

Influence of Putrescine Application on Storability, Postharvest Quality and Antioxidant Activity of Two Iranian Apricot (*Prunus armeniaca* L.) Cultivars

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Abstract

The limited postharvest storage life of apricot is the focus of this study. Presenting a solution to improve the postharvest storage of studied apricot cultivars is the goal. Studying the effect of different concentration of postharvest putrescine on quality attributes and antioxidant activity of two apricot cultivars during storage is the approach taken. The two apricot cultivars ('Lasgerdi' and 'Shahrodi') were harvested at the commercial ripening stage, and fruits were immersed in 1, 2, 3 and 4 mM putrescine as well as distilled water (control) for 5 min, then fruits were packed in boxes with polyethylene cover and stored at 4°C and 95% relative humidity for 20 days. The changes in weight loss, fruit firmness, total soluble solids, titratable acidity, pH, maturity index, ascorbic acid, total phenolics and antioxidant activity were estimated after 0, 5, 10, 15 and 20 days during storage. The results showed that the weight loss, total soluble solids, pH and maturity index increased significantly while the fruit firmness, titratable acidity, ascorbic acid, total phenolics and antioxidant activity decreased significantly during storage for both cultivars. During storage, a significant difference between control and putrescine treatments in all measured parameters is observed. The putrescine treatments reduced significantly the weight loss and maintained their firmness. In this condition, the highest and lowest of titratable acidity, ascorbic acid, total phenolics and antioxidant activity were observed in treatments of 4 mM putrescine and control, respectively. The data revealed that the quality of apricot fruits was improved by the use of putrescine treatment due to its effect on delaying the ripening processes.

Keywords: ascorbic acid, attributes, shelf life, total phenolics.

Introduction

The modern fruit industry needs research promoting the commercial attributes of fruit quality. For Apricot (*Prunus armeniaca* L.) this is of a great importance since attributes are too frequently not satisfactory to the customers (Davarynejad *et al.*, 2010). Due to its nutritional and antioxidant properties, considerable attention has been paid to it in recent years. Apricot is known to contain considerable of vitamins (A and C), minerals, fibre, carotenoids, flavonoids, lycopene and other antioxidant compounds (Hacisferogullari *et al.*, 2007; Munzuroglu *et al.*, 2003).

Apricot is climacteric fruit with a limited postharvest storage life due to acceleration of quality loss, affecting some properties such as fruit firmness, texture, total soluble solids and titratable acidity. A suitable method for shelf life extension, which avoids detrimental effects on quality of fruit, would be beneficial for both the consumer and the producer. A number of strategies have been used to improve the quality properties and shelf life of apricot fruit, such as low temperature storage and postharvest treatments with polyamines (Martínez-Romero *et al.*, 2002), aminoethoxyvinylglycine (AVG) and 1-methylcyclopropene (1-MCP) (Palou and Crisosto, 2003).

Polyamines (PAs) are known as a group of natural compounds with aliphatic nitrogen structure that are ubiquitous in plants, animals and microorganisms. The major polyamines are found in every plant cell, such as spermidine (Spd) and spermine (Spm) and putrescine (Put) (Galston and Sawhney, 1990). It is known that polyamines play important roles in many physiological processes in plants, including growth and development of cell and respond to environmental stresses. Treatment with exogenous polyamines has been reported to increase fruit firmness in apples (Kramer *et al.*, 1989, 1991; Wang *et al.*, 1993), strawberry (Ponappa *et al.*, 1993), tomato (Law *et al.*, 1991), lemon (Valero *et al.*, 1998 a, 1998b, 1998c), peach (Bregoli *et al.*, 2002) and plum (Serrano *et al.*, 2003). Other beneficial effects of exogenous polyamines have been reported for both climacteric and non-climacteric fruit such as delayed colour changes, reduced mechanical damage and susceptibility to chilling injury and increased shelf life (Martínez-Romero *et al.*, 2002; Pérez-Vicente *et al.*, 2002; Serrano *et al.*, 1996). Thus polyamines treatment has the potential for commercial control of quality properties and increased shelf life of harvested fruit.

However, little information exists on the use of different concentration of putrescine to preserve apricot fruit quality during storage. Therefore, the objective of this re-

search was to analyse and compare the effect of different concentrations of postharvest putrescine application on quality properties and antioxidant activity of two most important local and famous apricot cultivars ('Lasgerdi' and 'Shahrodi') during storage.

Materials and methods

The 'Lasgerdi' and 'Shahrodi' apricot cultivars harvested manually at commercial maturity stage at July 2011 from 14 years-old trees in Mashhad, Iran. The average temperature, the amount of rainfall and relative humidity in growing season (March to July) of 2011 were 28.6°C, 20 mm and 26%, respectively. Soil texture were being sand-loam, EC = 4.1 (ds.m⁻¹) and soil pH = 7.2. The trees were spaced 6 and 3 m between and along the rows, respectively. Trees were grown under traditional irrigation and routine cultural practices suitable for commercial fruit production.

Fruits were transported by a ventilated car to the laboratory soon after harvest, where apricots with defects (sunburns, cracks, cuts and bruises in peel) were discarded and then fruits were selected in accordance with their colour and weight. The homogeneous fruits were randomized and divided into 5 lots of 80 fruit for following treatments in 4 replicates (each replicate contained 20 individual fruit): control (distilled water) and different concentration of putrescine (1, 2, 3 and 4 mM). Treatments were performed by dipping fruits in 10 L of solution for 5 min, and then they were left to dry at room temperature and were packed in boxes with polyethylene cover and after stored at 4°C and 95% relative humidity (RH) for 20 days. After 0, 5, 10, 15 and 20 days (5 days intervals), 3 fruit from each replicate for each treatment (12 fruit) were sampled for analytical determinations. All reagents, solvents and standards were of analytical reagent grade.

Weight loss and firmness of fruit

The same samples were evaluated for weight loss of the fruit each time at 5 day intervals until the end of experiment. Fruits were weighted in the air on a balance of accuracy of 0.001 g. The weight loss was determined by the following formula: weight loss (%) = [(A-B)/A] × 100. Where A indicates the fruit weight at the time of harvest and B indicates the fruit weight after storage intervals. Fruit firmness was determined by a fruit pressure tester (8 mm diameter probe) on pared surfaces from opposite sides of each fruit and the results were expressed as Newtons (N).

Total soluble solids, titratable acidity, pH and maturity index

The total soluble solids (TSS) were determined with a digital refractrometer (Erma, Tokyo, calibrated using distilled water). Results were reported as degree °Brix at 21°C. The titratable acidity (TA) was determined by us-

ing a digital acidity assay and expressed as g of malic acid per 100 g of fresh weight (g/100 g FW). The pH measurements were performed using a digital pH meter (Metrohm 601) at 21°C. Maturity index was calculated by dividing total soluble solids to titratable acidity.

Ascorbic acid and total phenolics

Ascorbic acid was determined by employing the method described by Mazumdar and Magumdar (2003). Results were expressed as mg ascorbic acid per 100 g of fresh weight (mg/100 g FW). The total phenolics were determined by using Folin-Ciocalteu method (Singleton *et al.*, 1999). One gram of apricot tissue was extracted with 10 ml methanol (85%). 250 µl of this extract was dissolved in a 250 µl of sterile distilled water, and then samples were mixed with 2.5 ml of 10-fold-diluted Folin-Ciocalteu reagent and 2 ml of 7.5% sodium carbonate. The mixture was shaken for 1.5 to 2 hours before the absorbance was measured by a Cecil 2010 UV-visible spectrophotometer at 765 nm. Gallic acid was used as a standard. The results were expressed as mg gallic acid equivalent in 100 g fresh weight (mg/GAE 100 g FW).

Antioxidant activity

Antioxidant activity was assessed according to the method of Ismail *et al.* (2009). Briefly, 1 g of apricot tissue was extracted with 10 ml methanol (85%). One ml of this extracts were mixed with 2 ml of 0.15 mM DPPH in methanol. The mixtures were shaken vigorously and left to stand for 30 min (under dark condition). The control was prepared by adding 2 ml of DPPH to 1 ml methanol. Absorbance of the resulting solution was measured at 517 nm by a Cecil 2010 UV-visible spectrophotometer. The antioxidant activity is expressed in the form of the percentage of free radical scavenging.

Statistical analysis

This experiment was conducted according to factorial based on completely randomized block design with 4 replications. Data were analyzed by Statistical Analysis System (SAS) software Version 9.1 using analysis of variance (ANOVA) and differences among means were determined for significance at $p < 0.05$ using Tukey's test.

Results and discussion

Weight loss

The weight loss increased significantly during storage at 4°C in both cultivars (Fig. 1). Similar results were also reported by Ghasemnezhad *et al.* (2010). There were a significant difference ($p < 0.05$) between treatments of control and putrescine in terms of their effects on weight loss (Fig. 1). The control treatment had the highest weight loss during storage, followed by the 1 mM putrescine treatment, while the lowest was in 4 mM putrescine treatment. The results were in agreement with the findings re-

ported by Martínez-Romero *et al.* (2002) and Serrano *et al.* (2003).

According to Woods (1990), weight loss in fruit during storage could be due to the water exchange between the internal and external atmosphere, the transpiration rate being accelerated by cellular breakdown. In this sense, the putrescine treatment modified or consolidated the cell disposition and delays the removal of epicuticular waxes which play an important role in water exchange through the skin, and then lower weight loss would occur. With regard to the results, the putrescine treatments showed significantly less of weight loss during storage being a negative correlation between putrescine concentrations and weight loss.

Fruit firmness

As shown in Fig. 2, fruit firmness (expressed as force-deformation ratio) declined rapidly during storage at 4°C for both cultivars, that the fruit firmness levels at the initial of the storage period were higher than the end ones just for the all treatments. Martínez-Romero *et al.* (2002) has reported that apricot fruit firmness decreased significantly during storage. Significant differences ($p < 0.05$) were revealed among the treatments for fruit firmness (Fig. 2). The treatment of putrescine showed significantly highest

firmness levels than control treatment during storage. The higher the putrescine concentration applied, the greater the improvement in firmness, that highest firmness values were observed in 4 mM putrescine treatment. Similar results were also reported for apples (Wang *et al.*, 1993), other apricot cultivars (Martínez-Romero *et al.*, 2002), plum (Serrano *et al.*, 2003) and strawberry (Zokaee *et al.*, 2007).

Fruit softening during storage is the main factor limiting storage and shelf life of apricot fruit. The effect of polyamines on the reduction of fruit softening or firmness augmentation can be attributed to their capacity cross-link to pectic substances in the cell wall, resulting in rigidification that is detectable immediately after treatment (Abbot *et al.*, 1989) and also as inhibition of the action of wall-degrading enzymes, such as pectinesterase, pectinmethyl-esterase and polygalacturonase and reduce fruit softening during storage (Valero *et al.*, 2002). In accordance with this hypothesis, the putrescine exogenously applied went to cell walls to maintain high levels of fruit firmness and these high levels of firmness lead to increased shelf life.

Total soluble solids

For both cultivars, content of total soluble solids decreased during the first 5 days of storage and from this time

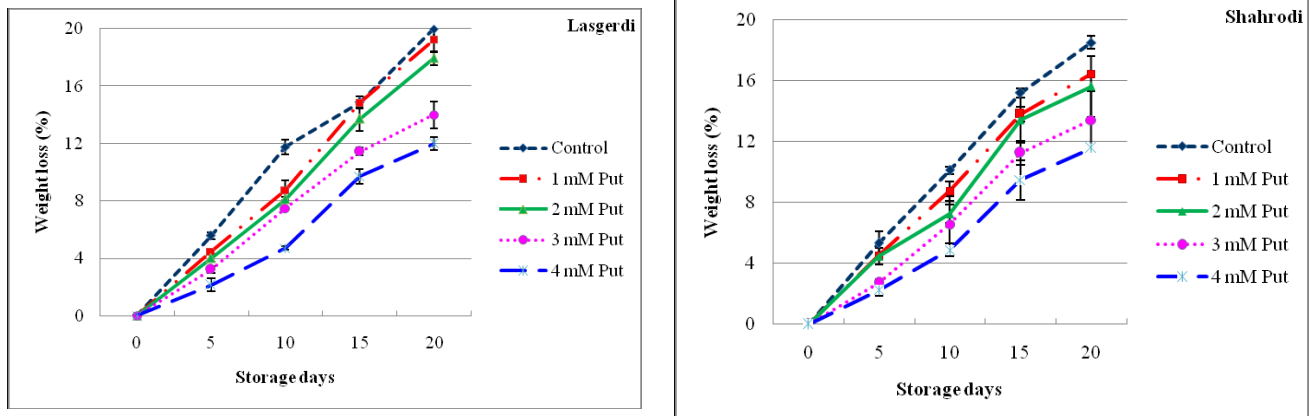


Fig. 1. Effect of putrescine on weight loss (%) of two Iranian apricot cultivars during storage at 4°C. The results represent the means of 12 fruit in 4 replicates ± standard errors

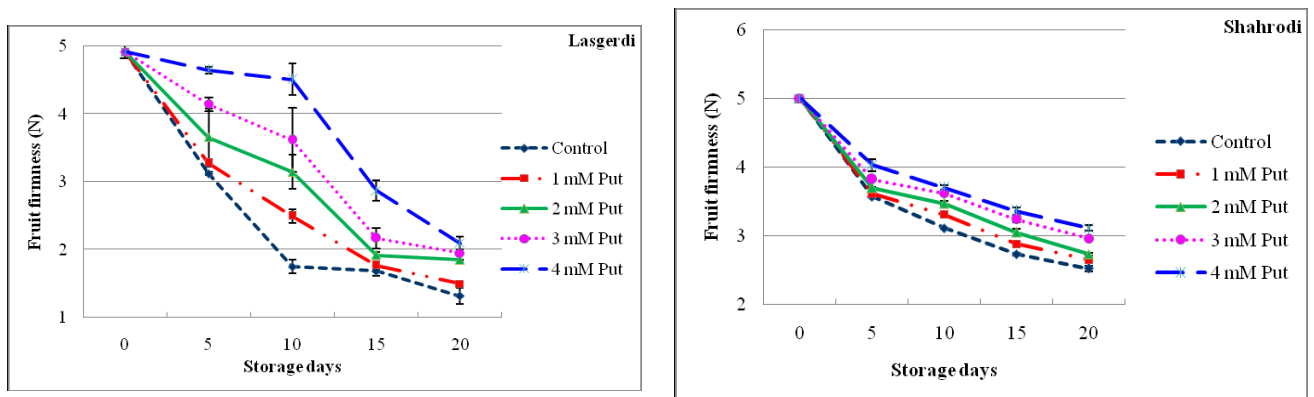


Fig. 2. Effect of putrescine on fruit firmness (N) of two Iranian apricot cultivars during storage at 4°C. The results represent the means of 12 fruit in 4 replicates ± standard errors

until end of the storage period increased (Fig. 3). Similar patterns of changes were reported by Zokaee and Esna-Ashari (2008). As shown in Fig. 3, a variation in terms of total soluble solids content was observed among the treatments and the differences were statistically significant ($p < 0.05$). The highest concentration of total soluble solids was observed for control treatment during storage, followed by 1 mM and 2 mM putrescine treatments while the lowest was in 4 mM putrescine treatment. Similar data were also reported for apricot (cv. 'Tokhm Sefid') and peach (cv. 'Zapferani') (Zokaee and Esna-Ashari, 2008).

The during storage, increase in content of total soluble solids was probably due to concentrated juice content as a result of dehydration and hydrolysis of polysaccharides. During storage, all treatments showed increases in content of total soluble solids, although the increases were significantly lower in treatment of putrescine than in control treatment. This effect of putrescine can be attributed to low levels of the respiration rate, ethylene production and delay in ripening process. According to data, one can say that there is an inversely relation between putrescine concentrations and level of total soluble solids during storage.

Titrateable acidity

The results showed that titrateable acidity content decreased significantly during storage at 4°C for both culti-

vars (Fig. 4), which is in agreement with results Ghasem-zhad *et al.* (2010). There was a significant difference ($p < 0.05$) between control and putrescine treatments in terms of their effects on level of titrateable acidity (Fig. 4). Among the studied treatments, 4 mM putrescine treatments had the highest amount of titrateable acidity and control treatment had the lowest titrateable acidity content during storage. Zokaee *et al.* (2007) also reported that the treated strawberry fruits with putrescine had the highest amount of titrateable acidity during storage.

The titrateable acidity is an important factor in maintaining the quality of apricot fruits, which is directly related to the organic acids content present in the fruit. The putrescine treatment showed decreases were significantly lower in content of titrateable acidity than control treatment during storage. Zokaee *et al.* (2007) and Ishaq *et al.* (2009) suggested that titrateable acidity decreases could be due to consumption of organic acids in fruits during respiration. In the present study it seems that putrescine treatments did have any significant effect on respiration process which could reduction or delay of respiration and maintain titrateable acidity.

pH

As shown in Fig. 5, pH values decreased during the first 5 days of storage and from this time until end of the storage

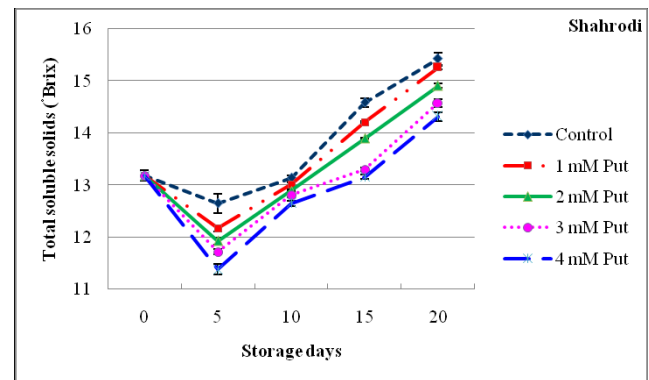
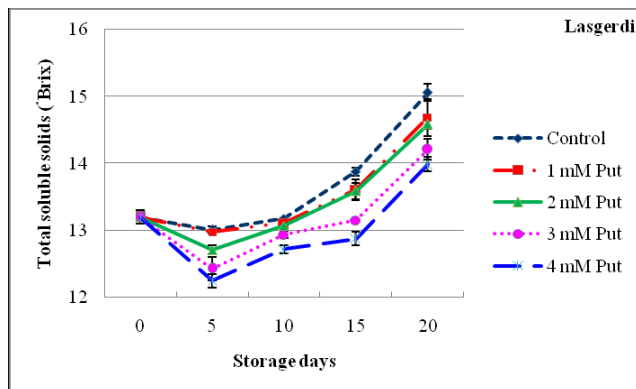


Fig. 3. Effect of putrescine on total soluble solids (°Brix) of two Iranian apricot cultivars during storage at 4°C. The results represent the means of 12 fruit in 4 replicates ± standard errors

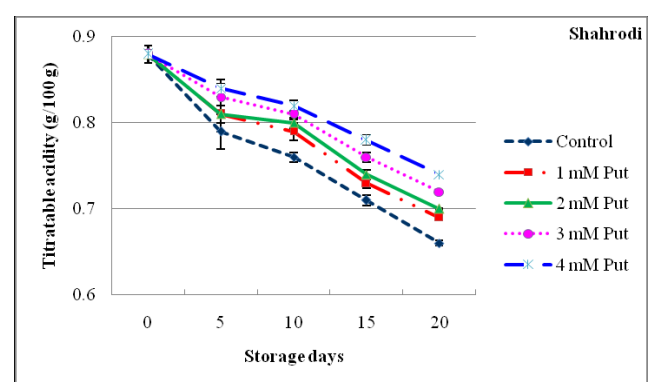
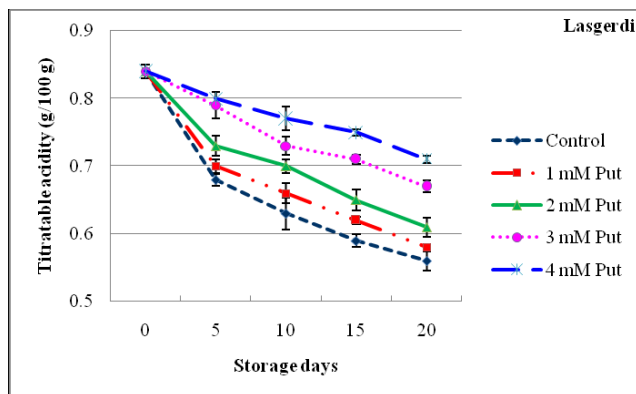


Fig. 4. Effect of putrescine on titrateable acidity (g/100 g fresh weight) of two Iranian apricot cultivars during storage at 4°C. The results represent the means of 12 fruit in 4 replicates ± standard errors

period increased for both cultivars. Significant differences ($p < 0.05$) were revealed among the different treatments for pH values (Fig. 5). The highest and lowest the pH values were observed in control and 4 mM putrescine treatments, respectively. Our results were in agreement with data reported by Zokaee and Esna-Ashari (2008).

The all treated fruits showed increases in pH values, although the increases were significantly lower in treated fruits with putrescine than in control fruit during storage. This effect of putrescine might be due to create a thin layer on the surface of fruit which delayed degradation process. With respect to titratable acidity and pH values, titratable acidity content significantly decreased while pH value significantly increased during storage for both cultivars. Thus, one can say that there is an inversely relation between titratable acidity and pH.

Maturity index

In both cultivars, the maturity index increased significantly during storage at 4°C, that the maturity index levels at the initial of the storage period were higher than the end ones just for the all treatments (Fig. 6). There were significant differences in the maturity index content of the different treatments, that control treatments had the highest amount of maturity index than the other treatments (Fig. 6). Similar results were also reported for plum (cv. 'Angelino') (Khan et al., 2008).

The maturity index (TSS/TA) is responsible for the taste and flavor of apricot. Khan et al. (2008) reported that the lower maturity index in putrescine treatment is might be due to their higher titratable acidity, as compared to control treatment, that is in agreement with our results.

Ascorbic acid

The content of ascorbic acid decreased significantly during storage at 4°C for both cultivars (Fig. 7). Ishaq et al. (2009) reported also the ascorbic acid content in apricot fruit was reduced during storage. As shown in Fig. 7, a significant variation in ascorbic acid concentration was found among the studied treatments. The lowest concentration of ascorbic acid was observed for control treatment during storage, followed by 1 mM and 2 mM putrescine treatments while the highest was in 4 mM putrescine treatment.

Ascorbic acid is an important nutrient quality factors, which is very sensitive to degradation due to its oxidation compared to other nutrients during storage. The all treatments showed decreases in content of ascorbic acid, although the decreases were significantly lower in treatment of putrescine than in control treatment during storage. Ishaq et al. (2009) reported that the content of ascorbic acid decreases during storage could be due to the conversion of dehydroascorbic to diketogulonic acid by oxidation. The effect of putrescine may be ascribed to decreased or delayed ascorbate oxidase activity.

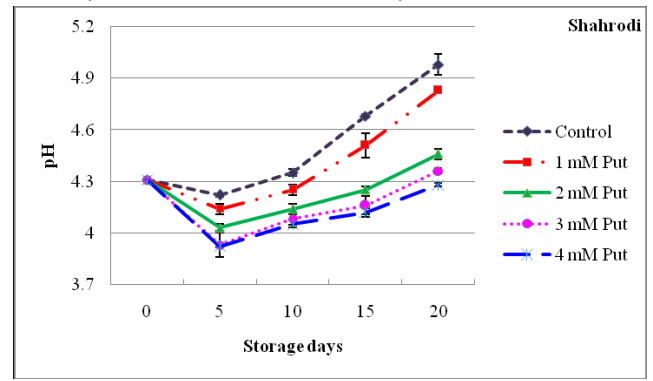
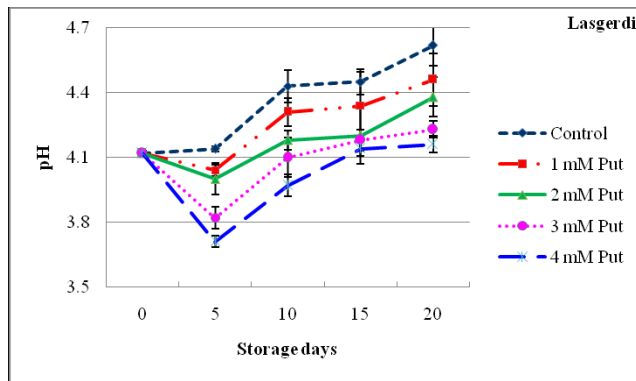


Fig. 5. Effect of putrescine on pH of two Iranian apricot cultivars during storage at 4°C. The results represent the means of 12 fruit in 4 replicates ± standard errors

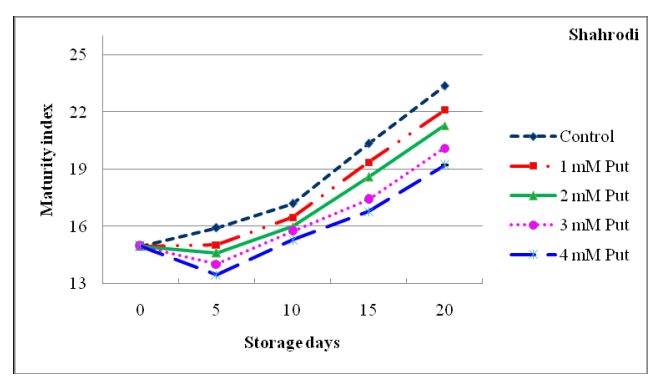
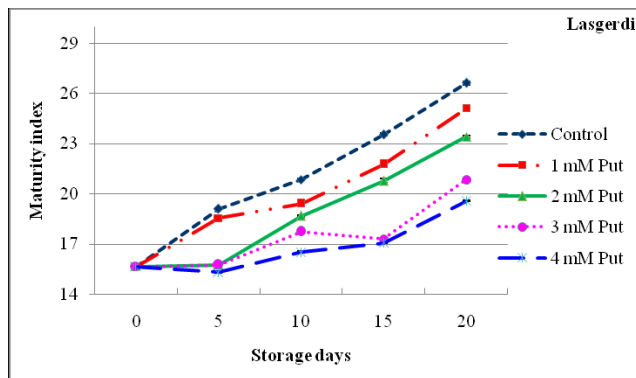


Fig. 6. Effect of putrescine on maturity index (TSS/TA) of two Iranian apricot cultivars during storage at 4°C. The results represent the means of 12 fruit in 4 replicates ± standard errors

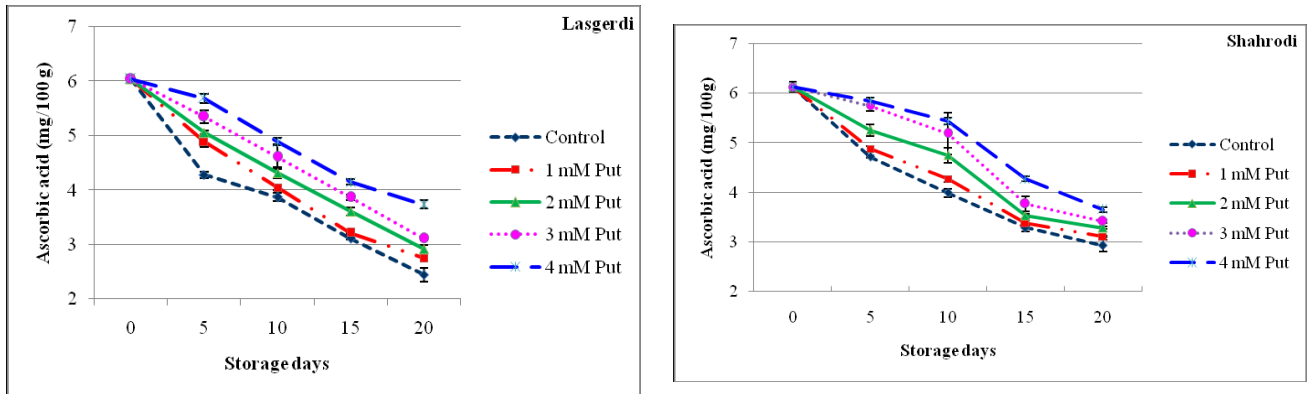


Fig. 7. Effect of putrescine on ascorbic acid (g/100 g fresh weight) of two Iranian apricot cultivars during storage at 4°C. The results represent the means of 12 fruit in 4 replicates ± standard errors

Total phenolics

For both cultivars, total phenolics content decreased significantly during storage at 4°C, that the total phenolics levels at the initial of the storage period were higher than the end ones just for the all treatments (Fig. 8). As shown in Fig. 8, a variation in terms of total phenolics content was observed among the treatments and the differences were statistically significant ($p < 0.05$). The maximum concentration of total phenolics was observed for 4 mM putrescine treatment during storage, followed by 3 mM and 2 mM putrescine treatments while the highest was in control treatment.

According to data, all treatments showed decreases in content of total phenolics, although the decreases were significantly lower in treatment of putrescine than in control treatment. During storage, level of total phenolics decrease might be due to breakdown of cell structure in order to senescence phenomena (Ghasemnezhad *et al.*, 2010). It was assumed that the effect of putrescine treatment on maintain of total phenolics content can be attributed to delay in senescence process.

Antioxidant Activity

The data indicated that the antioxidant activity decreased significantly during storage at 4°C for both cultivars (Fig. 9). There was a significant difference ($p < 0.05$)

between control and putrescine treatments in terms of their effects on level of antioxidant activity (Fig. 9). During storage, treatments of 4 mM putrescine had the highest antioxidant activity and control treatment had the lowest antioxidant activity.

The determination of antioxidant activity is one of the ways of expressing the nutritional and biological value of fruits. The results showed that the antioxidant activity decline along with decreases of total phenolic and ascorbic acid contents. Thus, it can be concluded that antioxidant activity is closely correlated with the total phenolics and ascorbic acid content. In previous researches, the positive correlation between antioxidant activity and total phenolics has been reported (Díaz-Mula *et al.*, 2009; Ghasemnezhad *et al.*, 2010). The treatment of putrescine maintained antioxidant activity of the fruit significantly during storage being a positive correlation between putrescine concentrations and antioxidant activity of fruit. This effect of putrescine treatment was probably due to maintain of total phenolics and ascorbic acid levels during storage.

Conclusion

Apricot is a climacteric fruit with limited postharvest storage life due to acceleration of quality loss. A suitable method for shelf life extension, which avoids detrimental

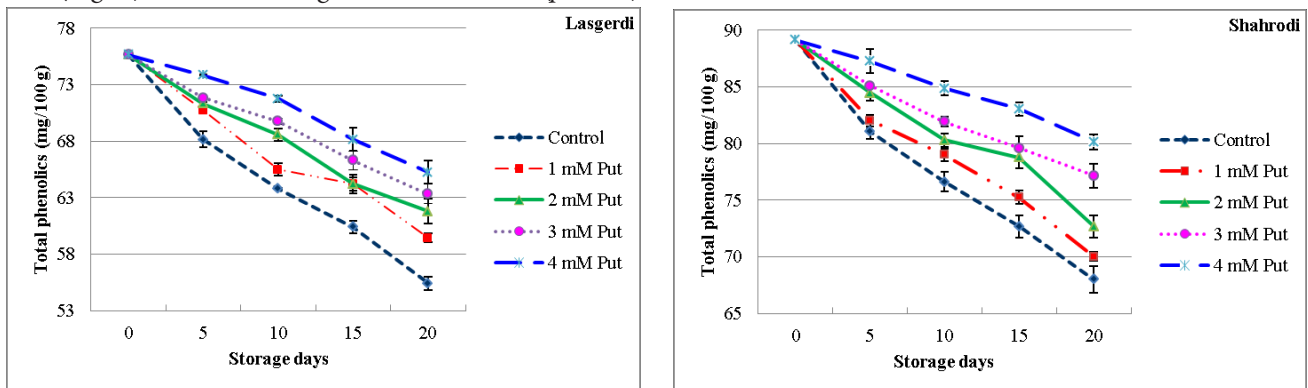


Fig. 8. Effect of putrescine on total phenolics (g/100 g fresh weight) of two Iranian apricot cultivars during storage at 4°C. The results represent the means of 12 fruit in 4 replicates ± standard errors

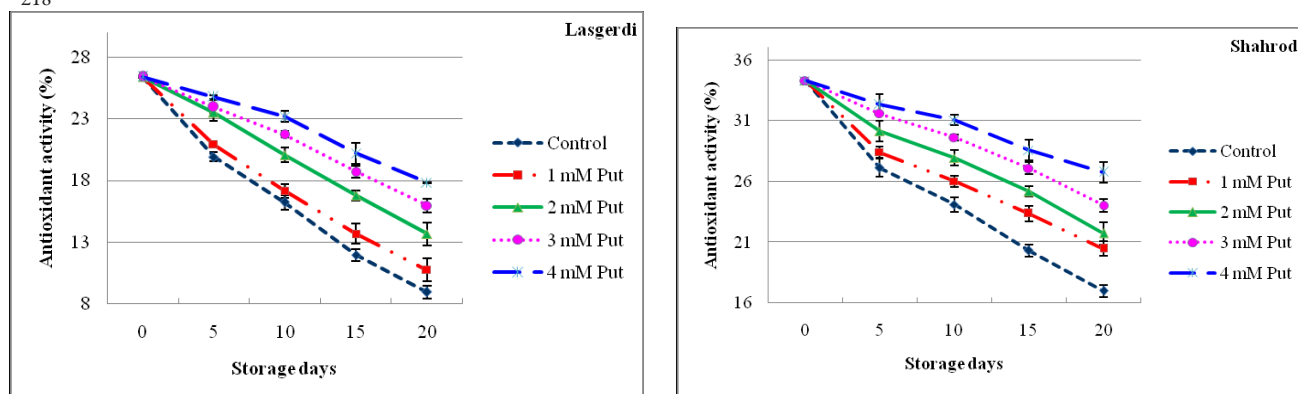


Fig. 9. Effect of putrescine on antioxidant activity (%) of two Iranian apricot cultivars during storage at 4°C. The results represent the means of 12 fruit in 4 replicates \pm standard error

effects on quality of fruit, would be beneficial for both the consumer and the producer. In this study, effect of different concentration of postharvest putrescine application on quality properties and antioxidant activity of two most important Iranian apricot cultivars ('Lasgerdi' and 'Shahrodi') during storage were investigated. This research showed the same behaviour in all measured factors during storage at 4°C for both cultivars apricot. The weight loss, total soluble solids, pH and maturity index increased significantly while the fruit firmness, titratable acidity, ascorbic acid, total phenolics and antioxidant activity decreased significantly during storage for both cultivars. In addition, statistically significant differences were observed between control and putrescine treatments in all measured parameters during storage. Exogenous putrescine treatments have shown improvement of apricot during storage at 4°C. Thus, the results suggest that putrescine treatment may be used commercially to extend the storage life of apricot.

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