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Extending postharvest life of Karaj persimmon by hot water and 1-MCP treatments

Mousa Rasouli^{1*}, Orang Khademi²

¹*Horticulture and Landscape Engineering Department, Faculty of Agriculture, Malayer University, Malayer, Hamedan, Iran*

²*Department of Horticulture, Shahed University, Tehran, Iran*

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Abstract

To extend the shelf life of 'Karaj' persimmon following cold storage, fruit were harvested at commercial maturity and treated with hot water at 45°C for 30min, 50°C for 20min or with 500nL/L 1-MCP and then stored at 1°C for 30 days. After storage, fruit were treated with CO₂ to remove astringency, then held at 25°C for 5 days (simulated shelf life) and evaluated for quality. cv. 'Karaj' persimmon was susceptible to chilling injury [CI], however the main symptoms CI, such as softening, loss of colour, flesh gelling and skin browning, did not appear during cold storage but developed when fruit were transferred to shelf temperatures. Treatment with hot water, especially at 50°C, reduced chilling injury development of fruit during cold storage, followed by shelf life, but neither hot water treatment prevented chilling symptoms completely. The major alleviation in chilling injury occurred following 1-MCP treatment. Increased ethylene production was associated with chilling injury in affected fruit and treatments that reduced chilling injury suppressed ethylene evolution. This result indicated that hot water and 1-MCP treatments have the potential to extend storage life of 'Karaj' persimmon fruit; however 1-MCP is more effective than hot water.

* **Corresponding Author:** Mousa Rasouli ✉ m.rasouli@malayeru.ac.ir

Introduction

Persimmon (*Diospyros kaki* Thub.) originated in China and has been cultivated in Eastern Asia for hundreds of years; however, recently interest in persimmon production has increased throughout the world (Taira, 1996). In 2010 estimated production of persimmon in Iran was 2100 tons (FAO, 2010). Most persimmon cultivars in Iran are astringent and 'Karaj' is one of the important astringent cultivars in Iran. In local markets, 'Karaj' fruit are commonly consumed as over-ripened soft fruit, which are non-astringent, although this cultivar has astringency removed easily by both CO₂ and ethanol treatments (Khademi *et al.*, 2010). In many other astringent cultivars, astringency could not be removed easily by either CO₂ or ethanol treatments (Yamada *et al.*, 2002).

Iran has great potential to extend persimmon production for export, but export has been limited because of poor handling practices and inadequate storage facilities. Ability to store well is an essential requirement for future development of the persimmon industry in Iran. 'Karaj' persimmon fruit, not treated for astringency removal, stored at 0°C were firmer than fruit stored at 5°C and hence it was concluded that, based on only this quality attribute, that 'Karaj' persimmon was chilling insensitive (Khademi *et al.*, 2012b). However, these 'Karaj' persimmons were evaluated immediately after storage at both 0°C and 5°C and showed loss of colour, skin browning, flesh gelling and flesh darkening typical CI symptoms in other persimmon cultivars such as 'Fuyu' (MacRae, 1987), 'Suruga' (Collins and Tisdell, 1995) and 'Rojo Brillante' (Arnal and DelRio, 2004). Hence, it is likely that 'Karaj' persimmon is susceptible to CI.

The beneficial effect of postharvest heat treatments to reduce CI during cold storage has been shown in different horticultural crops (Fallik, 2004). Heat treatments reduced susceptibility of some persimmons cultivars to CI. This phenomenon has been observed in hot air treated 'Fuyu' (Woolf *et al.*, 1997), hot water treated 'Fuyu' (Burmeister *et al.*,

1997, Lay-Yee *et al.*, 1997) and in hot water treated 'Rojo Brillante' (Besada *et al.*, 2008b) persimmons. Preliminary results showed that hot water treatments (HWTs), applied at 45°C for 30min or 50°C for 20min, maintained postharvest quality of 'Karaj' persimmon during storage for up to 2 months (Khademi *et al.*, 2012a).

1-methyl-cyclo propene (1-MCP), is a potent inhibitor of ethylene action, with potential to delay ripening and senescence and to reduce physiological disorders, thereby extending postharvest life of various horticultural crops (Blankenship and Dole, 2003). The relationship between ethylene and CI in persimmon fruit has been shown previously by some authors (Burmeister *et al.*, 1997, MacRae, 1987, Woolf *et al.*, 1997). Chill injured fruit produced more ethylene than non-chilled fruit on removal from storage 1-MCP reduced CI symptoms of cold stored 'Rojo Brillante' persimmon (Besada *et al.*, 2008a, Perez-Munuera, 2009, Salvador *et al.*, 2004), however the effects of 1-MCP on 'Karaj' persimmon have not been elucidated.

The objective of this work was to evaluate the effects of HWT and 1-MCP treatments on postharvest quality of 'Karaj' persimmon, which were submitted to de-astringency treatment after cold storage.

Material and methods

Plant materials and treatments

Astringent persimmons cv. 'Karaj' were harvested at the yellow-orange maturity stage from a commercial orchard in Karaj city, Iran, 25 October, 2012. Fruit were transported to the experimental station in Malayer University the same day, where they were sorted for uniformity of size, color and absence of defects. On the day of harvest a sample of 20 fruit were separated from the selected fruit, and analyzed directly (as at harvest). One day after harvest, fruit were randomly divided into 4 groups, each group containing 90 fruit, corresponding to the following treatments: Control (treatment with water at 25°C for 25min), HWT-45°C (treatment with hot water at 45°C for 30min), HWT-50°C (treatment with hot water at

50°C for 20min) and 1-MCP (treatment with 1-MCP of 500 nL.L⁻¹). 3 replicate samples were processed for each treatment.

For HWTs, persimmons were dipped in a recirculating hot water bath. Bath temperature was constantly monitored by thermometer and never fell less than 1°C below the established value during each treatment. Following treatment fruit were dried at room temperature for about 1 h and then transferred to 1°C and 90% RH for up to 30 days.

1-MCP (Smart Fresh™), provided by Agro Fresh Inc. (Rohm and Hass Co., Italy), is formulated as powder (0.14% 1-MCP). Fruit were placed in a 40L plastic container and exposed to 1-MCP with a concentration of 500 nL.L⁻¹ for 24h at room temperature (18°C) and 85% RH. Immediately following 1-MCP treatment, fruit were removed from the container and stored as the HWT-treated fruit.

After storage, fruit were held at 20°C for 12h and then was submitted to de-astringency treatments. De-astringency treatment was carried out as described in Yamada *et al.* (2002). Fruit were placed into a plastic container that was closed tightly. Internal gas in the container was replaced with ≈ 100% CO₂ by streaming air out of the container with CO₂. After 24h at 25°C, the container was opened and fruit was then kept at 20°C in air for 24 h. After de-astringent treatment, fruit were stored for 5 days at 20°C to simulate the shelf life period and then were assessed.

Fruit assessment

Fruit assessment was done at three sampling times: at the end of cold storage (CS), after de-astringency treatment (dAT) and at the end of shelf life (SL) period. The samples of 30 fruit per treatment (as 3 replications) in each sampling time were used for fruit assessment.

Fruit firmness was measured using an Effegi Penetrometer (model FT 327, Italy) fitted with an 8 mm tip. Firmness was measured at two opposite points around the equator on each fruit followed peel

removal and the result was expressed as Newton (N). For ethylene determination, six fruit per treatment were sealed individually in a 1 L airtight jar for 2 h at 20°C, then, a 1ml of headspace gas sample was withdrawn and injected into a gas chromatography (Shimatsu, Model:C-R4A, Japan), equipped with an activated alumina column and a flame ionization detector (FID). Ethylene production was expressed as μL C₂H₄ kg⁻¹h⁻¹.

Skin colour was measured using a colorimeter (Minolta, CR-400, Japan) at 3 equally spaced locations around the fruit circumference, and expressed as Hunter 'L', 'a', and 'b' values.

External (Skin) browning was assessed subjectively as described by Woolf *et al.* (1997) on a scale of 0-3 according to the amount of browning on the fruit surface: 0=no browning, 1=slight browning, 2=moderate browning and 3=severe browning. Browning index (BI) was calculated as follows:

$$BI = \frac{\sum[(\text{browning level}) \times (\text{number of fruit at each browning level})]}{(3 \times \text{total number of fruit in the lot})}$$

Extension of gelling within flesh was assessed visually by cutting fruit across the equator and gel formation was rated on a scale of 1 (no gel) to 5 (firm, dark gel over the entire cut surface; mottled external appearance) according to MacRae (1987). Gel index (GI) was calculated as follows:

$$GI = \frac{\sum[(\text{gelling level}) \times (\text{number of fruit at each gelling level})]}{(5 \times \text{total number of fruit in the lot})}$$

Astringency of fruit was estimated by sensory evaluation and the tannin print method as described by Arnal and DelRio (2003). Persimmon tannins, which are responsible for astringency taste, in soluble forms react with ferric chloride, forming tannin-Fe ion complexes, which are blue black. Degree of astringency can be estimated by evaluating colour development during this reaction. For that, 3 fruit from each replicate, were cut longitudinally and the freshly cut surface was immersed in a 5% ferric chloride solution for 5 min, after which fruit was removed and colour of the cut surface was evaluated visually form 1 (less colour development, no

astringency) to 4 (Maximum colour development, high astringency).

Statistical analysis

All data were subjected to analyses of variance (ANOVA) using SAS software (ver. 9.2), and comparison between means was evaluated by the LSD test at a $P=5\%$ level of error.

Results and discussion

Firmness

Firmness decreased throughout storage in all treatments, compared to firmness at harvest (Fig. 1). However, loss of firmness was markedly faster in control fruit than in fruit from HWTs and 1-MCP treatments. Fruit of HWT-45°C softened faster than fruit from HWT-50°C and 1-MCP treatments during cold storage. When fruit were transferred from cold storage to higher temperature and submitted to dAT treatment, followed by SL condition, softening was observed in all treatments, and was more pronounced in control fruit. Fruit of HWT-45°C were firmer than control fruit after dAT, however they began to soften rapidly during SL and reached almost the same firmness as control fruit after 5 days. HWT-50°C and 1-MCP treated fruit maintained higher firmness throughout this experiment.

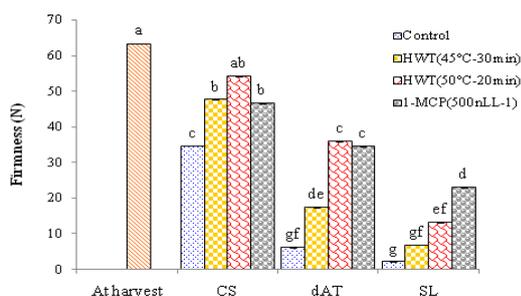


Fig. 1. Effect of hot water (HWT) and 1-MCP treatments on Firmness of 'Karaj' persimmon after 30d of cold storage (CS) at 1°C, followed by de-astringency treatment (dAT) and followed by shelf life condition (SL) of 5d at 20°C. Means with the same letter are not significantly different at 5% level of LSD test.

In some persimmon cultivars softening is a symptom of CI, which is manifested when fruit is transferred from cold to higher temperature (Arnal and DelRio,

2004, MacRae, 1987). In the current experiment control fruit showed extreme CI after removal from cold storage. HWT-50°C and 1-MCP were the most effective treatments at reducing CI, which was reflected by increased fruit firmness, while HWT at 45°C had a limited inhibitory effect on CI development. The effectiveness of HWT in delaying fruit softening is well known in other persimmon cultivars such as: 'Fuyu' (Burmeister *et al.*, 1997, Lay-Yee *et al.*, 1997, Promyo and Park, 2009), 'Rojo Brillante' (Besada *et al.*, 2008b) and 'Qiandawuhe' (Luo, 2006), and the beneficial effects of 1-MCP in maintaining firmness was also reported in 'Rojo Brillante' (Besada *et al.*, 2008b, Salvador *et al.*, 2004) and 'Qiandawuhe' (Luo, 2007) persimmons.

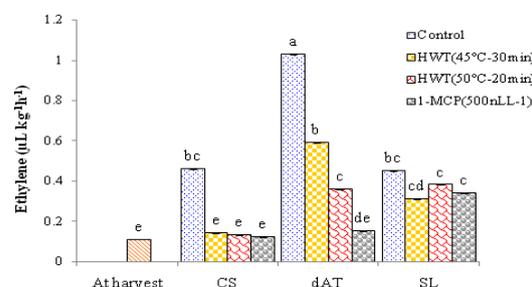


Fig. 2. Effect of hot water (HWT) and 1-MCP treatments on Ethylene production rate of 'Karaj' persimmon after 30d of cold storage (CS) at 1°C, followed by de-astringency treatment (dAT) and followed by shelf life condition (SL) of 5d at 20°C. Means with the same letter are not significantly different at 5% level of LSD test.

Ethylene

Persimmon is a climacteric fruit, whose softening and ripening is regulated by ethylene (Harima *et al.*, 2003, Luo, 2007, Salvador *et al.*, 2004). Ethylene production of control fruit was significantly higher than in 1-MCP and HWTs treated fruit on the day after removal from CS (Fig. 2), while none of HWTs- and 1-MCP treated fruit showed any increase in ethylene production during CS, as compared to ethylene level at harvest. Ethylene production of control and HWTs treated fruit increased during dAT, with maximum production in control fruit, then declined throughout the SL period. 1-MCP treatment inhibited this increase in ethylene production during dAT, however, ethylene production of 1-MCP treated

fruit increased gradually during SL. At the end of SL, there were no significantly differences in ethylene production among treatments (Fig. 2).

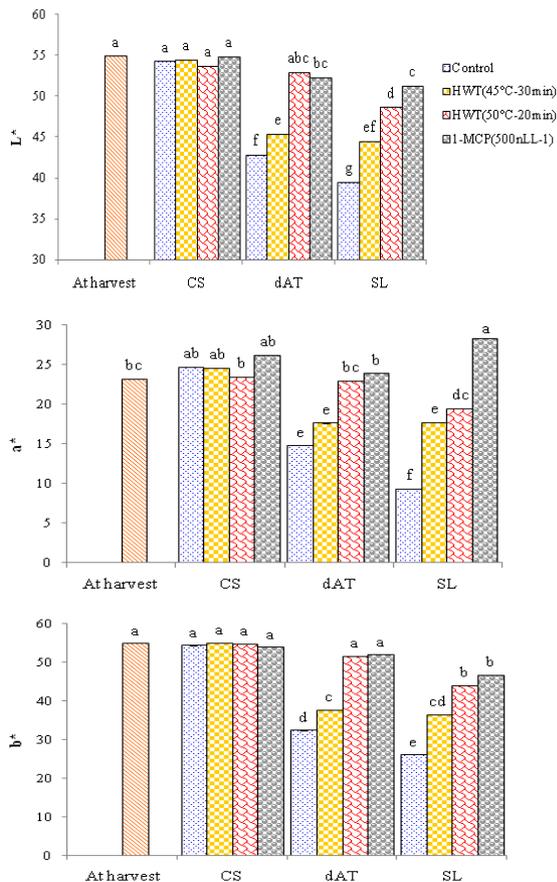


Fig. 3. Effect of hot water (HWT) and 1-MCP treatments on Hunter 'L*', 'a*', 'b*' values of 'Karaj' persimmon after 30d of cold storage (CS) at 1°C, followed by de-astringency treatment (dAT) and followed by shelf life condition (SL) of 5d at 20°C. Means with the same letter are not significantly different at 5% level of *LSD* test.

In this experiment, ethylene evolution was correlated with CI development (as softening) after removal from CS, where control fruit with severe CI also showed increased level ethylene production; high ethylene production rates after cold storage have been associated with increased CI in 'Fuyu' persimmon (Burmeister *et al.*, 1997, Woolf *et al.*, 1997). The role of ethylene in CI development has been confirmed as 1-MCP treatment, which ameliorated CI symptoms by effectively suppressing ethylene production. HWTs, especially at 50°C, also reduced CI symptoms and hence reduced ethylene evolution. These results suggest that either HWTs or 1-MCP treatments were

providing protection from CI during CS by inhibiting ethylene evolution, as observed in other persimmon cultivars (Burmeister *et al.*, 1997, Promyo and Park, 2009, Salvador *et al.*, 2004). 1-MCP (Liu *et al.*, 2009) and hot water (Lurie, 1998) treatments reduced ethylene production by inhibiting activities of ACS and ACO, key enzymes of the ethylene production pathway.

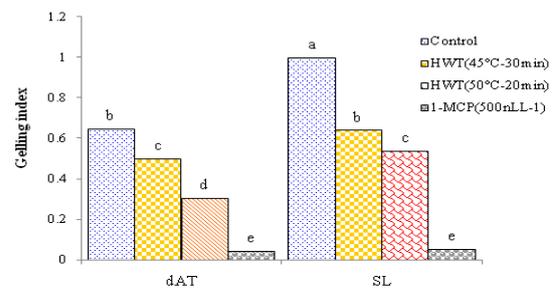


Fig. 4. Effect of hot water (HWT) and 1-MCP treatments on Gelling index of 'Karaj' persimmon after 30d of cold storage at 1°C, followed by de-astringency treatment (dAT) and followed by shelf life condition (SL) of 5d at 20°C. Means with the same letter are not significantly different at 5% level of *LSD* test.

Colour

No differences in peel colour were detected among treatments during storage, where Hunter 'L*', 'a*', 'b*' values remained at harvest level (Fig. 3). However on fruit removal from CS to higher SL temperature, Hunter 'L*', 'a*', 'b*' values tended to decrease gradually in all the fruit. This decrease was greater in control fruit than others. After dAT, and after SL period, Hunter 'L*', 'a*', 'b*' values were much lower in controls than in fruit from HWTs and 1-MCP treatments.

Following dAT, Hunter 'L*', 'a*', 'b*' values of HWT-45°C treated fruit were significantly lower than those of HWT-50°C and 1-MCP treated fruit, while no differences were observed in these three factors between 1-MCP and HWT-50°C treated fruit. At the end of the SL period, Hunter 'L*', 'a*', 'b*' values of 1-MCP treated fruit were generally higher than for HWTs treated fruits. Hunter 'L*', 'a*', 'b*' of HWT-50°C treated fruit were also higher than those of HWT-45°C treated fruit after shelf life period.

A decrease in Hunter 'L*', 'a*', 'b*' values is a consequence of CI in persimmon fruit, which occurred when fruit were transferred from cold to higher temperature (Collins and Tisdell, 1995, Woolf *et al.*, 1997). Therefore in the present experiment, control fruit had severe CI following CS. 1-MCP was the most effective treatment in alleviating CI during and this was reflected by an increase in colour parameters in the 1-MCP treatment. Similarly, HWTs tended to reduce CI, and CI severity decreased as temperature of HWT increased.

Gelling and Browning index

Tissue gelation appears to be a typical symptom of CI in several persimmon cultivars (MacRae, 1987, Salvador *et al.*, 2004). In the current study this symptoms did not appear during cold storage, but developed when fruit were transferred from cold to higher temperature and increased during SL periods (Fig. 4). Tissue gelation was higher in control fruit than fruit from HWTs or 1-MCP treatments reaching a maximum at the end of SL. This effect was associated with CI sensitivity of persimmon. Treatment with 1-MCP significantly inhibited CI symptoms in 'Karaj' persimmon, and such treated fruit had only slight symptoms of tissue gelation at the end of SL. Fruits submitted to HWTs showed less tissue gelation than control fruit throughout this experiment with HWT-50°C more effective than HWT-45°C. Therefore, while HWT-50 was the most effective heat treatment in reducing CI symptoms, it was less effective than 1-MCP. Similar results were also reported elsewhere following heat (Lay Yee *et al.*, 1997, Woolf *et al.*, 1997) and MCP (Salvador *et al.*, 2004) treatments.

Although no browning symptoms occurred in control fruit during CS, severe browning developed when fruit were transferred from CS to SL condition. Browning index in control fruit increased from 0.4 after dAT to 0.76 at the end of SL. No browning symptoms were observed in the fruit from 1-MCP or HWTs treatments. A 'Fuyu' persimmon browning disorder was linked with CI symptoms (MacRae, 1987). Regarding browning disorder, In this current

study, control fruit developed extreme symptoms of CI following CS, whereas 1-MCP and HWTs treatments was the most effective treatments at reducing browning in 'Karaj' persimmon.

Astringency

Fruit from all treatments showed a high level of astringency (data not shown) after cold storage, but both sensory evaluation and the tannin print method indicated that astringency was successfully removed from all fruit by high CO₂ treatment after CS. It is clear that the de-astringency process is not affected by 1-MCP or HWTs treatments.

Conclusion

The persimmon fruit 'Karaj' is chilling sensitive when stored at 1°C, but symptoms of this disorder, including reduction of firmness, loss of colour, skin browning and gelling of the flesh, do not appear in the cold room, but develop when fruit are transferred to shelf life condition. This contradicts our previous results in which 'Karaj' persimmon fruit stored at 0°C maintained higher quality than fruit stored at higher temperatures with the conclusion made that 'Karaj' persimmon was chilling insensitive (Khademi *et al.*, 2012b). Application of 1-MCP after harvest at a concentration of 500nL.L-1 alleviated CI and hence maintained quality of 'Karaj' persimmon fruit during cold storage at 1°C and subsequent shelf life. Treatment with hot water at 50°C for 20 min after harvest reduced susceptibility of 'Karaj' persimmon fruit to CI. Hot water treatment at 45°C for 30 min was less inhibitory to CI development than HWT-50. Results suggest that ethylene plays an important role in development of CI symptoms in 'Karaj' persimmon and both 1-MCP and hot water treatments were effective in reducing incidence and severity of chilling injury through suppressing ethylene production. Both 1-MCP and hot water treatments provide useful tools for maintaining postharvest life of 'Karaj' persimmon, with 1-MCP being the most effective treatment.

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