Effect of Calcium Chloride, Cultivar and Maturity on Shelf Life of Fresh Jujube Fruits

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ABSTRACT

Jujube is one of the most important horticultural fruits with high nutritional and medicinal value. Due to the short shelf life of fresh jujube, consumption of fresh fruit is low. This study aimed to evaluate the treatments affecting the quality of three fresh jujube cultivars. Treatments included jujube cultivars (commercial, Mazhan, and Siojan), fruit harvest time (semi-mature and fully mature), foliar spraying of trees (0 and 2%), and storage time (20 and 35 days). Assessed traits were brix, acidity, firmness, Ascorbic acid, total phenolic compounds, and color indexes ($L^*a^*b^*$). Calcium chloride solution was used to improve the quality and shelf life of fruits. Jujube fruits were stored in a refrigerator at 5°C. Data analysis was performed using a factorial experiment based on a completely randomized design and three replications. Results showed the Siojan cultivar had the best quality characteristics: its phenol content was 2.438 mg gallic acid/gr solid weight, the ascorbic acid value was 929.91 mg 100 g^{-1}, the firmness was 7,390 N m^{-1}, and its Lightness (L^*) was 27.71. Foliar spraying treatment was approved for the firmness and color of fruits. After 20 days, firmness (10,460 N m^{-1}) and ascorbic acid (924.843 mg 100 g^{-1}) were maintained, and after 35 days, total phenol (2.447 mg gallic acid g^{-1} solid weight) was increased. The sensory analyses results showed Siojan cultivar with other advantages, including large size, good taste, and high flesh to kernel ratio. Overall, Siojan cultivar had a good shelf life of up to 20 days at 5°C.

Keywords: Compositional quality, Jujube cultivar Siojan, Ripening, Ziziphus jujuba Mill.

INTRODUCTION

Jujube (*Ziziphus jujuba* Mill) is a member of the Rhamnaceae family. Jujube is an important plant species with its nutritive properties, which is especially important in Asia and in the European continent in recent years. The jujube plant, which can be grown in a wide range of ecological conditions, is also an important species with its herbal properties.

Iranian jujube trees are widely grown in South Khorasan Province, which is its most important production area in Iran (Zeraatgar *et al*., 2017). Jujube fruits can satisfactorily supply the various needs of consumers. The flesh is as sweet as honey and as crisp as an apple or pear (Liu *et al*., 2020). The fruit is particularly rich in nutrients and its contents of sugar, vitamin C and B, cyclic nucleotide, proline, triterpenic acid, potassium, iron, and zinc are the highest among many fruits (Hu, 2011. Liu *et al*., 2009). The fruit is also a rich source of polysaccharides, triterpenic acids, flavonoids, alkaloids, polyphenols, and pigments (Liu and Wang, 2019; Liu *et al*., 2016). Fresh jujube is recommended as a healthy and nutritious snack and herbal medicine in Middle-East countries (Chen *et al*., 2017). Jujube is not only a delicious fruit, but also aids weight gain, improves muscular strength, and increases stamina (Wonder, 2001). It is a medicine/food

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homolog and a famous commonly used traditional medicine.

There are many different jujube varieties grown worldwide. Some are fresh eating varieties, some are best for drying or processing, while others are multipurpose. It can be used for the preparation of some food products, such as beverages, jams, jelly as well as pickles, and compotes (Rashwan *et al*., 2020).

Jujube fruits are subject to rapid senescence after harvest, which leads to post-harvest decay, dehydration, tissue softening, or flesh browning, resulting in a poor sensory quality and economic loss (Zhang *et al*, 2019). Fresh jujube fruit has a short shelf life of about three days at ambient temperature, and it is characterized by flesh browning, shrinkage, and reduced eating quality (Moradinezhad *et al*., 2018).

The maturity stage at harvest time is an essential pre-harvest factor that determines the storage potential and final fruit quality (Braman *et al*., 2015). Fruit maturity at harvest time is one of the main factors that determine the compositional quality of fruits and vegetables, as well as storage life and final quality (Lee and Kader, 2000). Depending on the purpose, jujube fruit can be picked from the semi-mature and fully mature stages (Yao, 2013; Gihan and Allam, 2017). During storage and marketing, it encounters several problems such as weight loss, decrease in firmness, reduction of vitamin C, and pulp browning, which reduce the quality of fresh jujube fruit (Moradinezhad, *et al.,* 2018). Due to respiration and other physiological actions, fresh jujubes rot easily and lose water during transportation and storage (Wang *et al*., 2011).

The importance of calcium in different stages of fruit maturation and ripening is well established (Poovaiah, 1986). This can be supplied by pre-harvest spray or postharvest immersion (Tzoutzoukou and Bouranis, 1997). Calcium plays a key role in the cell wall and plasma membrane stability. In calcium deficiency, respiration rate increases, and 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 and Khoreiby, 1991; Moradinezhad *et al*., 2019). Calcium treatments increased fruit calcium concentrations and delayed ethylene production, as well as softening and color changes (Saba, *et al*., 2016). 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 pre-harvest calcium accumulation reaches the level that inhibits visual deficiency symptoms in fruits, postharvest application frequently has a beneficial effect such as shelf life extension (Park and Kim, 2016). Calcium plays an important role in 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 increase the amount of calcium in the fruit have a positive effect on improving the quality of the fruit and increasing its shelf life.

In addition, recent studies on jujube showed that pre harvest calcium chloride treatment significantly affected fruit qualitative and quantitative properties (Zeraatgar *et al*., 2017).

Fruit maturity stage at harvest time is a fundamental factor for successful storage and final quality of post-harvest fruit. The harvesting time is crucial for jujube fruit quality. There are 4 developmental stages for quality of Jujube fruits when harvested. They are white mature (light green), crisp mature (white-red), fully mature (red), and fully ripe mature (dehydrated brown). The results showed that fruit dry weight, TSS, TSS/TA increased significantly, while firmness, protein content and ash weight decreased as jujube fruit was harvested at progressed development stages. Ascorbic acid in fruit decreased from white to crisp mature stage and, thereafter, increased significantly to fully mature stage. However, the content of total phenol increased significantly from white to crisp mature stage and, thereafter, decreased at more maturity and ripening stages. Moreover, chlorophyll fluorescence parameters were influenced by harvesting time. Overall, jujube fruit harvested at crisp (white-red) and fully mature (red) stages, seem best in respect of postharvest handling and nutritional criteria.

There are some more recent related studies about jujube ripening. Keles (2020) investigated changes of some horticultural characteristics in jujube (*Ziziphus* jujube Mill.) fruit at different ripening stages. The ripening stages were determined by reference degree (%) of the red zone on the surface of the fruit. Fruit weight, length, width, color, and firmness were examined as morphological characteristics, phenolics, organic acids, fatty acids, and sugars were evaluated as biochemical characteristics.

In this study, the purpose was to determine the qualitative properties and shelf life of three fresh jujube cultivars. Fresh jujube fruits were harvested at 2 stages of maturing and calcium chloride was used in 2 forms including spraying and immersion.

MATERIALS AND METHODS

Plant Material and Treatments

Fresh jujube fruits of Iranian cultivars at semi-maturity (white-red) and full maturity (red) stages were harvested from the Agricultural Research Center of south Khorasan in the mid-August 2020, and then transferred to the quality control lab. The jujube trees were 5 years old. Treatments included jujube cultivars (commercial, Mazhan, and Siojan), foliar spraying of trees (0 and 2%) (Taain *et al*., 2016), and storage time (20 and 35 days). Assessed traits were brix, acidity, firmness, ascorbic acid, total phenol, and color indexes ($L^*a^*b^*$).

Jujube fruits were dipped in calcium salt solutions for 5 min. Then, the fruits (100 g per bag, about 20 fruits) were air-dried, placed in zip plastic bags, sealed, and stored in a refrigerator at 5±1°C for a few days until they were spoiled and crushed. The physicochemical and organoleptic characteristics of fresh fruit were evaluated during the storage period. Ten samples were collected from each replicate for chemical assessments including Soluble Solid Content (SSC), Acidity (TA), total phenol compounds, ascorbic acid, and firmness.

Measurement of Physicochemical Attributes

Total soluble solids content (Brix º)

The Total Soluble Solids (TSS) of fruits juice were measured at room temperature (20°C) using a refractometer (Carl Zeiss company, China). The TSS was expressed as a percentage.

Titratable Acidity

Titratable Acidity (TA) was determined 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 citric acid.

Ascorbic Acid (Vitamin C)

The juice extracted from jujube varieties 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 seconds). The ascorbic acid of the sample was determined according to Park and Kim (2016). The ascorbic acid was measured in terms of mg 100 g^{-1} of jujube sample.

Total phenolic compounds

The total phenol contents were determined in the jujube fruits by the Folin–Ciocalteau method as described by Singleton (1965). A sample of 300 µL of the supernatant was added into a solution of 1.5 mL 10% (v/v) Folin-Ciocalteau reagent solution and 1.2 mL saturated Na_2CO_3 solution (7.5%). The mixture was left in a place without light for 90 minutes. The absorbance was then measured at 760 nm using a spectrophotometer (UV-vis, Farasia Co, UK). The total phenolic content was expressed as mg Gallic Acid (GA) fresh weight.

Fruit Peel Color Parameters (L, a*, b*)*

Fruit color parameters were quantified using a Hunter Lab colorimeter (Color Flex model, USA). At each measurement, color components (L*– Brightness, a*– Redness and greens, and b*– Yellowness and blue color) were measured (Mc Gure, 1992).

Firmness

For this purpose, the firmness of jujube fruit tissue was determined by a penetration test in the texture analyzer (QTS25 CNS Farnell model, UK). In this test, jujubes were subjected to a steel probe with a diameter of 3 mm and an initial force of 0.1 N. The speed of the probe was 1 mm s^{-1}. The texture is expressed in N m^{-1}.

Organoleptic assessment

To evaluate the taste, firmness, ripeness, and general appearance, the five-point hedonic test was used with a score of 1–5 (5: Very good, 4: Good, 3: Acceptable, 2: Bad, and 1: Very bad) by 10 trained panelists.

Statistical Analysis

Data analysis was performed using a factorial experiment based on completely randomized design with three replications and Duncan's multiple range tests were used for means comparison. All statistical analyses were conducted with SPSS version 16. The mean comparison was investigated by the Least Significant Difference (LSD) test (Statistical Methods and Data Analytics).

RESULTS AND DISCUSSION

In this section, treatments that had a significant effect on the quality characteristics at the 1% level are discussed.

Cultivars Effect

Brix

Brix in different jujube cultivars is affected by genetic characteristics, climatic and weather conditions, and fruits ripening rate (Wu *et al*., 2012). The effect of cultivar on the brix of samples was significantly different at the 1% level. The highest and lowest brix belonged to jujube commercial and Siojan cultivars with 30.46 with 27.09, respectively (Table 1). The brix of 13 jujube fruits cultivars harvested at the commercial maturity stage were different (Mighani, 2017).

Acidity

The effect of cultivar on the acidity of jujube samples was significantly different. The highest acidity belonged to the Mazhan cultivar (1.2) and there was no significant difference between the other two cultivars in terms of acidity (Siojan 0.96 and commercial 0.965) (Table 1).

Total Phenolic Compounds

The effect of cultivars on the total phenol in the samples was significantly different. Most phenols were related to Siojan (2.438 mg gallic acid g^{-1} solid weight) and commercial cultivars (2.426 mg gallic acid g^{-1} solid weight) (Table 2). The researches have shown that the difference in phenol in jujube fruits is affected by the type of cultivar and the stage of fruit maturity (Memon *et al*., 2013). In the quality measurements of fruits in one study, the results showed that the amount of phenol in fruits depended on the genotype of the fruits and was influenced by climatic and environmental conditions. There was also a direct relationship between the amount of phenol and vitamin C in jujube fruit and their antioxidant properties (Mighani, 2017). The results of the mentioned research confirm the results of the present project.

Ascorbic acid

The effect of cultivars on ascorbic acid in the samples was significantly different. The highest and lowest ascorbic acid was related to Siojan (929.91 mg 100 g^{-1} fruit) and Mazhan (360.62 mg 100 g^{-1} fruit), respectively (Table 2). The results showed that ascorbic acid in different jujube cultivars were in the range of reports by other researchers (Koley *et al*., 2011; Obeed *et al*., 2008).

The amount of ascorbic acid in fruits was affected by production factors, environmental conditions, fruit maturity stage, fruit position on the tree, type of species and crop, movement, and storage conditions (Nyanga *et al*., 2013).

Firmness

The effect of cultivars on firmness in the samples was significantly different. The commercial cultivar had the highest firmness (9,391 N m^{-1}) and the Mazhan cultivar had the lowest firmness (3,695 N m^{-1}) (Table 2).

Color parameters (L, a*, b*)*

The effect of cultivar on the color parameter (L*) of jujube fruit peel was significantly different. The highest L * belonged to the Siojan cultivar (27.71) and the lowest belonged to the Mazhan cultivar (25.56) (Table 3).

L* indicates the amount of transparency and brightness in the color. According to the results, Siojan cultivar had the highest transparency compared to other cultivars. The effect of cultivar on the color parameter (a*) of jujube fruit peel was significantly different. The highest a* belonged to the commercial cultivar (19.97) and the lowest belonged to the Mazhan cultivar (18.53) (Table 3). The index of a* shows the amount of redness. According to the available data, the jujube commercial cultivar had the most redness in appearance.

The effect of cultivar on the color parameter (b*) of jujube fruit peel was significantly different. The highest b* belonged to the Siojan cultivar (19.08) and the lowest belonged to the Mazhan cultivar (16.71) (Table 3). This index indicates the amount of yellowing, so according to the results, the Siojan jujube cultivar had the most yellow in appearance.

The general evaluation of the effect of cultivar on color of fruits was that the commercial jujube cultivar had the most redness compared to the other two cultivars and the Siojan cultivar had the most transparency and yellowing.

Foliar spraying effect

Brix

The effect of foliar spraying on brix was significantly different. The control jujube (trees without foliar spraying) had more brix

Table 1. Comparison of the mean effects of treatments on brix and acidity of jujube fruit.

Treatment		Brix	Acidity
Variety	Siojan	27.09 ± 0.129 c	0.96 ± 0.006 b
	Mazhan	27.98 ± 0.129 b	1.2 ± 0.006 a
	Commercial	30.46 ± 0.129 a	0.965 ± 0.006 b
Foliar spraying	0%	30.22 ± 0.105 a	0.971 ± 0.005 NC
	2%	27.47 ± 0.105 b	0.979 ± 0.005 NC
Maturity stage	SM	27.21 ± 0.105 b	0.968 ± 0.005 NC
	FM	30.48 ± 0.105 a	0.981 ± 0.005 NC
Storage time	20 days	27.79 ± 0.105 NC	0.996 ± 0.005 a
	35 days	27.9 ± 0.105 NC	0.954 0.005 b

[a] (a-c) Numbers with the same letters in each column are not statistically significant (P< 0.01); nc: not significant P > 0.05.

Table 2. Comparison of the mean effects of treatments on phenol, ascorbic acid and firmness of jujube.

Treatment		Phenol (mg gallic acid g^{-1} solid weight)	Ascorbic acid (mg 100 g^{-1})	Firmness (N m^{-1})
Variety	Siojan	2.438 ± 0.013 a	929.91 ± 10.041 a	7390 ± 529.45 b
	Mazhan	2.168 ± 0.013 b	360.62 ± 10.041 c	3695 ± 529.45 c
	Commercial	2.426 ± 0.013 a	392.02 ± 10.041 b	9391 ± 529.45 a
Foliar spraying	0%	2.192 ± 0.01 NC	624.83 ± 8.199 NC	5496 ± 432.29 b
	2%	2.429 ± 0.01 NC	630.19 ± 8.199 NC	8154 ± 432.29 a
Maturity stage	SM	2.423 ± 0.01 a	688.61 ± 8.199 a	8118 ± 432.29 a
	FM	2.199 ± 0.01 b	366.41 ± 8.199 b	5533 ± 432.29 b
Storage time	20 days	2.176 ± 0.01 b	924.843 ± 8.199 a	10460 ± 432.29 a
	35 days	2.447± 0.01 a	330.551 ± 8.199 b	3185 ± 432.29 b

[a] (a-c) Numbers with the same letters in each column are not statistically significant (P< 0.01). nc: not significant P > 0.05.

Table 3. Comparison of the mean effects of treatments on the color parameters of jujube fruit.

Treatment		L*	a*	b*
Variety	Siojan	27.71 ± 0.207 a	19 ± 0.18 b	19.08 ± 0.265 a
	Mazhan	25.56 ± 0.207 c	18.53 ± 0.18 b	16.71 ± 0.265 c
	Commercial	27.03 ± 0.207 b	19.97 ± 0.18 a	18.31 ± 0.265 b
Foliar spraying	0%	26.25 ± 0.169 b	18.52 ± 0.147 b	16.98 ± 0.216 b
	2%	27.29 ± 0.169 a	19.81 ± 0.147 a	19.09 ± 0.216 a
Maturity stage	SM	27.42 ± 0.169 a	18.78 ± 0.147 b	18.75 ± 0.216 a
	FM	26.12 ± 0.169 b	19.55 ± 0.147 a	17.32 ± 0.216 b
Storage time	20 days	26.48 ± 0.169 NC	17.74 ± 0.147 b	17.52 ± 0.216 b
	35 days	27.05 ± 0.169 NC	20.6 ± 0.147 a	18.54 ± 0.216 a

[a] (a-c) Numbers with the same letters in each column are not statistically significant (P< 0.01). nc: not significant P > 0.05.

(Table 1). The decrease in the amount of soluble solids in samples seems to be due to the reduction of respiration rate and metabolism in the fruit, which delays fruit ripening (Pila *et al*., 2010). In one study, the effect of foliar application of calcium chloride on physicochemical properties of seedless fresh barberry fruit was evaluated. The results showed that treated samples had lower brix (Moradinezhad *et al*., 2019), confirming the results of this study.

Firmness

Foliar spraying of fruits with mineral elements can increase quality, and reduce post-harvest damages. Calcium is one of the minerals that are important in increasing the quantity, quality, and customer satisfaction of fruits. Calcium is a major component of the cell wall, which plays a key role in the construction of the middle septum of the cell. Increasing the amount of calcium in the cell increases the amount of calcium pectate and the thickness of the cell wall, thereby increasing the strength of the tissue. In fact, the use of calcium salts such as calcium chloride prevents the conversion of insoluble pectin into solution and reduces the strength of the tissue. In addition, researchers believe that the reason for increasing the strength of fruit tissue by calcium chloride is the key role of calcium in reducing carbon dioxide production, preventing ascorbic acid reduction, reducing water leakage of the cell and thus reducing plasmolysis and aging of the fruit. It is an intercellular binder and stabilizes the pectin compounds in the middle septum (Singh, 1990).

The effect of foliar spraying on firmness was significantly different at the probability level of 1%. Treated Jujube samples had higher tissue hardness. The highest firmness of fruit tissue was obtained from calcium chloride treatment (8,154 N m^{-1}) and the lowest firmness was related to the control (5,496 N m^{-1}) (Table 2). The effect of foliar application of jujube trees with some calcium salts on the physical and biochemical properties of jujube fruit was investigated in a study. The results showed that calcium chloride increased the firmness of fruit tissue by 0.5% and improved the physicochemical properties of fresh jujube fruit (Ghesmati *et al*., 2019).

In another study, foliar application of calcium chloride increased the firmness of apple fruit (Delmaghani, 2004). Increased apricot tissue strength under the influence of calcium chloride foliar application has also been reported (Tzoutzoukou and Bouranis, 1997).

Color parameters (L, a*, b*)*

Foliar spraying increased each of the color parameters compared to the control (no foliar spraying) (Table 3). In one study, the effect of foliar spraying with different concentrations of calcium chloride on the quality and quantity of Konar fruit was evaluated. Fruits were harvested from homogeneous trees after foliar spraying of calcium chloride (0.5, and 1.5 %). The results showed that foliar spraying was very effective. The treated fruits had less red color and their brightness and yellow color were not significantly different from the control samples. Calcium chloride foliar spraying at a concentration of 0.5% had an effective role in improving the quality characteristics of the fruit (Shanbeh Poor Bandari, 2019).

Fruit maturity effect

Brix

The effects of fruit maturity stage on the brix of jujube samples were significantly different. Brix of jujube samples in Full Maturity (FM) (red) with 30.4 % was significantly higher than Semi-Maturity (SM) (red and white) with 27.21% (Table 1). In addition to genetic characteristics, the amount of brix also depends on the ripening stage of the fruit (Wu *et al*., 2012). In one study, the effects of kiwi fruit harvesting times on its quantity and quality characteristics were investigated. The results showed that with more ripening of kiwi and delay in harvest time, the acidity decreased and the soluble solids (brix) of fruit increased, which improved its quality and reduced shelf life of kiwi fruit (Farzam *et al*., 2020), consistent with the results of our study.

Ascorbic Acid

The effects of fruit maturity stage on ascorbic acid of jujube samples were significantly different. Ascorbic acid of SM jujube samples (688.61 mg 100 g^{-1} of fresh fruit) was significantly higher than ascorbic acid of FM jujube samples (366.41 mg 100 g^{-1}) (Table 2). The amount of ascorbic acid in fruits is affected by production factors and environmental conditions, the stage of fruit maturity, and the location of the fruit on the tree. Therefore, by gradually increasing the ripeness of the fruit, ascorbic acid in jujube fruits decreased (Nyanga *et al*., 2013).

Firmness

The effects of the fruit maturity stage on the firmness of jujube samples were significantly different. SM jujube had higher tissue firmness (8,118 N m^{-1}) than FM (5,533 N m^{-1}) (Table 2).

In one study, the effects of factors affecting the maturity of fruits in different pear cultivars were investigated. There are effective factors to determine the exact time of fruit harvest from flowering time to harvesting time. The results showed that the firmness of fruit tissue during ripening decreased. Measuring the firmness of tissue was one of the most effective methods of determining the maturity of pear fruit (Dooleh, 2011).

Color parameters (L, a*, b*)*

The effect of fruit maturity on color parameters L*, a* and b* was significantly different. The L* content of SM samples was higher than FM samples. SM samples had more clarity than FM. The amount of redness (a*) of FM jujube samples (19.55) was significantly higher than SM (18.78). As the fruits ripen, the redness of the skin increases. The yellowness of SM jujube samples (18.75) was higher than FM (17.32). The SM jujube had more yellowness (Table 3).

The general result is that during fruit ripening, the redness of the fruits increased and the yellowness and transparency of the fruits decreased.

Maturity is the most important and complex stage in the development of the fruit, where they acquire sensory characteristics that define it as edible.

Fruit storage time

Acidity

The effects of fruit storage time at 5°C on acidity were significantly different. The acidity of jujube samples after 20 days of storage at 5°C was significantly higher than 35 days of storage (Table 1). Over time, the ripeness of the fruit increased and its acidity decreased, which seems logical. The results obtained from the research of Moradinezhad *et al*. (2018) confirm this issue. In one study, the effect of 40-day storage at 10-day intervals on some quality factors of fresh jujube fruit was investigated. The results showed that the acidity was reduced during the storage time (Zeraatgar *et al*, 2020), confirming our research.

Firmness

The effects of jujube storage time at 5°C on the firmness of jujube samples were significant. Jujube samples after 20 days of storage had higher tissue firmness (10,460 N m^{-1}) and were higher than the tissue firmness after 35 days (3,185 N m^{-1}) (Table 2). In one study, the effect of different stages of fruit ripening at harvesting time on the shelf life of apple fruit was investigated. Fruits were harvested in 4 different stages of ripening, and with increase in the degree of ripeness, their firmness decreased (Orangi *et al*., 2011), similar to our results for jujube.

The effects of harvest and storage times on the quality of fig fruit at 4 °C, different storage times caused significant changes in firmness, which decreased over time (Moradinezhad *et al*., 2020).

Ascorbic Acid

The effects of fruit storage time at 5°C on the amount of ascorbic acid in jujube samples were significantly different. Jujube samples after 20 days of storage had more

Table 4. Comparison of mean sensory parameters of jujube. [a]

Sample	Taste	Hardness	Maturity	Appearance
SM Siojan	2.25 ± 1.28 c	2.75 ± 1.28 b	2.62 ± 1.06 c	2.37 ± 1.06 c
FM Siojan	4.75 ± 0.46 a	4.25 ± 0.7 a	4.87 ± 0.35 a	4.37 ± 0.74 a
SM Mazhan	3.37 ± 0.91 bc	3.37 ± 0.91 ab	2.62 ± 0.51 c	3.25 ± 0.7 bc
FM Mazhan	3. 5 ± 0.75 b	3.75 ± 0.46 ab	4 ± 0.75 ab	4.5 ± 0.75 a
SM Commercial	3.25 ± 0.88 bc	3.25 ± 0.88 ab	3.25 ± 0.46 bc	4 ± 0.75 ab
FM Commercial	4.25 ± 0.46 ab	4.37 ± 0.74 a	4.37 ± 0.51 a	4.37 ± 0.51 a

[a] (a-c) Numbers with the same letters in each column are not statistically significant (P< 0.01).

ascorbic acid (924.843 mg per 100 g of fresh fruit) than jujube after 35 days of storage (330.551 mg 100 g^{-1} of fresh fruit) (Table 2). There is evidence that ascorbic acid is sensitive to, and degraded by, some factors, such as heat, air, light, and mechanical action. Ascorbic acid oxidizing enzymes are activated in the environment and oxidize ascorbic acid. Ascorbic acid in the fruits gradually decreases during storage. Because it is a water-soluble vitamin, it is killed faster in juicy fruits by reduction of water or by rotting and crushing the fruit (Tabatabaii *et al*., 1995).

In another study, the effect of jujube shelf life on ascorbic acid in fresh fruit at different temperatures and conditions was investigated. The stability of ascorbic acid in fresh jujube fruit was assessed during storage. The results showed that ascorbic acid decreased during storage at different temperatures (Kohansal *et al*., 2020).

Total Phenol Compounds

The effects of fruit storage time at 5°C on the phenol content of jujube samples were significantly different. Jujube samples after 35 days of storage had more phenol (2.447 mg gallic acid g^{-1} solid weight) than after 20 days of storage (2.176 mg gallic acid g^{-1} solid weight) (Table 2).

During cold storage of fruit, due to the stress caused by low temperatures following the increase of reactive oxygen species, the accumulation of phenolic compounds in the cell is increased, such that their accumulation in ripe tomatoes is more than in unripe fruits (Dea *et al*., 2017). In overripe peach fruits, the increase in total phenols may be due to chemical and enzymatic changes that lead to the production of water-insoluble phenolic compounds in the form of polymerization of free phenolic compounds (Remorini *et al*., 2008). One study showed that, following the post-cherry treatment, the phenolic content of the fruit increased during storage. The effect of blueberry harvest time on some antioxidant properties during storage was investigated. The results showed that with the development of maturity and fruit ripening during storage, the amount of phenolic compounds increased (Esmaeili *et al*, 2020). These results are similar to ours for jujube.

Color Parameters (L, a*, b*)*

The effect of jujube fruit storage time on color parameters of b* and a* was significantly different at 1 and 5% levels, respectively, but the effect of storage on the L* parameter was insignificant. The redness (a*) of jujube samples after 35 days of storage was significantly higher after 20 days of storage. Over time, the redness increased due to more maturing samples. The yellow rate (b*) of the samples after 35 days, was more than 20 days (Table 3). Over time, the mature samples became more yellow. The general result is that with more fruit ripening, the amount of redness and yellowness of the samples increased.

Sensory Evaluation Results

Comparison of the means of sensory characteristics showed that they were significantly different (Table 4). The highest score in taste belonged to FM Siojan. In terms of texture, the best samples were FM Siojan and commercial cultivars, which did not differ significantly. In terms of maturity, FM Siojan and commercial were selected as the best samples. The appearance of the FM Mazhan, commercial, and Siojan were better than SM samples.

Overall, in terms of sensory properties, FM Siojan and commercial scored the highest. Finally, FM Siojan was selected with more advantages such as larger size, sweetener taste, and higher fruit flesh to seed ratio.

CONCLUSIONS

In the present study, we observed that the maturity at harvest time is an important factor in determining jujube fruit nutritional quality and its shelf life. Harvesting time must take into account these parameters, along with the quality characteristics essential for postharvest technology, but also for consumer acceptance. Overall, jujube fruit harvested at SM conditions (white-red) was the best. Results showed that Siojan cultivar had the best quality and sensory characteristics, such that its phenol was (2.438 mg gallic acid/gr solid weight), ascorbic acid value was (929.91 mg 100 g^{-1}), firmness was (7,390 N m^{-1}), and its transparency (L^*) was (27.71). Foliar spraying treatment was approved for the firmness and color of fruits. After 20 days storage of jujube fruits, firmness (10,460 N m^{-1}) and ascorbic acid (924.843 mg 100 g^{-1}) were the highest. After 35 days, total phenol (2.447 mg gallic acid g^{-1} solid weight) was increased. The sensory analyses results showed Siojan cultivar with other advantages such as larger size, better taste, and higher flesh to kernel ratio, therefore, it was selected. Overall, Siojan cultivar had a good shelf life of up to 20 days at 5°C.

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تاثیر کلرید کلسیم، رقم و میزان رسیدگی میوه بر ماندگاری عناب تازه

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چکیده

عناب از جمله محصولات باغی مهم است که ارزش غذایی و دارویی زیاد دارد. با توجه به پایین بودن عمر نگهداری عناب تازه ، مصرف تازه خوری کم دارد. هدف از پروژه انجام شده ارزیابی تیمارهای موثر بر کیفیت سه رقم عناب تازه بود. تیمارها ارقام عناب (کلون تجاری، رقم ماژان و رقم سیوجان)، زمان برداشت میوه (نیمه رسیده، رسیده کامل)، محلول پاشی درختان (۰ و ۲ درصد) و زمان نگهداری (۲۰ و ۳۵ روز)بودند. آزمایشات بریکس، اسیدیته، سفتی بافت، اسید آسکوربیک، فنل کل و شاخص های رنگی ($L^*a^*b^*$) بودند. از محلول کلرید کلسیم به منظور محلول پاشی برای بهبود کیفیت و عمر نگهداری عناب استفاده شد. سپس

عناب ها در یخچال با دمای C° ۵ نگهداری شدند. داده ها با آزمون فاکتوریل بر اساس طرح کامل تصادفی با سه تکرار آنالیز شدند. نتایج نشان داد رقم سیوجان دارای بیشترین میزان فنل (mg gallic acid/gr solid weight ۲/۴۳۸)، اسید آسکوربیک (۹۲۹/۹۱ mg/100 g) و درخشندگی(۲۷/۷۱) بود. میوه ها در حالت نیم رس نسبت به حالت رسیده کیفیت بهتر داشتند به طوری که سفتی بافت‌N/m ۸۱۱۸ ، اسید آسکوربیک ۶۸۸/۶۱ mg/100 g ، فنل کل ۲/۴۲۳mg gallic acid/gr solid weight داشتند. محلول پاشی باعث بهبود سفتی بافت و رنگ میوه ها شد. بعد از ۲۰ روز نگهداری، سفتی بافت میوه ۱۰۴۶۰ N/m و اسید آسکوربیک‌mg/100 g ۹۲۴/۸۴۳ اندازه گیری شدند. پس از ۳۵ روز نگهداری، میزان فنل کل به mg ۲/۴۴۷gallic acid/gr solid weight افزایش یافت. نتایج آزمایشات حسی نشان داد رقم سیوجان با داشتن مزایایی نظیر اندازه بزرگ، بافت مطلوب و نسبت گوشت به هسته بالا مورد پذیرش قرار گرفت. در کل رقم سیوجان در دمای C° ۵ تا ۲۰ روز به خوبی نگهداری شد.