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Postharvest application of hot water and putrescine treatments reduce brown rot and improve shelf life and quality of apricots

Mehdi HOSSEINIFARAHI[1,*], Seyedeh Marzieh MOUSAVI[2], Mohsen RADI[2], Mohammad Mahdi JOWKAR[3], Gianfranco ROMANAZZI[4,*]

[1] *Department of Horticultural Science, Yasooj Branch, Islamic Azad University, Yasooj, Iran*
[2] *Department of Food Science and Technology, Yasooj Branch, Islamic Azad University, Yasooj, Iran*
[3] *Department of Horticultural Science, Kermanshah Branch, Islamic Azad University, Kermanshah, Iran*
[4] *Department of Agricultural, Food and Environmental Sciences, Marche Polytechnic University, Via Brecce Bianche, 60131 Ancona, Italy*
*Corresponding authors. E-mails: m.h.farahi@iauyasooj.ac.ir (MHF), g.romanazzi@univpm.it (GR)

Summary. Iran is an important apricot production and export country. Postharvest losses of apricots from brown rot (caused by *Monilinia* spp.) are major concerns for producers. Effects were assessed of postharvest hot water, putrescine and acetic acid treatments on apricot quality and shelf life. After treatment applications, fruit were cold stored at 5°C and 80% (±5%) relative humidity for 40 d. During this period, physical and physiological properties of the apricots were evaluated at 10-d intervals. Parameters assessed were fruit weight, decay, firmness, total soluble solids, titratable acidity, and skin colour values (L^*, a^*, b^*). The 55°C hot water and 2.0 mM putrescine treatments gave the least fruit weight loss, brown rot incidence, and firmness loss after 40 of storage. For all treatments, fruit total soluble solids increased during storage, and these were greatest for the control (untreated) apricots. Apricots treated with hot water and putrescine had the greatest titratable acidity. The skin colour of all untreated and treated apricots improved throughout storage (from red to deep yellow). These data support the use of postharvest hot water and putrescine treatments for improved quality of apricots during storage. The scaling up of these treatments to packinghouse situations is important for evaluation of their technical and economic feasibility.

Key words. Decay, fruit firmness, *Monilinia* spp., skin colour.

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INTRODUCTION

Apricot (*Prunus armeniaca* L.) is one of the most important fruits cultivated in Iran since ancient times. Iran is the second largest producer of apricots in the world, after Turkey, with an annual production of more than 400,000 MT (Salehi *et al.*, 2018). Apricots can provide many benefits for

human health and well-being. These are due to the antiseptic, antipyretic, ophthalmic, and emetic properties of apricots (Ghasemnezhad *et al*., 2010). Apricots contain sugars, saccharides, organic acids, mineral nutrients (e.g., Fe, B, K, Ca), vitamins (e.g., B group, C), and polyphenols, and also contain high levels of antioxidant compounds and phytochemicals, such as flavonoids, carotenoids, lycopene, and carotenes (Hajilou *et al*., 2013).

Due to poor postharvest management, including poor handling, packaging, and storage, a lot of fruit and vegetables are wasted every year due to postharvest diseases, which result in greatly increased production costs. Preharvest and postharvest application of synthetic fungicides is an effective strategy for controlling postharvest fruit and vegetable decay, although these applications may have harmful environmental or human health effects. Many studies have focused on replacing synthetic fungicides with natural compounds and biocontrol agents as postharvest treatments (Spadaro and Droby, 2016).

Brown rot is a major stone fruit postharvest disease, and it is especially prevalent in apricot. Brown rot is caused by *Monilinia* spp., and it can result in severe fruit losses and economic damage to producers and consumers (Oliveira Lino *et al*., 2016; Landi *et al*., 2018, 2020; De Miccolis Angelini *et al*., 2019). Apricots are also very sensitive to storage conditions; they are climacteric fruit and undergo accelerated ripening under uncontrolled conditions. Due to these drawbacks, apricots are particularly sensitive to decay and softening during storage, handling and transport, and they cannot be kept at low temperatures for extended periods (Siddiq, 2007). Furthermore, apricots have high rates of postharvest climacteric respiration and high water contents, and are thus highly susceptible to decay, which results in short shelf life (Zokaee-Khosroshahi and Esna-Ashari, 2008). Therefore, slowing ripening rates to delay senescence of apricots is important for increased fruit shelf life.

Compounds such as polyamines can delay fruit ripening and thus improve shelf life and quality characteristics of various climacteric fruit (Valero *et al*., 2002). Polyamines are ubiquitous biogenic amines that are recognized as having important roles in biological processes, including cell growth, division, proliferation, apoptosis/senescence, embryogenesis, organ development, and responses to abiotic and biotic stressors (Mattoo and Handa, 2008). Putrescine, spermidine, and spermine are the main polyamines found in plant tissues (Valero and Serrano, 2010).

Application of polyamines to peaches to delay ripening and aging was reported by Bregoli *et al.* (2002), and Serrano *et al.* (2003) reported beneficial effects of polyamine application to plums. The effects of hot water, ethanol and acetic acid vapour on the physicochemical and sensory properties of peaches have also been investigated (Sharayei and Ganji Moghadam, 2013). Acetic acid vapour helped to maintain the quantitative, qualitative, and sensory characteristics of peaches (Zokaee-Khosroshahi and Esna-Ashari, 2008). Postharvest application of 1 mM putrescine to peaches increased their firmness and resistance to mechanical damage, while decreasing their respiration rates and delaying senescence (Martínez-Romero *et al*., 2000).

On kiwifruit, application of putrescine and spermidine provided improved postharvest quality (Assar *et al*., 2012). On strawberries, postharvest applications of putrescine and UV light increased firmness, vitamin C, anthocyanin, phenolic contents, and antioxidant capacity (Siruieneja *et al*., 2013). On Granny Smith apples, preharvest and postharvest treatments with putrescine and salicylic acid reduced weight loss and increased firmness (Asgarpour *et al*., 2016). Similarly, on broccoli florets, putrescine prevented chlorophyll degradation, promoted maintenance of antioxidant compounds, and delayed senescence (Jafarpour *et al*., 2014).

Hot water treatments after harvest are physical nondestructive methods for the control of postharvest decay in fruit and vegetables (Larrigaudière *et al*., 2002; Usall *et al*., 2016), with no residues left on produce after treatment. Therefore, hot water can be used in packinghouses as a simple way to reduce infections by postharvest fruit pathogens. Hot water treatments have numerous advantages, which include ease of application and short treatment times, with consistent monitoring of the water and fruit temperatures. These treatments can also disinfect fruit skins by removal of surface-borne decay microorganisms (Fallik, 2004). As heat transfer in water is efficient, fruit immersion in hot water is preferred over other heat treatments, with hot water treatment now accepted as a commercial method to maintain postharvest quality of certain fruit commodities (Paull and Jung Chen, 2000). Casals *et al.* (2010) reported that on nectarines and peaches, hot water treatment at 60°C for 40 s controlled brown rot. Shorter treatments (20 s) at 60°C also reduced brown rot by 80% when these fruit were drenched with water while passing through rotating brushes (Karabulut *et al*., 2002).

Acetic acid has been shown to be a potent natural antimicrobial agent that can also be used for disinfection of fruit surfaces. Radi *et al.* (2010) reported that treatment of apples with warm acetic acid solution controlled postharvest decay mostly caused by *Penicillium expansum*. Sholberg and Gaunce (1995, 1996) reported

that application of acetic acid vapour to stone fruit controlled Rhizopus rot and brown rot, and to application table grapes controlled gray and blue molds.

The aim of the present study was to evaluate the effects of hot water, putrescine, and acetic acid treatments of apricots on postharvest quality and decay development during storage.

MATERIALS AND METHODS

Plant materials

Apricots cv. Shahrodi at their commercially mature stage were picked early in the morning in a local orchard in the suburb of Yasooj City, Iran, and were immediately transferred to the Laboratory of Food Science. Damaged fruit were discarded, and 1,080 fruit that had uniform colour, shape, and size were selected.

Treatments

The selected apricots were randomly divided into ten groups. Treatments consisted of different water temperatures (25, 45, and 55°C), different putrescine concentrations (0.5, 1.5, and 2.0 mM; Sigma Aldrich Chemicals Co.) and different acetic acid concentrations (1, and 2%; Merck). Ten apricots of each replicate were used to evaluate the fruit characteristics at harvest. The fruit treatments were carried out by immersion for 5 min, followed by 30 min drying at room temperature. The apricots were then kept in polyethylene macroperforated fruit packs, at 5°C and 80% (±5%) relative humidity for 40 d. Fruit characteristics were evaluated immediately before storage and at 10-d intervals during the storage period (i.e., after 10, 20, 30, and 40 d of storage).

Fruit weight loss

To determine weight loss, the apricots were individually weighed before storage and at 10-d intervals during storage.

Fruit decay

The proportion of apricots showing decay was determined by counting the number showing decay symptoms during storage. The causal pathogens were identified according to their morphological properties (Abdipour *et al.*, 2019).

Fruit firmness

The firmness of the apricots was measured by the puncturing test before and during storage, using a texture analyzer (CT3; Brookfield Engineering). This used a flat-tipped, cylindrical, 5 mm diam. stainless steel probe, with permeation depth 2 mm and rate 5 mm s^{-1}.

Fruit titratable acidity and pH

The pH of the juice from the apricots was determined using a pH meter (Knick), and titratable acidity (TA, as malic acid) of the juice was determined by titration of 50 mL juice with 0.1 N NaOH to an endpoint of pH 8.1. pH and titration data were recorded before and during storage, with the titrations converted to g kg^{-1} malic acid (Radi *et al.*, 2010).

Fruit total soluble solids

Total soluble solids (TSS) of fruit were determined before and during storage using a refractometer (NAR-3T; Abbe) and are expressed as °Brix.

Fruit colour determinations

Fruit colour parameters were determined before and during storage using a digital colorimeter (CR400; Konika-Minolta) in three points on the surface of each apricot, with mean values determined for each fruit. The parameters measured were: L^* for lightness; a^* for redness; b^* for yellowness; C^* for chroma; and H^* for hue angle. C^*, H^*, and total colour difference (ΔE^*) were calculated, respectively, according to Equations (1), (2) and (3) (Huang *et al.*, 2013).

$$C^* = [a^{*2} + b^{*2}]^{1/2} \quad (1),$$

$$H^* = \arctan[b^*/a^*] \quad (2),$$

$$\Delta E^* = [(L^* - L_o^*)^2 + (a^* - a_o^*)^2 + (b^* - b_o^*)^2]^{1/2} \quad (3),$$

where L_0^*, a_0^*, and b_0^* are the control values for the untreated apricots.

Experimental design and data analyses

A completely randomized experimental design was used, with factorial arrangement that included the nine treatments each with three replications, with each rep-

lication consisting of ten observations (separate fruit). All trials were repeated at least twice. The data generated underwent analysis of variance (ANOVA) using the SPSS 21 statistical software. Significant differences were defined at $P \leq 0.05$, and the means were separated using least significant differences (LSD) tests.

RESULTS AND DISCUSSION

Fruit weight loss

All apricots lost weight throughout the storage period (Figure 1). The smallest weight losses after 40 d of storage were for the fruit treated with 55°C hot water (mean loss = 6.3%) and with 2.0 mM putrescine (7.3%). These hot water and putrescine treatments gave significantly less weight losses ($P < 0.05$) compared with that for the untreated control fruit (mean = 15.5%), and also less ($P < 0.05$) than for 2% acetic acid (10.7%), which still provided less ($P < 0.05$) weight loss than the control. Thus, the greatest weight loss after 40 d of storage was recorded for the control fruit.

Loss of weight of apricots due to water loss (evaporation from the fruit surface) is an important fruit quality factor. Water loss during storage results in apricots with shrivelled and dry appearance, and these symptoms increase with increases in storage duration and temperature.

Serrano *et al.* (2004) reported that for mechanically damaged plums, 45°C hot water treatment for 10 min reduced weight loss through reductions in ripening-related membrane changes. Useful effects of hot water to reduce fruit weight loss have also been reported for melons (Lamikanra and Watson, 2007), blueberries (Fan *et al.*, 2008), pears (Hosseini *et al.*, 2015), and Mexican limes (Obeed and Harhash, 2006). The mechanism by which hot water treatments reduce fruit weight loss may involve the melting of the fruit epicuticular waxes, which cover and seal cracks and lenticels in the fruit surfaces, preventing water vapour losses through these openings (Valero and Serrano, 2010). Hot water treatments may also reduce respiration rate and ethylene evolution, and postpone fruit ripening (Zoran *et al.*, 2001; Fallik, 2004).

Putrescine binds to cell membranes and protects the cuticle wax layers, and probably reduced water evaporation from apricots in the present study. Similar positive effects of putrescine for reducing water loss have been described for other fruit, including plums (Serrano *et al.*, 2003), courgettes (Palma *et al.*, 2015), and pears (Hosseini *et al.*, 2015).

Similar to the findings in the present study, previous reports have shown that acetic acid treatment of fruit, including apples, grapes, tomatoes, and kiwifruit, can also reduce weight loss and postharvest decay (Sholberg and Gaunce, 1995). However, in the present study, acetic acid treatment was not as effective as the other treatments that were applied.

Fruit decay

Decay caused by fungal pathogens are one of the most important factors for economic losses of fresh horticultural crops (Palou *et al.*, 2016). Postharvest brown rot was observed for the apricots in the present study. Incidence of brown rot (as the proportion of apricots affected) increased during the storage period (Figure 2). By day 40 of storage, the greatest protection for the apri-

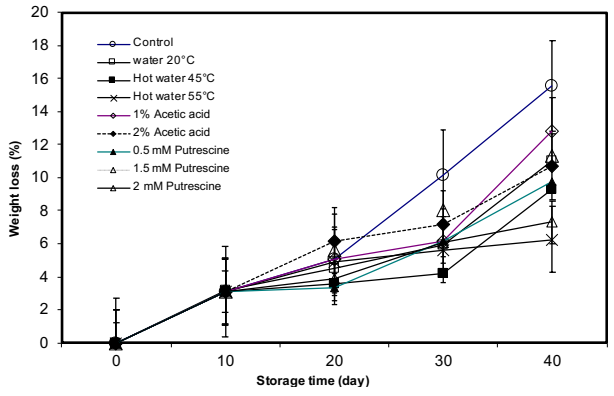

Figure 1. Mean weight loss (± standard deviation; n = 3) of cv. Shahrodi apricots before and during storage for 40 d at 5°C following different treatments.

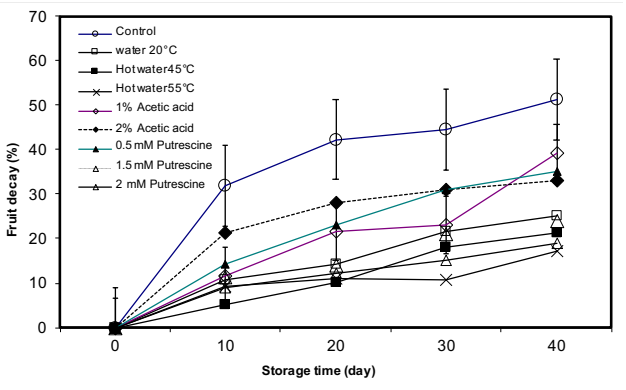

Figure 2. Mean incidence (± standard deviation; n = 3) of decay due to brown rot for cv. Shahrodi apricots before and during storage for 40 d at 5°C following different treatments.

cots against brown rot was obtained from the treatments with 55°C hot water (mean = 19.0% decay) or 2.0 mM putrescine (17.3% decay), which were significantly less ($P < 0.05$) than for the untreated (control) apricots (mean = 51.3% decay). The 2% acetic acid treatment (33.2% decay) was not as effective as hot water or putrescine ($P < 0.05$), although it reduced ($P < 0.05$) decay during storage compared to the untreated fruit. Similar data for acetic acid treatments have been reported for other fruit, including apples, grapes, tomatoes, and kiwifruit (Sholberg and Gaunce, 1995).

Decay is one of the main limiting factors that determines the shelf life of fresh agricultural and horticultural products, with losses reported to be 20 to 50% in developing countries and 5 to 25% in developed countries (Valero and Serrano, 2010). Many studies on postharvest hot water treatments showed that they are commonly used for quality maintenance of fruit crops, including peaches, nectarines (Sisquella *et al.*, 2013; Spadoni *et al.*, 2014), limes (Kaewsuksaeng *et al.*, 2015), and pears (Hosseini *et al.*, 2015).

Some studies have shown that fruit ripening can be delayed by applying hot water treatments, and at the same time fungal decays can be reduced without major changes in fruit quality (Fattahi Moghadam and Ebadi, 2012). According to Kou *et al.* (2007), the use of 45°C hot water for 8 min for table grapes was the most effective treatment. When strawberries were treated with 63°C hot water for 12 s and kept under a controlled atmosphere with 15 kPa CO_2, they showed low amounts of decay (Wszelaki and Mitcham, 2003). Pavoncello *et al.* (2001) reported that on grapefruit, resistance to green mold was achieved with water at 62°C applied for 20 s. Kiwifruit quality after storage was also improved by hot water treatments at 55 and 60°C for 1.5 min, which provided extended fruit shelf life and good preservation (Koukounaras *et al.*, 2008). The impacts of such hot water treatments for prevention of pathogen establishment and spread may be related to the initiation of host defense mechanisms that can be activated in the outer layers of fruit epicarps that can kill pathogens on fruit surfaces (Ben-Yehoshua *et al.*, 2000).

Khosroshahi *et al.* (2007) reported that application of putrescine (1-2 mM) increased the storage life of strawberries compared to untreated control fruit. Mangoes treated with 2.0 mM putrescine retained particularly good quality with a good blend of acidity, TSS, high 'deliciousness' ratings, and low physiological spoilage and weight loss (Jawandha *et al.*, 2012). Postharvest application of polyamines has also been reported to improve the quality and shelf life of fruit, including pomegranates (Mirdehghan *et al.*, 2007), plums (Pérez-Vicente *et al.*, 2002; Serrano *et al.*, 2003; Khan *et al.*, 2008), peaches (Martínez-Romero *et al.*, 2000; Bregoli *et al.*, 2002), mangoes (Malik and Singh, 2005), and apricots (Martínez-Romero *et al.*, 2002).

Fruit firmness

Firmness under all of the apricot treatments decreased during the storage period (Figure 3). At the end of the 40 d of storage, greatest firmness was recorded for the apricots treated with 55°C hot water (mean = 2859 mN) or with 2.0 mM putrescine (2841 mN), while least firmness was for the untreated (control) apricots (mean = 2196 mN; $P < 0.05$). The 2% acetic acid treatment also significantly maintained fruit firmness of the apricots (mean = 2570 mN; $P < 0.05$).

Apricots have short postharvest shelf lives compared to most other fruits, with fruit firmness being an important indicator for increased shelf life, processing, and marketing (Kakkar and Rai, 1993). The maintenance of the flesh firmness is one of the main effects of postharvest polyamine applications for vegetables and fruit. The softness of fruit tissues results from changes in the cell wall structure, including reductions in hemicellulose and pectin de-polymerization, due to the activities of cell wall-hydrolyzing enzymes. Maintenance and improvement of fruit firmness (and thus delayed ripening) using pre- and postharvest putrescine treatments have been reported for fruit, including courgettes (Palma *et al.*, 2015), pears (Hosseini *et al.*, 2015), plums (Serrano *et al.*, 2003; Khan *et al.*, 2008), peaches and nectarines (Bregoli *et al.*, 2002), strawberries (Zokaee Khosroshahi *et al.*, 2007), and apricots (Martínez-Romero *et al.*, 2001).

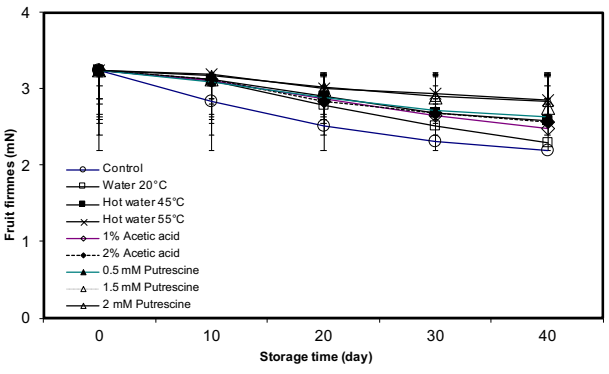

Figure 3. Mean firmness (± standard deviation; n = 3) of cv. Shahrodi apricots before and during storage for 40 d at 5°C following different treatments.

Several mechanisms have been suggested to explain maintenance of fruit firmness after putrescine treatments. One suggested mechanism was decreased activities of the ethylene biosynthetic enzymes 1-aminocyclopropane-1-carboxylate synthase and oxidase, and inhibition of endo- and exo-polygalacturonases, endo-β-1,4-glucanases, and pectin methylesterase related to cell-wall degradation (and thus to fruit softening). An additional mechanism may involve polyamine cross-linking of pectic substances in cell walls, which would help to maintain fruit firmness (Martínez-Romero *et al.*, 2002; Pérez-Vicente *et al.*, 2002). This binding would also prevent the access of degrading enzymes, which decrease softening rates during storage (Valero *et al.*, 2002).

In the present study, the hot water treatments increased apricot firmness throughout the 40 d of storage. Beneficial effects of hot water treatments for maintenance of fruit firmness have been reported for other fruit, including pears (Hosseini *et al.*, 2015), kiwifruit (Beirão-da-Costa *et al.*, 2006), melons (Lamikanra and Watson, 2007), peaches (Koukounaras *et al.*, 2008), and mangoes (Djioua *et al.*, 2009). Heat treatments may protect cell wall integrity, and thus maintain fruit firmness (Valero and Serrano, 2010). Heat treatments can also activate endogenous calcium to form calcium pectate, which delays activities of mainly the polygalacturonase and pectin methylesterase cell wall-degrading enzymes (Serrano *et al.*, 2004; Valero and Serrano, 2010). Direct consequences of heat treatments on the inactivation of these enzymes were suggested by Paull and Jung Chen (2000) and Serrano *et al.* (2004).

Fruit total soluble solids

The changes in the TSS of the apricots during storage are shown in Figure 4. In general, there were gradual increases in the TSS during the storage period. The untreated (control) fruit had the greatest TSS from about day 10 onwards, while all the other treatments gave less TSS. The 55°C hot water and 2.0 mM putrescine treatments resulted in the least TSS (respectively, mean = 6.1% ±0.2% and 5.2% ±0.02%). The general increase in TSS of stored fruit was probably due to increased fruit respiration and weight reduction during the storage period. Several studies have reported improved maintenance of TSS from putrescine treatments, mainly due to the impact that putrescine has on respiration, ethylene production, and delayed ripening (Martínez-Romero *et al.*, 2002; Serrano *et al.*, 2003; Zokaee Khosroshahi *et al.*, 2007).

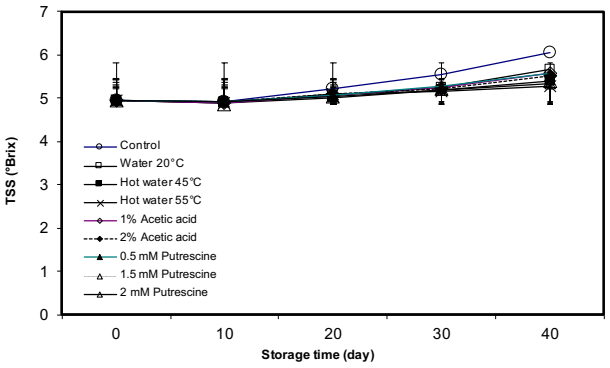

Figure 4. Mean total soluble solids (TSS; ± standard deviation; n = 3) of cv. Shahrodi apricots before and during storage for 40 d at 5°C following different treatments.

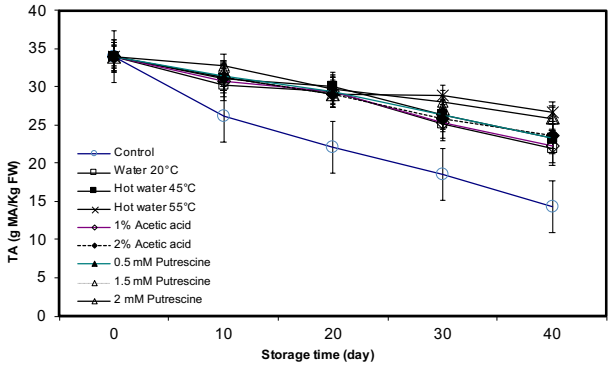

Figure 5. Mean titratable acidity (TA; ± standard deviation; n = 3) of the cv. Shahrodi apricots before and during storage for 40 d at 5°C following different treatments

Fruit titratable acidity

TA decreased during the storage period for all of the apricot treatments (Figure 5). These data showed that after 40 d of storage, the greatest TA was in the apricots treated with 55°C hot water (mean = 26.7 g MA kg^{-1} FW) or with 2.0 mM putrescine (25.8 g MA kg^{-1} FW), which were both greater ($P < 0.05$) than that in the control apricots. The untreated apricots had the lowest TA at the end of the 40 d of storage (mean = 14.3 g MA kg^{-1} FW). TA is directly influenced by the levels of organic acids in fruit (Ghasemnezhad *et al.*, 2010). The decreases in TA during storage may have been due to metabolic changes in the fruit or to the degradation of organic acids during respiration. Similar protection against reductions in TA during storage have been observed on pears treated with hot water and putrescine (Hosseini *et al.*, 2015), strawberries treated with putrescine (Zokaee Khosroshahi *et al.*, 2007), limes treated with hot water (Kaewsuksaeng *et*

al., 2015), and apricots coated with chitosan (Ghasemnezhad *et al*., 2010).

Fruit skin colour changes

The L^* (brightness) of the apricots for all of the treatments generally increased during the first 30 d of storage, and then remained essentially unchanged to 40 d (Table 1). Increased L^* indicated that the fruit changed to brighter colour during most of the storage period. The greatest final L^* (after 40 d storage) was in the untreated (control) apricots and the least L^* was in the fruit subjected to the acetic acid and putrescine treatments.

The a^* (green to red) increased after all of the treatments during the first 10 d of storage (Table 1). This indicated that initially the skin colour showed diminished green tints (change from negative to zero a^*), and then shifted further from pale green to pale red (change from negative to positive a^*). After 40 d storage, the greatest a^* was in the untreated (control) apricots (mean = 5.11) and the least a^* was in the apricots treated with 55°C hot water (mean = 0.18) or with 1.5 mM putrescine (mean = 0.20; $P < 0.05$). These changes in colour from green to red (as in the control samples) are a good indication of apricot fruit ripening.

The b^* (blue to yellow) after all of the fruit treatments continued to increase during the 40 d of storage (Table 1). Increased b^* indicated a deeper yellow colour. The data showed that, as for a^*, the greatest b^* after 40 d storage was in the untreated (control) (mean = 34.13), although the increase was similar ($P > 0.05$) for most of the other treatments. The least b^* after 40 d was in the apricots treated with 45°C hot water (mean = 28.21) or with 0.5 mM and 2.0 mM putrescine (respectively, 28.10 and 28.25), which were less ($P < 0.05$) than on all of the other treatments.

The C^* and H^* after these treatments showed different changes during 40 d of storage. The C^* generally increased by day 40, although this was almost exclusively during the first 10 d, and then remained essentially unchanged. The greatest C^* after 40 d was in the untreated (control) apricots (mean = 7.76) and the least C^* was in the fruit treated with 45°C or 55°C hot water (respectively, 5.45 and 5.44), 2.0 mM putrescine (5.43), or 1% acetic acid (5.41) (Table 2). In contrast, H^* showed little or no initial increase to day 10, and then generally increased to day 40 for these treatments. The least H^* at 40 d was for the untreated (control) apricots (mean = 81.48), which also showed the overall lowest H^* at day 20 of storage (74.75). In the fruit treated with water at different temperatures, the H^* initially declined at day 10, but then generally increased to day 40, as similarly recorded

Table 1. Mean L^*, a^*, and b^* colour parameters of cv. Shahrodi apricots during storage for 40 d at 5°C after application of different treatments.

Treatment		Mean colour parameters after different periods (d) of storage															
		0			10			20			30			40			
		L^*	a^*	b^*	L^*	a^*	b^*	L^*	a^*	b^*	L^*	a^*	b^*	L^*	a^*	b^*
Control	---	34.20 aA	-3.00 aA	12.10 aA	46.42 dB	4.00 aB	17.32 bB	55.44 eE	6.33 dC	23.22 aC	53.23 dD	3.61 bB	33.19 cD	51.11 dC	5.11 bC	34.13 bD
Water	20°C	34.20 aA	-3.00 aA	12.20 aA	46.12 cB	5.10 aD	15.23 aB	50.11 cCD	2.43 bC	23.11 aC	51.23 bD	1.22 aB	25.13 abD	49.12 cC	2.10 aBC	29.11 abE
	45°C	34.20 aA	-3.00 aA	12.10 aA	46.63 eB	4.47 aC	17.22 bB	49.21 bCD	2.11 bB	24.12 abC	50.11 abD	1.39 aB	23.38 aC	48.12 bC	1.20 aB	28.21 aD
	55°C	34.20 aA	-3.00 aA	12.10 aA	45.52 bB	5.23 aD	16.11 abB	46.61 aB	3.44 cC	24.17 abC	49.21 aC	2.44 abC	24.11 abC	48.1 bBC	0.18 aB	29.51 abD
Putrescine	0.5 mM	34.20 aA	-3.00 aA	12.10 aA	46.28 cdB	4.21 aC	17.92 bB	51.45 cdC	1.31 aB	25.11 bC	50.23 abC	1.00 aB	25.70 bC	47.19 abB	1.17 aB	28.10 aD
	1.5 mM	34.20 aA	-3.00 aA	12.10 aA	46.11 cB	5.21 aD	16.89 abB	52.76 dC	3.11 bcC	22.81 aC	53.10 dC	1.10 aB	25.90 bD	46.79 aB	0.20 aB	29.19 abE
	2.0 mM	34.20 aA	-3.00 aA	12.10 aA	46.12 cB	4.41 aC	16.89 abB	52.11 dC	1.29 aB	22.81 aC	52.19 cC	0.31 aB	22.71 aC	47.36 abB	1.41 aB	28.25 aD
Acetic acid	1%	34.20 aA	-3.00 aA	12.10 aA	45.11 aB	4.21 aC	17.34 bB	47.10 aC	2.12 bB	22.31 aC	50.10 abD	1.22 aB	25.99 bD	47.12 abC	1.22 aB	29.11 abE
	2%	34.20 aA	-3.00 aA	12.10 aA	46.62 eB	4.44 aC	17.21 bB	52.66 dC	3.43 cC	22.71 aC	51.11 bC	1.21 aB	23.22 aC	46.27 aB	1.82 aB	29.67 abD

Means accompanied by different lower case letters in each column are significantly different ($P < 0.05$; LSD tests).
Means accompanied by different capital letters in each row within each treatment are significantly different between days of storage ($P < 0.05$; LSD tests).

Table 2. Mean H^*, C^*, and ΔE^* colour parameters of the cv. Shahrodi apricots during storage for 40 d at 5°C after application of different treatments.

Treatment		Mean colour parameters after different periods (d) of storage														
		0			10			20			30			40		
		C^*	H^*	ΔE^*	C^*	H^*	ΔE^*	C^*	H*	ΔE^*	**C***	H^*	ΔE^*	C^*	**H***	ΔE^*
Control	--	4.59 p	76.08 ij	36.40	5.77 ei	77.00 gi	49.71	7.96 a	74.75 ij	60.44	6.80 b	83.79 cf	62.83	7.76 a	81.48 fh	61.67
Water	20 °C	4.59 p	76.08 ij	36.40	6.42 bd	71.49 j	48.84	5.39 in	84.00 cf	55.24	5.16 ko	87.22 ad	57.07	5.79 ei	85.87 af	57.14
	45 °C	4.59 p	76.08 ij	36.40	6.10 ce	75.45 ij	49.91	5.35 in	85.00 af	54.84	5.03 lp	86.60 ae	55.31	5.45 hm	87.56 ac	55.79
	55 °C	4.59 p	76.08 ij	36.40	6.59 bc	72.01 ij	48.57	6.00 df	81.90 eg	52.62	5.48 gl	84.22 cf	54.85	5.44 hn	89.65 a	56.43
Putrescine	0.5 mM	4.59 p	76.08 ij	36.40	5.92 eh	76.35 ij	48.51	5.18 ko	84.57 bf	52.16	5.24 jo	87.31 ac	56.45	5.53 fk	87.60 ac	55.40
	1.5 mM	4.59 p	76.08 ij	36.40	6.08 dg	75.53 ij	49.89	4.77 op	89.82 a	57.35	4.97 mp	87.02 ad	56.15	5.74 ei	86.49 ac	55.00
	2.0 mM	4.59 p	76.08 ij	36.40	5.97 dg	76.78 hi	49.81	5.18 ko	87.01 ab	57.27	5.17 ko	87.77 ac	56.43	5.43 hn	87.62 ac	54.94
Acetic acid	1%	4.59 p	76.08 ij	36.40	6.64 b	72.86 ij	49.38	5.70 ej	82.24 df	57.56	5.21 jo	87.57 ac	59.09	5.41 in	89.61 a	55.15
	2%	4.59 p	76.08 ij	36.40	6.03 de	75.37 ij	49.31	4.95 np	86.76 ae	56.90	4.78 op	89.22 ab	56.92	5.50 gl	87.14 ac	55.16

Means for each treatment accompanied by different letters are significantly different between days of storage ($P < 0.05$; LSD tests).

for the acetic acid treatments. For the putrescine treatments, H^* was initially unchanged (at day 10), before increasing to day 30, with no change to day 40 (Table 2).

The total colour difference (ΔE^*) indicated the magnitude of colour difference between untreated and treated apricots. The untreated (control) fruit had the greatest ΔE^* from day 20 (mean = 60.44) to day 40 (61.67), while the other treatments all gave similar ΔE^* by day 40 (Table 2).

Polyamines have been reported to inhibit chlorophyll degradation and reduce colour changes in cucumber (Jia *et al.*, 2018), table grapes (Champa *et al.*, 2014), strawberries (Zokaee Khosroshahi *et al.*, 2007), and apricots (Martínez-Romero *et al.*, 2002). Similarly (Zheng *et al.*, 2019) reported that treatment with putrescine reduced L^* in broccoli.

The impacts of temperature on apricot injury were studied by Demartino *et al.* (2002). They reported discolouration of bruised cv. San Castrese apricots as loss of yellow pigment. The L^* (lightness) and b^* (yellowness) of bruised apricots were decreased by keeping them at 18°C. In contrast, in the present study, the b^* of apricots increased for all of the treatments during the 40 d storage period (Table 2). Dong *et al.* (2002) investigated the effects of 1-methylcyclopropene on ripening of cv. Canino apricots. They reported that the H^* of these fruit decreased after 30 d of storage. They also reported that during ripening, H^* decreased for both the untreated fruit and those treated with 1-methylcyclopropene, although this treatment slowed the decrease in H^* compared to the control. Similarly, we observed that treatments that improved apricot quality also reduced the H^* decline. Martínez-Romero *et al.* (2002) also reported that with putrescine application, the colour index (a*/b*) of cv. Mauricio apricots increased during storage.

In conclusion, this study has shown that hot water and putrescine treatments, and to a lesser extent those with acetic acid, can maintain the postharvest quality of apricots by reducing the fresh weight loss, brown rot incidence, and fruit softening. Postharvest use of treatments with 55°C hot water or 2.0 mM putrescine for postharvest quality improvements of apricots in cold storage is recommended. Whether these treatments can be scaled up to the fruit packinghouse level is an important issue that requires of the evaluation of the technical and economic feasibility of these treatments.

LITERATURE CITED

Abdipour M., Hosseinifarahi M., Naseri N., 2019. Combination method of UV-B and UV-C prevents post-

harvest decay and improves organoleptic quality of peach fruit. *Scientia Horticulturae* 256: 108564. DOI: 10.1016/j.scienta.2019.108564.

Asgarpour A., Babalar M., Ali M., Sarcheshmeh A., 2016. The effect of preharvest spray of putrescine and salicylic acid solutions on some qualitative properties of 'Granny Smith' apple fruit. *Iranian Journal of Horticultural Science* 47: 445–456.

Assar P., Rahemi M., Taghipour L., 2012. Effect of postharvest treatments of spermidine and putrescine on 'Hayward' kiwifruit quality during storage. *Iranian Journal of Horticultural Science* 43: 331–336.

Beirão-da-Costa S., Steiner A., Correia L., Empis J., Moldão-Martins M., 2006. Effects of maturity stage and mild heat treatments on quality of minimally processed kiwifruit. *Journal of Food Engineering* 76: 616–625. DOI: 10.1016/j.jfoodeng.2005.06.012.

Ben-Yehoshua S., Peretz J., Rodov V., Nafussi B., Yekutieli O., … Regev R., 2000. Postharvest application of hot water treatment in citrus fruits: the road from the labratory to the packing-house. *Acta Horticulturae* 518: 19–28.

Bregoli A.M., Scaramagli S., Costa G., Sabatini E., Ziosi V., … Torrigiani P., 2002. Peach (*Prunus persica*) fruit ripening: aminoethoxyvinylglycine (AVG) and exogenous polyamines affect ethylene emission and flesh firmness. *Physiologia Plantarum* 114: 472–481. DOI: 10.1034/j.1399-3054.2002.1140317.x.

Casals C., Teixidó N., Viñas I., Silvera E., Lamarca N., Usall J., 2010. Combination of hot water, Bacillus subtilis CPA-8 and sodium bicarbonate treatments to control postharvest brown rot on peaches and nectarines. *European Journal of Plant Pathology* 128: 51–63. DOI: 10.1007/s10658-010-9628-7.

Champa H.A.H., Gill M.I.S., Mahajan B.V.C., Arora N.K., 2014. Postharvest treatment of polyamines maintains quality and extends shelf-life of table grapes (*Vitis vinifera* L.) cv. Flame Seedless. *Postharvest Biology and Technology* 91: 57–63. DOI: 10.1016/j.postharvbio.2013.12.014.

De Miccolis Angelini R.M., Romanazzi G., Pollastro S., Rotolo C., Faretra F., Landi L., 2019. New high-quality draft genome of the brown rot fungal pathogen *Monilinia fructicola*. *Genome Biology and Evolution* 11: 2850–2855. DOI: 10.1093/gbe/evz207.

De Martino G., Massantini R., Botondi R., Mencarelli F., 2002. Temperature affects impact injury on apricot fruit. *Postharvest Biology and Technology* 25: 145–149. DOI: 10.1016/S0925-5214(01)00165-X

Djioua T., Charles F., Lopez-Lauri F., Filgueiras H., Coudret A., … Sallanon H., 2009. Improving the storage of minimally processed mangoes (*Mangifera indica* L.) by hot water treatments. *Postharvest Biology and Technology* 52: 221–226. DOI: 10.1016/j.postharvbio.2008.10.006.

Dong L., Lurie S., Zhou H.W., 2002. Effect of 1-methylcyclopropene on ripening of "Canino" apricots and "Royal Zee" plums. *Postharvest Biology and Technology* 24: 135–145. DOI: 10.1016/S0925-5214(01)00130-2.

Fallik E., 2004. Prestorage hot water treatments (immersion, rinsing and brushing). *Postharvest Biology and Technology* 32: 125–134. DOI: 10.1016/j.postharvbio.2003.10.005.

Fan L., Forney C.F., Song J., Doucette C., Jordan M.A., … Walker B.A., 2008. Effect of hot water treatments on quality of highbush blueberries. *Journal of Food Science* 73. DOI: 10.1111/j.1750-3841.2008.00838.x.

Fattahi Moghadam J., Ebadi H., 2012. The effect of hot water treatments on gray mold and physicochemical quality of kiwi fruit during storage. *Journal of Ornamental and Horticultural Plants* 2: 73–82.

Ghasemnezhad M., Shiri M.A., Sanavi M., 2010. Effect of chitosan coatings on some quality indices of apricot (*Prunus armeniaca* L.) during cold storage. *Caspian Journal of Environmental Sciences* 8: 25–33.

Hajilou J., Fakhim Rezaei S., Dehghan G.R., 2013. Comparison of the quality attributes and antioxidant capacity of plum-apricot interspecific hybrid with some plum and apricots cultivars in harvesting time. *Journal of Food Research* 23: 107–119.

Hosseini M.S., Babalar M., Askari M.A., Davarpanah S., 2015. Comparison of putrescine application and heat treatment on storage quality of "Shahmiveh" and "Spadona" pears. *Iranian Journal of Horticultural Science* 45: 234–225.

Huang W., Bi X., Zhang X., Liao X., Hu X., Wu J., 2013. Comparative study of enzymes, phenolics, carotenoids and color of apricot nectars treated by high hydrostatic pressure and high temperature short time. *Innovative Food Science and Emerging Technologies* 18: 74–82. DOI: 10.1016/j.ifset.2013.01.001.

Jafarpour F., Bakhshi D., Ghasemnezhad M., Sajedi R.., 2014. Effect of putrescine on postharvest quality, and phenolic compounds and antioxidant capacity of Broccoli (*Brassica oleracea* L. cv. Italica) florets. *Journal of Horticulture Science* 28: 303–311.

Jawandha S.K., Gill M. S., Singh N., Gill P.P.S., Singh N., 2012. Effect of post-harvest treatments of putrescine on storage of mango cv. Langra. *African Journal of Agricultural Research* 7: 6432–6436. DOI: 10.5897/AJAR12.1425.

Jia B., Zheng Q., Zuo J., Gao L., Wang Q., … Shi J., 2018. Application of postharvest putrescine treatment to maintain the quality and increase the activity of anti-

oxidative enzyme of cucumber. *Scientia Horticulturae* 239: 210–215. DOI: 10.1016/j.scienta.2018.05.043.

Kaewsuksaeng S., Tatmalaa N., Srilaong V., Pongprasert N., 2015. Postharvest heat treatment delays chlorophyll degradation and maintains quality in Thai lime (*Citrus aurantifolia* Swingle cv. Paan) fruit. *Postharvest Biology and Technology* 100: 1–7. DOI: 10.1016/j.postharvbio.2014.09.020.

Kakkar R.K., Rai V.K., 1993. Plant polyamines in flowering and fruit ripening. *Phytochemistry* 33: 1281–1288. DOI: 10.1016/0031-9422(93)85076-4.

Karabulut O.A., Cohen L., Wiess B., Daus A., Lurie S., Droby S., 2002. Control of brown rot and blue mold of peach and nectarine by short hot water brushing and yeast antagonists. *Postharvest Biology and Technology* 24: 103–111. DOI: 10.1016/S0925-5214(01)00132-6.

Khan A. s, Singh Z., Abbasi N.A., Swinny E.E., 2008. Pre- or post-harvest applications of putrescine and low temperature storage affect fruit ripening and quality of 'Angelino' plum. *Journal of the Science of Food and Agriculture* 88: 1686–1695. DOI: 10.1002/jsfa.

Kou L., Luo Y., Wu D., Liu X., 2007. Effects of mild heat treatment on microbial growth and product quality of packaged fresh-cut table grapes. *Journal of Food Science* 72: 567–573. DOI: 10.1111/j.1750-3841.2007.00503.x.

Koukounaras A., Diamantidis G., Sfakiotakis E., 2008. The effect of heat treatment on quality retention of fresh-cut peach. P*ostharvest Biology and Technology* 48: 30–36. DOI: 10.1016/j.postharvbio.2007.09.011.

Lamikanra O., Watson M.A., 2007. Mild heat and calcium treatment effects on fresh-cut cantaloupe melon during storage. *Food Chemistry* 102: 1383–1388. DOI: 10.1016/j.foodchem.2006.05.060.

Landi L., Angelini R.M.D.M., Pollastro S., Abate D., Faretra F., 2018. Genome sequence of the brown rot fungal pathogen *Monilinia fructigena*. *BMC Research Notes* 11, 758. DOI: 10.1186/s13104-018-3854-z.

Landi L., Pollastro S., Rotolo C., Romanazzi G., Faretra F., de Miccolis Angelini R.M., 2020. Draft genomic resources for the brown rot fungal pathogen *Monilinia laxa*. *Molecular Plant-Microbe Interactions* 33: 145–148. DOI: 10.1094/MPMI-08-19-0225-A.

Larrigaudière C., Pons J., Torres R., Usall J., 2002. Storage performance of clementines treated with hot water, sodium carbonate and sodium bicarbonate dips. *Journal of Horticultural Science and Biotechnology* 77: 314–319. DOI: 10.1080/14620316.2002.11511499.

Malik A.U., Singh Z., 2005. Pre-storage application of polyamines improves shelf-life and fruit quality of mango. *Journal of Horticultural Science and Biotechnology* 80: 363–369. DOI: 10.1080/14620316.2005.11511945.

Martínez-Romero D., Serrano M., Carbonell A., Burgos L., Riquelme F., Valero D., 2002. Effects of postharvest putrescine treatment on extending shelf life and reducing mechanical damage in apricot. *Journal of Food Science*, 1706–1712. DOI: 10.1111/j.1365-2621.2002.tb08710.x.

Martínez-Romero D., Valero D., Riquelme F., Zuzunaga M., Serrano M., … Carbonell A., 2001. Infiltration of putrescine into apricots hepls handling and storage. *Acta Horticulturae* 553: 189–192. DOI: 10.17660/ActaHortic.2001.553.41.

Martínez-Romero D., Valero D., Serrano M., Burló F., Carbonell A., … Riquelme F., 2000. Exogenous polyamines and gibberellic acid effects on peach (*Prunus persica* L.) storability improvement. *Journal of Food Science* 65: 288–294. DOI: 10.1111/j.1365-2621.2000.tb15995.x.

Mattoo A.K., Handa A.K., 2008. Higher polyamines restore and enhance metabolic memory in ripening fruit. *Plant Science* 174: 386–393. DOI: 10.1016/j.plantsci.2008.01.011.

Mirdehghan S.H., Rahemi M., Martínez-Romero D., Guillén F., Valverde J.M., … Valero D., 2007. Reduction of pomegranate chilling injury during storage after heat treatment: Role of polyamines. *Postharvest Biology and Technology* 44: 19–25. DOI: 10.1016/j.postharvbio.2006.11.001.

Obeed R.S., Harhash M.M., 2006. Impact of postharvest treatments on storage life and quality of "Mexican" lime. *Journal of Advanced Agricultural Technologies* 11: 533–549.

Oliveira Lino L., Pacheco I., Mercier V., Faoro F., Bassi D., … Quilot-Turion B., 2016. Brown rot strikes prunus fruit: An ancient fight almost always lost. *Journal of Agricultural and Food Chemistry* 64: 4029–4047. DOI: 10.1021/acs.jafc.6b00104.

Palma F., Carvajal F., Ramos J.M., Jamilena M., Garrido D., 2015. Effect of putrescine application on maintenance of zucchini fruit quality during cold storage: Contribution of GABA shunt and other related nitrogen metabolites. *Postharvest Biology and Technology* 99: 131–140. DOI: 10.1016/j.postharvbio.2014.08.010.

Palou L., Ali A., Fallik E., Romanazzi G., 2016. GRAS, plant- and animal-derived compounds as alternatives to conventional fungicides for the control of postharvest diseases of fresh horticultural produce. *Postharvest Biology and Technology* 122: 41–52. DOI: 10.1016/j.postharvbio.2016.04.017.

Paull R.E., Jung Chen N., 2000. Heat treatment and fruit ripening. *Postharvest Biology and Technology* 21: 21–37. DOI: 10.1016/S0925-5214(00)00162-9.

Pavoncello D., Lurie S., Droby S., Porat R., 2001. A hot water treatment induces resistance to *Penicillium digitatum* and promotes the accumulation of heat shock and pathogenesis-related proteins in grapefruit flavedo. *Physiologia Plantarum* 111: 17–22. DOI: 10.1034/j.1399-3054.2001.1110103.x.

Pérez-Vicente A., Martınez-Romero D., Carbonell Á., Serrano M., Riquelme F., … Valero D., 2002. Role of polyamines in extending shelf life and the reduction of mechanical damage during plum (*Prunus salicina* Lindl.) storage. *Postharvest Biology and Technology* 25: 25–32. DOI: 10.1016/S0925-5214(01)00146-6.

Radi M., Jouybari H.A., Mesbahi G., Farahnaky A., Amiri S., 2010. Effect of hot acetic acid solutions on postharvest decay caused by *Penicillium expansum* on Red Delicious apples. *Scientia Horticulturae*, 421–425. DOI: 10.1016/j.scienta.2010.06.023.

Salehi M., Salehi E., Siampour M., Quaglino F., Bianco P.A., 2018. Apricot yellows associated with '*Candidatus* Phytoplasma phoenicium' in Iran. *Phytopathologia Mediterranea* 57: 269–283. DOI: 10.14601/Phytopathol_Mediterr-22588.

Serrano M., Martínez-Romero D., Castillo S., Guillén F., Valero D., 2004. Role of calcium and heat treatments in alleviating physiological changes induced by mechanical damage in plum. *Postharvest Biology and Technology* 34: 155–167. DOI: 10.1016/j.postharvbio.2004.05.004.

Serrano M., Martinez-Romero D., Guillén F., Valero D., 2003. Effects of exogenous putrescine on improving shelf life of four plum cultivars. *Postharvest Biology and Technology* 30: 259–271. DOI: 10.1016/S0925-5214(03)00113-3.

Sharayei P., Ganji Moghadam E., 2013. Effect of hot water, ethanol and acetic acid vapor on physical, chemical and organoleptic characteristics of peaches (*Prunus persica* batsch cv. Elberta). *Journal of Agricultural Engineering Research* 14: 59–72.

Sholberg P.L., Gaunce A.P., 1995. Fumigation of fruit with acetic-acid to prevent postharvest decay. *HortScience* 30: 1271–1275.

Sholberg P.L., Gaunce A.P., 1996. Fumigation of stonefruit with acetic acid to control postharvest decay. *Crop Protection* 15: 681–686. DOI: 10.1016/s0261-2194(96)00039-7.

Siddiq M., 2007. Plums and Prunes. In: *Handbook of Fruits and Fruit Processing*, (Y.H. Hui ed.). DOI: 10.1002/9780470277737.ch29

Siruieneja B., Mortazavi S.M.H., Moalemmi N., Eshghi S., 2013. The effect of postharvest application of putrescine and UV-C irradiation on strawberry (*Fragaria* × *ananassa* cv. Selva) fruit quality. *Journal of Plant Production* 36: 117–127.

Sisquella M., Casals C., Viñas I., Teixidó N., Usall J., 2013. Combination of peracetic acid and hot water treatment to control postharvest brown rot on peaches and nectarines. *Postharvest Biology and Technology* 83: 1–8. DOI: 10.1016/j.postharvbio.2013.03.003.

Spadaro D., Droby S., 2016. Development of biocontrol products for postharvest diseases of fruit: The importance of elucidating the mechanisms of action of yeast antagonists. *Trends in Food Science and Technology* 47: 39–49. DOI: 10.1016/j.tifs.2015.11.003.

Spadoni A., Guidarelli M., Sanzani S.M., Ippolito A., Mari M., 2014. Influence of hot water treatment on brown rot of peach and rapid fruit response to heat stress. *Postharvest Biology and Technology* 94: 66–73. DOI: 10.1016/j.postharvbio.2014.03.006.

Usall J., Ippolito A., Sisquella M., Neri F., 2016. Physical treatments to control postharvest diseases of fresh fruits and vegetables. *Postharvest Biology and Technology* 122: 30-40. DOI: 10.1016/j.postharvbio.2016.05.002.

Valero D., Martínez-Romero D., Serrano M., 2002. The role of polyamines in the improvement of the shelf life of fruit. *Trends in Food Science and Technology* 13: 228–234. DOI: 10.1016/S0924-2244(02)00134-6.

Valero D., Serrano M., 2010. *Postharvest Biology and Technology for Preserving Fruit Quality*. CRC-Taylor & Francis, Boca Raton, USA, 287 pp.

Wszelaki A.L., Mitcham E.J., 2003. Effect of combinations of hot water dips, biological control and controlled atmospheres for control of gray mold on harvested strawberries. *Postharvest Biology and Technology* 27: 255–264. DOI: 10.1016/S0925-5214(02)00095-9.

Zheng Q., Zuo J., Gu S., Gao L., Hu W., … Jiang A., 2019. Putrescine treatment reduces yellowing during senescence of broccoli (*Brassica oleracea* L. var. italica). *Postharvest Biology and Technology* 152: 29–35. DOI: 10.1016/j.postharvbio.2019.02.014.

Zokaee-Khosroshahi M., Esna-Ashari M., 2008. Effect of putrescine application on post-harvest life and physiology of strawberry, apricot, peach and sweet cherry fruits. *Journal of Crop Production and Processing* 12: 219–230.

Zokaee Khosroshahi M.R.Z., Esna-Ashari M., Ershadi A., 2007. Effect of exogenous putrescine on post-harvest life of strawberry (*Fragaria ananassa* Duch.) fruit, cultivar Selva. *Scientia Horticulturae* 114: 27–32. DOI: 10.1016/j.scienta.2007.05.006.

Zoran I., Yulita P., Sharon A.T., Azica C., Elazar F., 2001. Short prestorage hot water rinse and brushing reduces decay development in tomato, while maintaining its quality. *Tropical Agricultural Research and Extention* 4: 1–6.