (Wang et al., 2011).

The importance of calcium in different stages of fruit maturation and ripening is well established (Poovaiah, 1986). Calcium has been applied at pre- and postharvest stages to delay ripening and to prevent physiological disorders of various fruits because the immobility of calcium in plant tissues has been proved (Cheour et al., 1990). Therefore, foliar application of calcium salts is the most effective way to increase the calcium content in the fruit. Although preharvest calcium accumulation reaches levels that inhibit visual deficiency symptoms in fruits, postharvest application frequently has beneficial effect such as shelf life extension (Park and Kim, 2016). Calcium plays an important role in the cell wall stability. It is well known that calcium deficiency leads to increased respiration and ultimately reduces the shelf life of fruits. However, developing an acceptable method of successfully increasing calcium in fruit is a continuing challenge (Conway et al., 2002). Therefore, methods that can help to increase fruit calcium faster and effectively can improve the quality and increase the shelf life (Salem and El Koreiby, 1991).

Several studies show the positive effects of postharvest calcium treatments on various fruits (Biggs et al., 1997; Moradinezhad and Jahani, 2016, 2017). In addition, recent studies on jujube show that preharvest calcium chloride and calcium nitrate treatments significantly affected fruit qualitative and quantitative properties (Zeraatgar et al., 2017). However, few studies have compared the effects of postharvest dipping in various calcium salts on quality attributes such as changes of fresh Chinese jujube after refrigerated storage (Taain, 2011). Therefore, the objective of this study was to compare the effects of the postharvest application of calcium chloride ($CaCl_2$), calcium nitrate ($Ca(NO_3)_2$), and calcium sulfate ($CaSO_4$) on physico-chemical and sensory quality attributes of fresh jujube fruit grown in South Khorasan province, Birjand, Iran during refrigerated storage.

2 Materials and Methods

2.1 Plant material and treatments

Fresh jujube fruits at crisp mature (whitish red) stage were picked from a local commercial jujube orchard early in August in Birjand, Iran (Moradinezhad et al., 2016). Postharvest fruit dipping in calcium salts (Merck, Germany) was investigated using a completely randomized design with four replications at the University of Birjand, Iran. Treatments were distilled water (as control), $CaCl_2$, $Ca(NO_3)_2$ and $CaSO_4$ at 0.5 and 1% (w/v) concentrations. Uniform fruits free from defect were selected in terms of size and color. The fruits were then dipped in calcium salts solutions for 5 min at room temperature, air-dried, packed in Nano plastic bags (Deco, Italy) (250 g bag^{-1} as replicate) and stored at 4±1 °C, with 85% relative humidity (RH). The physico-chemical and sensory quality attributes of fresh fruit were evaluated after 50 d of cold storage.

2.2 Measurement of physico-chemical attributes

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:

$$WL\ (\%) = \frac{W_I - W_F}{W_I} \times 100 \qquad (1)$$

where WL (%) = weight loss (%), W_I = initial weight (g), and W_F = final weight (g).

Firmness The fruit firmness was measured by a fruit hardness tester (FHT 200, Extech Co., USA) with a tip of 2 mm, and expressed in terms of N cm^{-2}.

Decay Decay was determined by the following equation as suggested by Taain (2011):

$$\text{Decay}\ (\%) = \frac{F_d}{F_T} \qquad (2)$$

where, F_d = number of deteriorated fruits pack^{-1}, and F_T = number of deteriorated fruits pack^{-1}.

Shrinkage In order to evaluate the shrinkages of the fruit, a five-point hedonic test was performed, as a score of 1: healthy fruits, 2: little, 3: low, 4: moderate, and 5 for high shrinkages of the fruit.

pH and total soluble solids content The pH was determined using a digital pH meter. The total soluble solids (TSS) of fruit juice was measured at room temperature (20 °C) using a hand-held refractometer (RF10, 0-32%, Brix, Extech Co., USA). The TSS was expressed as a percentage.

Determination of ascorbic acid (vitamin C) The amount of ascorbic acid was measured by titration of 2 and 6-dichlorophenol-indophenol. The juice was titrated with sodium 2-6-D-chlorophenol-Indophenol standard until the color of the juice of the pink juice remained low (which remained about 30 sec). The ascorbic acid content of the sample was determined according to Park and Kim (2016) method.

Determination of total phenol The total phenol contents were determined in the flesh of jujube fruits by the Folin–Ciocalteau method as described by Bahloul et al. (2009). 1 mL of the supernatant was added into a solution of 1 mL 50% (v/v) Folin-Ciocalteau reagent solution and 2 mL saturated Na_2CO_3 solution. The mixture was left at room temperature for 30 min. The absorbance was then measured at 750 nm using spectrophotometer (Unico 2100, China). The total phenolic content was expressed as μg gallic acid (GA) g^{-1} fresh weight.

2.3 Organoleptic evaluation

Sensorial quality for acceptability of the fruit was evaluated by a panel of eight trained subjects according to Moradinezhad et al. (2018) method with slight modifications. The evaluation was scored on a scale of 1–5, where a score of 5 indicated the fruit was very good (evident harvest freshness, and absence of off-flavor), and a score of 1 was considered a very bad degree (complete dislike, brown flesh colour with low juiciness). A score of 2.5 (like moderate with retention of freshness and crispness of flesh) and above was considered acceptable for marketing.

2.4 Data analysis

The statistical analysis of the obtained data was done using the Genstat program (Version 12.1, VSN, International, Ltd., UK, 2009) and the means comparison were investigated by the least significant difference (LSD) test.

3 Results and Discussion

The quality of harvested fresh jujube fruits were evaluated during cold storage at 10 d intervals in our previous study (Moradinezhad et al., 2018) and there was no significant reduction from the overall acceptability aspect of control fruits during 40 d of storage. Therefore, in the present study the physico-chemical and sensory quality attributes of fresh fruit were evaluated and reported after 50 d of cold storage in order to assess the quality traits of control and calcium salts treated jujube fruits which were stored for longer period.

3.1 Fruit weight loss

The results of the analysis of variance indicate that weight loss was not influenced by the postharvest calcium dips.

3.2 Firmness

Immersion of jujube fruits in different concentrations of calcium salts had a significant effect on the firmness of the fruit tissue at 1% level (Fig. 1a). The highest firmness was in treated-fruit with 1% $CaCl_2$ and the lowest was recorded in 0.5% $CaCl_2$ and control treatments, whereas no differences were observed among $Ca(NO_3)_2$ and $CaSO_4$ treatments. After 15 d of storage, postharvest application of 1% $CaCl_2$ in jujube fruit maintained the tissue firmness compared to control (Li et al., 2011), which is consistent with the results of this research. Calcium plays a structural role in the cell wall by cross-bridging esterified pectin chains that increase cell wall strength and tissue firmness (Quiles et al., 2007; Alandes et al., 2009). Thus, the role of calcium in maintaining flesh firmness depends on the levels of calcium and pectins in the cell wall (Quiles et al., 2007; Alandes et al., 2009).

Higher levels of calcium can result in higher calcium bound to pectin carboxyl groups and higher fruit firmness (Conway et al., 1995). Gupta et al. (2010) reported that the firmness of peach fruit tissue decreases during storage, but in fruits treated with 1% $CaCl_2$ firmness was much higher than the other treatments until the end of storage time. The pectates in the cell wall of the high plants are degraded by the polygalacturonase enzyme. High concentrations of calcium significantly reduce enzyme activity and the degradation (Cheour et al., 1991), as well as increased tissue calcium concentrations, reduce the respiration rate of the tissues, which leads to a decrease in the production of ethylene in the tissue and decreases the rate of fruit ripening.

3.3 Fruit decay

All calcium treatments had a significant effect on the percentage of fruit decay (Fig. 1b). Among different treatments, $CaCl_2$ had the highest effect on reducing decay percentage. However, there was no significant difference between 0.5 and 1% concentrations in each calcium salt. Taain (2011) reported that 4% $CaCl_2$ and $Ca(NO_3)_2$ treatments decreased decay percentage of jujube fruit (*Ziziphus mauritiana*) cv. Tufahi during cold storage due to pathogenic fungi compared to the control. Conway and Sams (1985) showed that the application of postharvest calcium decreased the decay of apples due to higher tissue firmness. They also stated that calcium induces resistance to pathogenic fungi and prevents the activation of the softening enzymes in the cell wall. Fungal pathogens are located on the cell wall. The existence of adequate calcium in the cell wall causes the cell wall has a stronger strength that prevents the activity of the pectin solubilizing enzymes and slows down the elongation of the fungal hyphae that led to lower decay (Amiri et al., 2009). Postharvest calcium salts treatments have been shown to markedly stimulate calcium-dependent protein kinases (CDPKs) activity in hypodermal-mesocarp plasma membranes at harvest and during handling and storage (Lester et al.,

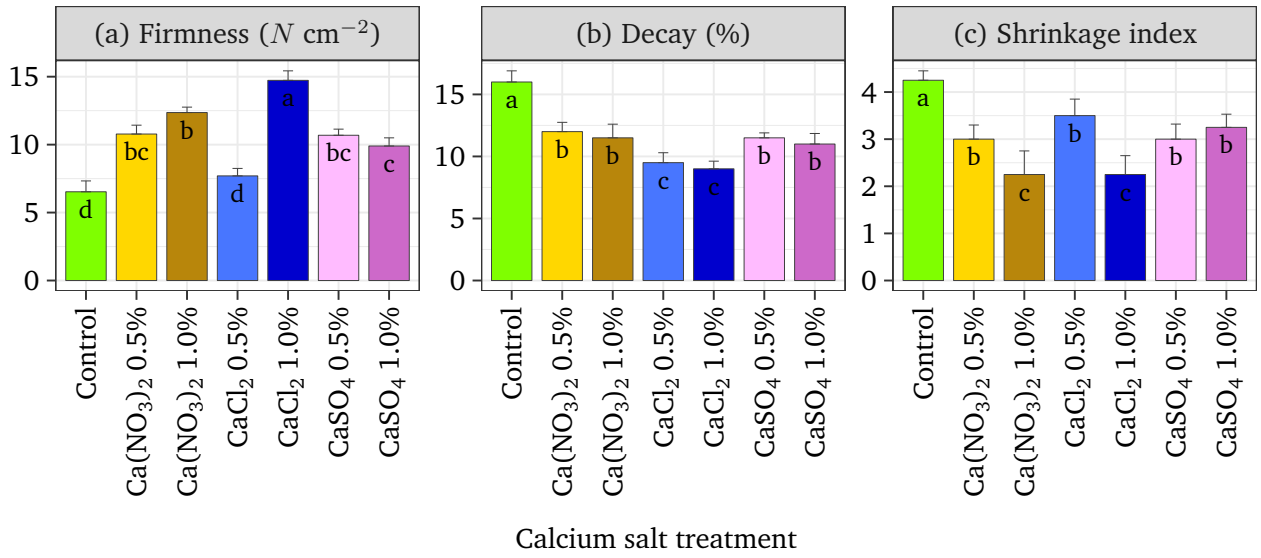

Figure 1. Effect of postharvest calcium salts treatment on (a) firmness, (b) decay, and (c) shrinkage index of fresh jujube fruit after 50 d of cold storage

1998), suggesting that calcium can stimulate CDPK activity, maintaining proper defense responses and reducing tissue susceptibility to pathogens during ripening and senescence.

3.4 Fruit shrinkage

Different levels of calcium salts significantly reduced the amount of fruit shrinkage (Fig. 1c) compared to the control. The highest shrinkage observed in the control fruits and the lowest obtained in fruits immersed at 1% $CaCl_2$ and $Ca(NO_3)_2$ treatments. Guava fruits immersed in 2% $CaCl_2$ for 5 min had less shrinkage than control fruit (Jagadeesh and Rokhade, 1998). Postharvest calcium dipping also reduces shrinkage and prevents water loss in peach fruit (Manganaris et al., 2007). These findings were in agreement with the results of the current study.

3.5 pH and total soluble solids content

The effect of different levels of calcium salts on the pH of the fruit was not significant whereas the TSS significantly affected by postharvest calcium salts treatment. The highest total soluble solids (TSS) and the lowest were found in control and 1% $CaCl_2$ treated-fruit, respectively (Fig. 2a). An increment at the concentration of applied calcium salts, the TSS decreases. Li et al. (2011) reported that $CaCl_2$ treatment did not affect TSS in control, although it was higher in control, which is consistent with our results. Moradinezhad et al. (2013) stated that the TSS of control in pomegranate fruits was higher than calcium treated-fruit. It has also been shown that as storage time of fruits increases the concentration of soluble solids raised. Some of the works have been reported the TSS reduction in tomato (Paliyath et al., 2009) and peach (Aguayo et al., 2006) as a result of $CaCl_2$ dips. Reductions in SSC in $CaCl_2$ treated fruits may be due to decreased respiration and metabolism in the fruit tissue (Pila et al., 2010).

3.6 Ascorbic acid (Vitamin C)

Results showed that the vitamin C content of jujube fruit significantly was higher in both $CaCl_2$, $Ca(NO_3)_2$ and $CaSO_4$ at 1% concentrations compared to control after storage period (Fig. 2b). It can be seen that calcium salts application has prevented the reduction of vitamin C during storage. The increasing value of ascorbic acid content in calcium-treated jujube fruit might be because higher concentrations of calcium delayed the rapid oxidation of ascorbic acid and/or due to continuing biosynthesis of ascorbic acid as a result of damages caused by calcium salts treatments, particularly in 1% concentration (Poovaiah, 1986).

Vitamin C is not only a quality evaluation indicator pervasively used, but also an essential nutrient for the demand of human being (Gao et al., 2013). Wang et al. (2014) reported that the vitamin C content of calcium treated sweet cherry fruits was higher at the end of the shelf life compared to the control fruits. It was also shown that postharvest application of $Ca(NO_3)_2$ caused strawberry fruits to have the highest maintenance of vitamin C compared to the control (Shafiee et al., 2010). Vitamin C is an important nutritional parameter in fruits and vegetables. Generally, there is a progressive loss of vitamin C with time and storage temperature (Kårlund et al., 2014). During handling and storage of harvested fruits and vegetables, they degrade and hydrolyze the oxidase enzymes results in vitamin C reduction (Singh et al., 2007).

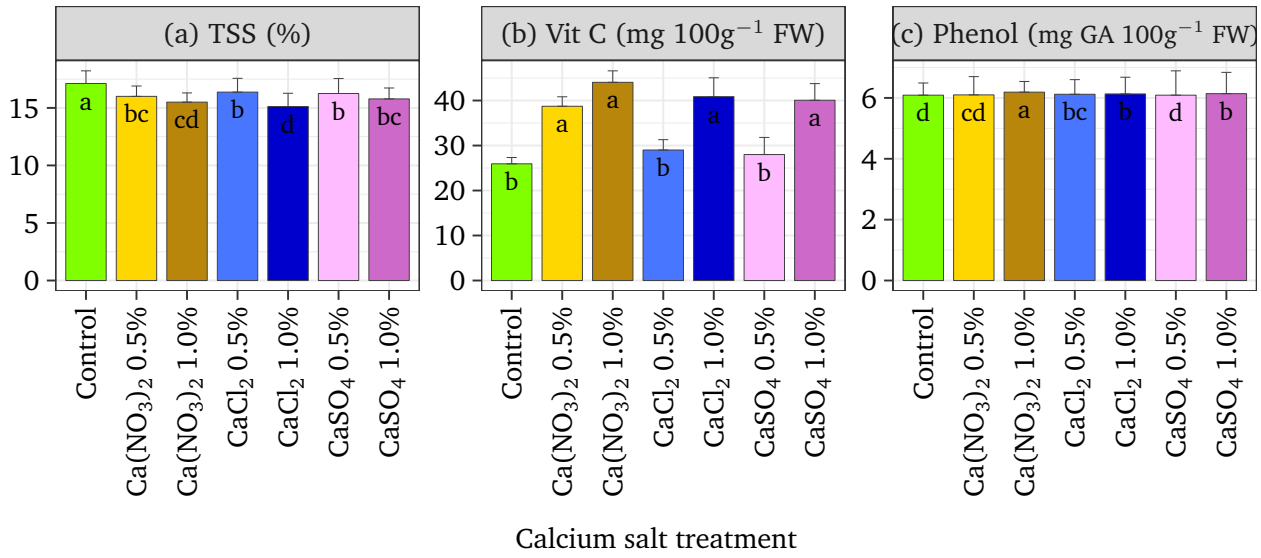

Figure 2. Effect of postharvest calcium salts treatment on (a) total soluble solids (TSS), (b) vitamin C, and (c) total phenol contents of fresh jujube fruit after 50 d of cold storage

3.7 Total phenolic content

Jujube fruits have higher phenolic content than other fruits known for their high phenolic content, such as apple, cherries, and red grape (Gao et al., 2013). Interestingly, in the present study, total phenol content of fruit was influenced by calcium salts treatments and the highest total phenol content was obtained in treated fruits with 1% $Ca(NO_3)_2$ and the lowest was found in control fruits, however, there was no significant difference between $CaCl_2$ and $CaSO_4$ treatments at a concentration of 0.5% (Fig. 2c). Studies on strawberry fruit indicated that postharvest calcium application had a positive effect on the phenolic content (Xu et al., 2014). Turmanidze et al. (2016) also reported that treatment of raspberry, blackberry, and strawberry fruits with 1 or 2% $CaCl_2$ had a positive effect on retaining polyphenols during the storage period. This is likely because the addition of $CaCl_2$ to fruits strengthened the cell wall and minimized leaching of water-soluble compounds such as polyphenols. $CaCl_2$ treatment also decreases polyphenol oxidase (PPO) activity (Tomás-Barberán et al., 1997) and by such way prevents polyphenols oxidation. In addition, calcium prevents the senescence stress condition by maintaining the membrane's strength, resulting in the presence of calcium in the membrane and cell wall, retaining cellular strength and consequently the loss of phenolic compounds is delayed (Lester and Grusak, 1999).

3.8 Overall acceptability

Dipping jujube on different calcium salts had a significant effect on the acceptability of fruit samples (Fig. 3).

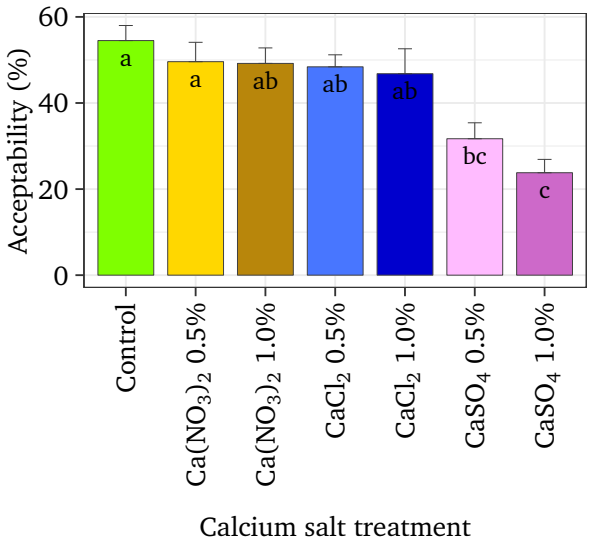

Figure 3. Effect of postharvest calcium salts treatment on the overall acceptability of fresh jujube fruit after 50 d of cold storage

Treated fruit $CaSO_4$ significantly reduced the overall sensory assessment of fruits in terms of eating quality and taste acceptability as the lowest score awarded by the panelists to the bitter taste. However, $CaCl_2$ and $Ca(NO_3)_2$ treatments had no negative effect on fruit acceptability and overall sensory quality evaluation. Moradinezhad et al. (2016) observed that apricot fruits treated with 2% $CaCl_2$ had better taste compared to the control samples. Phanumong et al. (2016) also reported that $CaCl_2$ treatment was the best salt to maintain the eating quality and texture of litchi arils than calcium propionate and calcium lactate.

4 Conclusions

Postharvest calcium salts application preserved the bioactive compounds, quality and retain the overall quality of jujube fruit, especially at a concentration of 1%. However, $CaSO_4$ reduced the fruit acceptability compared to $CaCl_2$ and $Ca(NO_3)_2$ treatments. Interestingly, calcium salts treatments not only reduced the percentage of decay and the amount of fruit shrinkage but also increased firmness and TSS content during storage. Preserving vitamin C and total phenol content during storage is important because it protects the fruit against free radicals produced due to senescence and stress lead to increase the fruit shelf life. The study suggests that postharvest $CaCl_2$ and $Ca(NO_3)_2$ application can be used effectively to maintain quality and preserve the bioactive compounds of fresh jujube fruit during cold storage.

Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

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The Official Journal of the **Farm to Fork Foundation**
ISSN: 2518–2021 (print)
ISSN: 2415–4474 (electronic)
http://www.f2ffoundation.org/faa