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Effect of Hot Water Treatment on Astringency Removal in Persimmon Cultivars

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ABSTRACT

The aim of this study was to investigate the effect of hot water treatments on the removal of astringency in 'MKU Harbiye,' 'Kaki Tipo,' and 'Vainiglia' persimmon cultivars. Fruits were dipped in tap water at hot water at 40°C for 5 h (HW 40°C-5 h) or hot water at 50°C for 1 h (HW 50°C-1 h). Untreated (Control 1), 20°C for 1 (Control 2, 20°C-1 h), or 5 h (Control 3, 20°C-5 h) and treated fruits were then kept at 20°C for 10 days of shelf life period. Changes in weight loss, appearance, firmness, total soluble solids, taste, fungal decay, fruit skin color, soluble and insoluble tannin content were determined during shelf life. In all cultivars, HW 40°C-5 h was found to be successful in reducing the astringency and maintained firmness above the marketability limit for 10 days of shelf life period. The fruit treated with HW 40°C-5 h became edible after 7 days at 20°C while control fruits remained astringent based on soluble tannin content the entire shelf-life period. Although the HW 50°C-1 h and Control 2 and 3 (20°C-1 h or 20°C-5 h) treatments received acceptable taste scores after 10 days, fruits from these treatments were slightly astringent.

KEYWORDS

Persimmon; hot water; shelf life; astringency

Introduction

Persimmon fruits (*Diospyros kaki* L.) are classified as astringent and non-astringent based on their astringent degree at the harvest (Zheng et al., 2006). Although non-astringent fruits are preferred, the production of astringent cultivars is also prevalent (Itamura et al., 2005). The shelf life of persimmons is short. Postharvest quality losses such as fruit softening, weight loss, and fungal decay lead to limit its market value and storage duration (Candir et al., 2010).

The astringency in persimmons is derived from the tannins accumulated in specialized cells of the mesocarp during the development of the fruits (Tessmer et al., 2014). In persimmon fruits, the soluble and insoluble forms of tannins are synthesized and accumulated during the growth phase (Bubba et al., 2009; Taira et al., 1998) and decreased toward harvest and during storage (Bibi et al., 2001; Candir et al., 2009; Clark and Mac-Fall, 2003;

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Salvador et al., 2007). The amount of water-soluble tannin is higher in the astringent persimmon cultivars than the non-astringent cultivars at the maturity stage. The astringent persimmon fruits harvested at the maturity stage with a higher astringent need to be the removal of the astringency to ensure fruit eating quality and to be consumed immediately. The pollination-variant non-astringent persimmon fruits may also be required for artificial removal of astringency if fruits have few or no seeds due to lack of pollination (Taira, 1996). Ethylene can be used to remove astringency but the excessive softening leads difficulties in the marketing of persimmon fruits (Crisosto, 2016). It is essential to remove the astringency of astringent cultivars before marketing. Removal of astringency of persimmons with maintaining fruit quality had been carried out by many studies; high CO_2 using dry ice or CO_2 gas (Ben-Arie and Sonego, 1993; Kuzucu et al., 2005; Orihuel Iranzo et al., 2003; Öz and Özelkök, 2003; Salvador et al., 2006, 2007; Testoni, 2002; Yamada et al., 2002), hot water (Ben-Arie and Sonego, 1993; Kuzucu et al., 2005; Özdemir et al., 2017), ethanol (Candir et al., 2012; Edagi et al., 2009; Orihuel Iranzo et al., 2003; Oshida et al., 1996; Sugiura et al., 1975; Taira et al., 1989; Tessmer et al., 2018; Testoni, 2002; Toplu et al., 2016; Yamada et al., 2002) and cold storage (Candir et al., 2008; Hribar et al., 2000; Özdemir et al., 2014b, 2014a).

Removal of astringency with CO_2 is suitable commercially because provides non-astringent fruit in a short period of 1 to 3 days (Kato, 1990). In the past, ethanol treatment to remove astringency produces firm, high-quality on-astringent fruits but is commercially impractical because of the long time of 10 days required at room temperature (Kato, 1990; Kitagawa and Glucina, 1984), today ethanol treatments are commercially applied in some countries like Brazil (Tessmer et al., 2018) Although the use of warm water treatment is not used commercially for removal of astringency, has been shown to have an advantage in maintaining flesh firmness better than 80% of CO_2 and 35% of ethanol vapor treatments in fresh-cut persimmon fruit during storage at 10°C for 6 days (Chung et al., 2015).

Postharvest heat treatment as environmental-friendly method is used in fruits and vegetables. Today, there has been increasing interest in non-chemical and environmental-friendly methods for postharvest decay, insect control, disinfestation, and others. Various preharvest and postharvest factors affect fruit quality. Pre-postharvest factors affecting quality are growing conditions, ecology, rootstock, temperature, relative humidity, ethylene, aromatic volatiles, plant regulators, waxing, fungicides, precooling, and packaging. Previous studies have shown that postharvest heat treatment for removing astringency in 'Triumph,' 'Rojo Brillante,' and 'Giombo' persimmon varieties, etc. There are few reports on the effects of postharvest heat treatment on the storage and shelf life of 'Kaki Tipo' persimmon variety. There are not reports on the effects of postharvest heat treatment on the

storage and shelf life of 'MKU Harbiye' and 'Vainiglia' persimmon varieties. Effects of postharvest heat treatment for removing astringency on postharvest quality of these persimmons are not completely known. Therefore, effects of postharvest heat treatment for removing astringency on shelf life performances of these variety fruits have gained importance.

The aim of this study is to investigate the effects of hot water treatment on removal of astringency in 'MKU Harbiye,' 'Kaki Tipo,' and 'Vainiglia' persimmon cultivars and quality losses during shelf life.

Materials and methods

In this study, pollination-variant non-astringent fruits cv. 'MKU Harbiye,' 'Kaki Tipo,' and 'Vainiglia' persimmons were obtained from the 15-year-old trees grafted on ***Diospyros lotus*** rootstocks and planted 5 × 6 m in Dörtyol (Latitude 36° 51.10 N; Longitude 36° 09.57E and altitude 9 m) Research Station of Faculty of Agriculture, Mustafa Kemal University.

Fruits were harvested at firm-ripe and full orange color stage (Candir et al., 2010). After harvest, fruits were sorted for size (150–200 g), color uniformity, and absence of calyx damage and surface defects at the postharvest laboratory at the Horticultural Department of Mustafa Kemal University (Antakya-Hatay). Fruits were divided into five lots and subjected to following treatments: (1) Untreated fruit was served as a **Control 1** treatment; (2) and (3) Fruits were dipped in tap water at 20°C for 1 (Control 2, 20°C-1 h) and 5 h (Control 3, 20°C-5 h), respectively; (4) Fruits were dipped in hot water at 40°C for 5 h (HW 40°C-5 h); (5) Fruits were dipped in hot water at 50°C for 1 h (HW 50°C-1 h). Untreated (control) 20°C for 1 (Control 2, 20°C-1 h) or 5 h (Control 3, 20°C-5 h) and hot water-treated fruits were then kept at 20°C and 70–75% relative humidity for 10 days of shelf life period. Quality parameters were measured after 3, 5, 7 and 10 days.

Thirty fruits were numbered and individually weighted using a laboratory balance with an accuracy of 0.01 g to determine weight loss. Weight loss was calculated as percentage loss in reference to the initial weight. Flesh firmness was measured using an Effegi penetrometer (Model FT 327) according to Candir et al. (2010) and expressed as Newton (N). Total soluble solid content was assessed using a refractometer (Atago Model ATC-1E, Tokyo, Japan) at 20°C and results were expressed as %. An expert panel of 10 trained panelists (nonsmoker 7 male and 3 female, ages 20 to 45) evaluated appearance (1 - 5) of fruits on a 5-point scale, where: 1 = very poor; 2 = poor; 3 = good (limit of marketability); 4 = very good; 5 = excellent. Fruit appearance was evaluated externally. The panelists also evaluated taste (1 - 9) of peeled and sliced fruits from each treatment using a hedonic scale of 1 = disliked to 9 = liked. Samples were served to panelists in trays labeled with random 3-digit codes

at room temperature. The acceptable limit in taste evaluation is 5. Fungal decay was calculated a percentage of decayed fruit that has more than 1% of their surface area covered with black spots (Prusky et al., 2001). Fruit was examined visually for physiological disorders such as chilling injury as described previously (MacRae, 1987). Fruit skin color (L* C* h°) was measured using the CIELAB (L*a*b*) color space by a CR-300 Minolta Chroma Meter (Konica Minolta, Osaka, Japan). Contents of soluble and insoluble tannin were measured spectrophotometrically (UV/Vis spectrophotometer, Agilent Cary 60, USA) of the method described by Oshida et al. (1996) and results were expressed as g 100 mL-1. To measure the tannin content, 5 g of flesh from each of three fruits was homogenized with 20 mL of 80% (v/v) MeOH in a Polytron for per variety. The homogenate was centrifuged at 3600 g for 5 min and pellet was washed again with the same solvent. The combined supernatant, containing soluble tannins, was made up to 50 mL with further solvent. The pellet containing insoluble tannins was then suspended in 1% (v v-1) hydrochloric acid in methanol (1% HCl-MeOH) and left standing for 30 min at room temperature. The extract was centrifuged and the pellet was washed again with 1% HCl-MeOH. The combined supernatant, i.e. resolubilized tannin fraction, was adjusted to 50 mL with solvent. A suitable aliquot of each fraction was made up to 8.5 ml with water and mixed with phenol reagent (0.5 mL) and saturated sodium carbonate solution (1 mL). Then, after 1 h, the absorptivity was determined at 725 nm using as a blank containing 8.5 mL water and reagents only.

The experiment was conducted in a factorial experiment in a completely randomized block design and the data were analyzed by two-way ANOVA using SAS 9.4 software of SAS Institute, Cary, N.C. (SAS, 2017). There were two factors: Treatments (Control 1, Control 2, Control 3, HW 40°C – 5 h and HW 50°C – 1 h) and Shelf life (after 3, 5, 7 and 10 days). The data were obtained from three replicates per treatments for each cultivar. Each replicate contained 10 fruits. Mean comparison was performed by Fisher's least significant difference (LSD) test at a $P < .05$ level using the SAS Proc GLM procedure.

Results and discussion

Weight loss increased with the prolonging shelf life period in all cultivars. In 'MKU Harbiye' cultivar, higher weight loss occurred in Control 1 fruits (2.93%) and Control 2 (2.80%) treatments while the treatment of Control 3 (1.96%) resulted in lowest weight loss after 10 days of shelf life period (Table 1). In 'Kaki Tipo' cultivar, control fruits (2.92%) and fruits treated with HW 50°C-1 h (2.80%) had higher weight loss while the treatment of Control 2 (2.34%) resulted in lowest weight loss after 10 days of shelf life period (Table 2). In 'Vainiglia' cultivar, higher weight loss occurred in Control 1 fruits (2.87%) and Control 2

Table 1. Effects of hot water treatments on quality parameters of persimmon fruits 'MKU Harbiye' during the shelf-life period at 20°C for 10 days.

					Skin color						
Treatments	Weight loss (%)	Firmness (N)	TSS (%)	Fungal decay (%)	L*	C*	h°	Appearance (1–5)[1]	Taste (1–9)[2]	Soluble tannin	Insoluble tannin
At harvest	-	68.21 a	17.67 a	-	68.66 b-f	67.18 a-d	91.62 a	5.00 a	1.85 l	0.61 a	0.26 o
After 3 days at 20°C											
Control 1	1.18 g	38.81 d-g	17.40 ab	0.00 c	70.74 abc	64.96 bcd	89.87 abc	4.67 ab	3.15 jk	0.54 b	0.33 n
Control 2	1.26 g	47.04 bc	17.10 b-f	0.00 c	69.93 a-e	63.89 bcd	87.17 c-f	4.67 ab	3.00 k	0.61 a	0.27 o
Control 3	0.84 h	36.75 e-h	15.90 h	0.00 c	69.93 a-e	67.65 a-d	88.96 a-d	4.67 ab	3.60 ghı	0.52 b	0.40 lm
HW 40°C – 5 h	1.22 g	51.65 b	16.73 efg	0.00 c	73.51 a	73.92 a	85.83 ef	4.67 ab	4.80 e	0.32 e	0.61 h
HW 50°C – 1 h	0.85 h	42.43 c-f	17.70 a	0.00 c	71.17 abc	66.74 a-d	90.81 ab	4.67 ab	3.80 gh	0.24 f	0.66 g
After 5 days at 20°C											
Control 1	1.94 d	41.45 c-f	16.67 fg	0.00 c	70.82 abc	68.19 abc	88.83 bcd	4.67 ab	3.60 ghı	0.55 b	0.42 l
Control 2	1.97 d	46.16 bcd	17.13 b-e	0.00 c	67.41 c-f	63.38 b-e	85.03 fg	4.67 ab	4.25 f	0.53 b	0.36 mn
Control 3	1.33 fg	34.59 f-ı	17.10 b-f	0.00 c	68.32 c-f	64.80 bcd	87.18 c-f	4.33 ab	4.88 e	0.32 e	0.56 ıj
40°C – 5 h	1.61 e	31.56 g-j	16.93 c-f	0.00 c	73.32 ab	74.00 a	84.62 fg	4.33 ab	5.30 d	0.19 f	0.72 ef
50°C – 1 h	1.55 ef	43.02 cde	17.27 abc	0.00 c	70.78 abc	68.69 abc	87.81 cde	4.33 ab	3.88 g	0.16 g	0.73 de
After 7 days at 20°C											
Control 1	2.56 bc	38.81 d-g	16.73 efg	0.00 c	70.51 a-d	68.89 abc	86.37 def	4.33 ab	3.30 ıjk	0.46 c	0.52 jk
Control 2	2.53 c	40.57 c-f	17.33 abc	8.33 ab	65.80 d-g	61.61 cde	82.75 gh	4.33 ab	3.50 hıj	0.46 c	0.40 lm
Control 3	1.66 e	21.85 k	16.47 g	0.00 c	65.32 efg	61.91 cde	84.41 fg	3.00 d	4.88 e	0.23 f	0.60 hı
40°C – 5 h	2.05 d	29.79 hıj	17.10 b-f	0.00 c	65.61 efg	63.64 b-e	81.45 h	4.33 ab	7.18 b	0.02 ı	0.92 a
50°C – 1 h	2.03 d	42.34 c-f	17.13 b-e	0.00 c	71.33 abc	70.54 ab	84.95 fg	4.33 ab	4.35 f	0.22 f	0.68 fg
After 10 days at 20°C											
Control 1	2.93 a	27.24 ıjk	17.13 b-e	4.17 bc	68.88 a-f	68.49 abc	84.91 fg	4.33 ab	3.60 ghı	0.51 b	0.38 lm
Control 2	2.80 ab	25.28 jk	16.73 efg	12.50 a	64.28 fg	60.40 de	80.72 h	3.33 cd	4.38 f	0.38 d	0.49 k
Control 3	1.96 d	19.893 k	16.73 efg	4.17 bc	61.25 g	56.13 e	80.96 h	2.67 d	6.00 c	0.09 h	0.77 cd
40°C – 5 h	2.51 c	20.38 k	17.20 bcd	0.00 c	51.92 h	42.38 f	76.19 ı	4.00 bc	8.00 a	0.01 ı	0.84 b
50°C – 1 h	2.45 c	27.73 ıjk	16.80 d-g	4.17 bc	71.97 abc	73.02 a	84.59 fg	4.33 ab	5.00 de	0.12 gh	0.79 c

Means (n = 3) followed by different letters within a column are significantly different at $p < 0.05$ according to Fisher's LSD test.
[1]Evaluated based on a 5 point scale, where: 1 = very poor; 2 = poor; **3 = good (limit of marketability)**; 4 = very good; 5 = excellent.
[2]Evaluated based on a hedonic scale of 1 = disliked extremely to 9 = liked extremely.

Table 2. Effects of hot water treatments on quality parameters of persimmon fruits 'Kaki Tipo' during the shelf-life period at 20°C for 10 days.

					Skin color						
Treatments	Weight loss (%)	Firmness (N)	TSS (%)	Fungal decay (%)	L*	C*	h°	Appearance (1–5)[1]	Taste (1–9)[2]	Soluble tannin	Insoluble tannin
At harvest	-	72.81 a	18.67 a	-	67.66 def	65.70 c-h	93.37 abc	5.00 a	1.80 j	0.68 a	0.20 h
After 3 days at 20°C											
Control 1	1.14 ı	43.61 bcd	18.47 ab	0.00 a	68.74 cde	61.93 hıj	92.66 bc	4.67 ab	3.77 ghı	0.58 bc	0.23 gh
Control 2	0.85 j	41.65 bcd	17.93 bcd	0.00 a	69.12 cd	63.64 e-j	91.59 cde	4.67 ab	3.30 ı	0.63 b	0.21 h
Control 3	1.00 ıj	45.77 bc	16.53 jk	0.00 a	66.81 efg	60.36 j	94.72 a	4.67 ab	3.40 hı	0.57 c	0.28 g
HW 40°C – 5 h	0.84 j	42.92 bcd	18.07 bcd	0.00 a	72.16 ab	70.34 b	86.32 hıj	4.67 ab	7.00 b	0.20 ı	0.76 b
HW 50°C – 1 h	0.81 j	47.04 bc	17.67 c-f	0.00 a	68.60 cde	62.90 f-j	93.77 ab	4.67 ab	3.77 ghı	0.46 efg	0.36 f
After 5 days at 20°C											
Control 1	1.92 g	39.49 cde	18.20 abc	0.00 a	69.13 cd	65.06 c-ı	91.88 bcd	4.67 ab	3.67 ghı	0.54 cd	0.36 f
Control 2	1.48 h	32.93 efg	18.07 bcd	0.00 a	68.97 cd	65.98 c-g	90.02 def	4.33 abc	3.87 ghı	0.54 cd	0.28 g
Control 3	1.62 h	43.02 bcd	17.87 cde	0.00 a	67.33 d-g	62.21 g-j	93.27 abc	4.33 abc	4.22 fg	0.42 fg	0.39 f
40°C – 5 h	1.49 h	39.30 cde	17.93 bcd	0.00 a	73.43 a	75.07 a	85.29 ıjk	4.33 abc	7.53 ab	0.10 j	0.80 b
50°C – 1 h	1.62 h	48.02 b	18.07 bcd	0.00 a	70.02 c	67.90 bc	89.91 ef	4.33 abc	4.06 gh	0.41 g	0.47 de
After 7 days at 20°C											
Control 1	2.55 cd	33.12 efg	17.80 cde	0.00 a	69.74 c	68.06 bc	88.83 fg	4.67 ab	3.73 ghı	0.47 ef	0.34 f
Control 2	1.98 g	33.12 efg	17.60 d-g	4.17 a	68.46 cde	65.41 c-ı	87.44 gh	4.33 abc	3.80 ghı	0.50 de	0.34 f
Control 3	2.23 ef	36.26 def	16.87 h-k	0.00 a	67.25 d-g	64.40 c-ı	90.20 def	4.00 bcd	6.20 c	0.21 ı	0.51 d
40°C – 5 h	2.05 fg	32.54 efg	17.53 d-g	0.00 a	72.28 a	75.26 a	83.41 k	4.33 abc	8.00 a	0.06 j	0.78 b
50°C – 1 h	2.15 efg	36.26 def	17.07 g-j	0.00 a	70.15 bc	67.49 bcd	86.33 hıj	3.33 de	5.44 de	0.31 h	0.53 d
After 10 days at 20°C											
Control 1	2.92 a	32.83 efg	17.07 g-j	4.17 a	68.15 c-f	66.78 b-e	86.70 hı	4.33 abc	3.30 ı	0.45 fg	0.37 f
Control 2	2.34 de	32.54 efg	17.33 e-h	4.17 a	66.14 fg	63.97 d-j	84.64 jk	4.33 abc	4.78 ef	0.35 h	0.44 e
Control 3	2.57 c	30.87 fg	16.40 k	4.17 a	65.33 g	61.80 ıj	89.67 ef	4.00 bcd	5.97 cd	0.21 ı	0.53 d
40°C – 5 h	2.66 bc	27.15 g	17.13 f-ı	0.00 a	57.97 h	51.80 k	78.82 l	3.67 cd	8.13 a	0.05 j	0.85 a
50°C – 1 h	2.80 ab	32.93 efg	17.05 g-j	0.00 a	68.44 cde	66.44 c-f	85.27 ıjk	2.67 e	6.22 c	0.21 ı	0.68 c

Means (n = 3) followed by different letters within a column are significantly different at $p < 0.05$ according to Fisher's LSD test.
[1]Evaluated based on a 5 point scale, where: 1 = very poor; 2 = poor (limit of marketability); 3 = good; 4 = very good; 5 = excellent.
[2]Evaluated based on a hedonic scale of 1 = disliked extremely to 9 = liked extremely.

(2.65%) treatments while the treatments of HW 40°C-5 h (2.34%) and Control 3 (2.43%) resulted in lower weight loss after 10 days of shelf life period (Table 3). Similarly, different researchers had reported increased weight loss during storage and shelf life (Candir et al., 2012; Kuzucu et al., 2005; Öz and Özelkök, 2003, 2017; Özdemir et al., 2014b; Salvador et al., 2004; Toplu et al., 2016). In our study, no visible of shriveling symptoms were observed on fruits of any cultivars since weight loss was below 10% (Candir et al., 2010).

According to the assessment of the panelists, the initial appearance score of 5.00 decreased during shelf life, but it was above the acceptable limit of about 3 in all cultivars. Similarly, Özdemir et al. (2014b; 2017) and Toplu et al. (2016) reported decreases in appearance scores of persimmon fruits during shelf life. In 'MKU Harbiye' cultivar, higher appearance scores were obtained from the control and HW 50°C-1 h treatments at the end of shelf-life period (Table 1). In 'Kaki Tipo' cultivar, the **Control 1** and **Control 2** treatments were rated with higher appearance scores at the end of shelf-life period (Table 2). In 'Vainiglia' cultivar, were obtained from the **Control 1** treatment resulted in a higher appearance score at the end of shelf-life period (Table 3).

Fruit softening limits the success of shipping and marketing of persimmon fruits. Fruit flesh firmness tented to decrease in all cultivars during shelf period but remained above the marketability limit of 17.8 N in all cultivars after 10 days of shelf life period (Crisosto, 2016). In 'MKU Harbiye' cultivar, the treatments of Control 3 resulted in lower firmness after 7 days. Fruits from Control 1 and hot water treatments had similar firmness after 10 days (Table 1). In 'Kaki Tipo' cultivar, the treatments of Control 3 resulted in lower firmness; there were no significant differences in firmness among other treatments after 10 days of shelf life period (Table 2). In 'Vainiglia' cultivar, the HW 40°C-5 h treatment resulted in one of the highest firmness after 3, 5 and 7 days, but there were no significant differences in firmness among treatments after 10 days of shelf life period (Table 3).

Total soluble solids content decreased during shelf life in all cultivars. In 'MKU Harbiye' and 'Vainiglia' cultivars, there were no significant differences in total soluble solids content among treatments after 10 days of shelf life period (Tables 1 and 3). In 'Kaki Tipo' cultivar, fruits of the treatment of Control 3 had lower total soluble solids content than other treatments at the end of shelf-life period (Table 2). In agreement with our results, previous studies indicated a decrease in total soluble solids content during shelf life period as a result of respiration process of fruits using sugars (Öz and Özelkök, 2003; Özdemir et al., 2017; Toplu et al., 2016). In addition, it has been reported that the reduction in the content of total soluble solids is caused by the conversion of soluble tannins into the resulting insoluble tannins (Candir et al., 2012; Matsuoa et al., 1991; Taira et al., 1997).

Table 3. Effects of hot water treatments on quality parameters of persimmon fruits 'Vainiglia' during the shelf-life period at 20°C for 10 days.

					Skin color						
Treatments	Weight loss (%)	Firmness (N)	TSS (%)	Fungal decay (%)	L*	C*	h°	Appearance (1–5)[1]	Taste (1–9)[2]	Soluble tannin	Insoluble tannin
At harvest	-	76.44 a	18.33 ab	-	68.07 de	65.53 c-f	94.82 ab	5.00 a	1.97 k	0.58 a	0.23 j
After 3 days at 20°C											
Control 1	0.97 ıj	51.06 cde	18.53 a	0.00 b	69.69 cd	63.08 d-g	93.59 abc	4.67 ab	3.20 ıj	0.50 bc	0.31 ı
Control 2	1.17 ı	51.94 cd	17.87 b-f	0.00 b	69.95 cd	61.49 fg	91.04 c-f	4.67 ab	3.00 j	0.48 cd	0.31 ı
Control 3	1.06 ıj	53.21 bcd	17.53 def	0.00 b	69.76 cd	62.09 fg	92.89 a-d	4.67 ab	3.50 g-j	0.36 e	0.44 efg
HW 40°C – 5 h	1.18 ı	48.41 de	18.13 abc	0.00 b	72.69 ab	72.45 ab	86.20 hı	4.67 ab	4.87 d	0.24 fg	0.66 bcd
HW 50°C – 1 h	0.79 j	57.53 b	18.10 a-d	0.00 b	69.79 cd	61.52 fg	95.22 a	4.67 ab	3.73 f-ı	0.36 e	0.48 ef
After 5 days at 20°C											
Control 1	1.72 fgh	55.86 bc	18.07 a-d	0.00 b	69.33 cd	65.35 c-g	92.74 a-d	4.67 ab	3.72 f-ı	0.46 cd	0.41 fgh
Control 2	1.88 efg	46.65 ef	17.60 c-f	0.00 b	70.38 bcd	65.46 c-g	92.82 a-d	4.33 abc	4.03 fg	0.47 cd	0.36 hı
Control 3	1.72 fgh	43.12 fg	17.93 b-e	0.00 b	68.47 de	62.91 efg	90.48 d-g	4.33 abc	4.77 de	0.22 fg	0.61 d
40°C – 5 h	1.56 gh	34.79 hı	18.27 ab	0.00 b	73.51 a	74.05 a	85.33 hı	4.33 abc	5.20 d	0.18 gh	0.71 bc
50°C – 1 h	1.52 h	49.88 de	17.87 b-f	4.17 ab	71.30 abc	67.28 cde	91.96 b-e	4.67 ab	4.22 ef	0.25 f	0.62 d
After 7 days at 20°C											
Control 1	2.39 bcd	49.88 de	18.13 abc	0.00 b	69.73 cd	68.01 bc	90.25 d-g	4.67 ab	3.40 hıj	0.44 cd	0.49 e
Control 2	2.37 bcd	38.81 gh	18.27 ab	0.00 b	71.44 abc	66.84 cde	90.08 d-g	4.00 bcd	4.08 f	0.46 cd	0.38 ghı
Control 3	2.13 de	40.28 g	17.33 f	0.00 b	66.35 e	55.77 h	87.52 gh	3.67 cde	4.83 d	0.13 hı	0.64 cd
40°C – 5 h	1.92 ef	33.52 ı	18.20 ab	0.00	69.14 cd	44.01 ı	81.83 j	3.67 cde	7.22 b	0.01 k	0.87 a
50°C – 1 h	2.18 de	41.94 fg	17.53 def	8.33 a	71.35 abc	67.01 cde	89.49 efg	4.33 abc	3.78 fgh	0.21 fg	0.65 bcd
After 10 days at 20°C											
Control 1	2.87 a	25.68 j	17.80 b-f	4.17 ab	69.19 cd	68.01 bc	88.29 fgh	4.33 abc	3.40 hıj	0.41 de	0.40 fgh
Control 2	2.65 abc	23.72 jk	17.53 def	8.33 a	69.95 cd	66.84 cde	90.12 d-g	4.00 bcd	3.44 hıj	0.55 ab	0.35 hı
Control 3	2.43 bcd	26.66 j	17.87 b-f	0.00 b	62.37 f	55.77 h	84.41 ıj	3.33 de	6.11 c	0.09 ıj	0.72 b
40°C – 5 h	2.34 cd	18.82 k	17.47 ef	4.17 ab	53.28 g	44.01 ı	74.71 k	3.67 cde	7.93 a	0.04 jk	0.87 a
50°C – 1 h	2.67 ab	24.21 j	17.93 b-e	8.33 a	69.88 cd	67.01 cde	85.90 hı	3.00 e	5.10 d	0.18 gh	0.66 bcd

Means (n = 3) followed by different letters within a column are significantly different at $p < 0.05$ according to Fisher's LSD test.
[1]Evaluated based on a 5 point scale, where: 1 = very poor; 2 = poor (limit of marketability); 3 = good; 4 = very good; 5 = excellent.
[2]Evaluated based on a hedonic scale of 1 = disliked extremely to 9 = liked extremely.

Soluble tannins are responsible for the sensory astringency in persimmon fruit (Taira, 1996). The initial taste score of about below 2 increased as soluble tannin content of all persimmon cultivars decreased during shelf life period (Tables 1-3) as reported previously Kuzucu et al. (2005), Candir et al. (2012), Özdemir et al. (2014b; 2017) and Toplu et al. (2016). The treatment of HW 40°C-5 h received higher taste scores in all cultivars during shelf life. After 5 days at which soluble tannin content reached to level that fruits were considered non-astringent, only the HW 40°C-5 h treatment received taste score above 5 of the acceptable limit in all cultivars. After 10 days, the taste of fruits from Control 3 and HW 50°C-1 h treatments were also rated above 5 in all cultivars.

The incidence of fungal decay was observed after 7 days in 'MKU Harbiye' and 'Kaki Tipo' cultivars (only fruits from 20°C-1 h) and 5 days in 'Vainiglia' cultivar (only fruit from HW 50°C-1 h) during shelf life period (Tables 1 and 3). In 'MKU Harbiye' cultivar, fungal decay was not observed in the fruits from HW 40°C-5 h throughout shelf life period while decay percentage reached the highest level of 12.5% in the fruits from Control 2 after 10 days (Table 1). In 'Kaki Tipo' cultivar, fungal decay was not observed in the fruits from HW 40°C-5 h and HW 50°C-1 h throughout shelf-life period, differences in decay incidence were not significant among after 10 days (Table 2). In 'Vainiglia' cultivar, fungal decay was not observed in the fruits from **Control 3** throughout the shelf-life period (Table 3). In this cultivar, decay incidence occurred only on the fruits from HW 50°C-1 h treatment after 5 and 7 days while similar decay incidence was determined among treatments after 10 days, except for Control 3 treatment. In all cultivars, we observed only black spot disease or Alternaria rot caused by A. alternata as previously indicated by (Prusky et al., 2001). Physiological disorders did not develop on fruits of any cultivar throughout shelf-life period.

Fruit skin color L*, C* and h° decreased after 10 days compared to the initial values in all cultivars. As persimmon fruit ripens in the air, there is a decrease in L*, C* and h° values as the fruit becomes more orange color and less yellow and the color becomes duller in appearance (Mitcham et al., 1997). Consistent with our results, Öz and Özelkök (2003), Perez-Gago et al. (2004), Kuzucu et al. (2005), Candir et al. (2008, 2010, 2012), Toplu et al. (2016) and Özdemir et al. (2009, 2012, 2017) reported that L* and h° values decreased during storage and shelf life in persimmon. The HW 40° C-5 h treatment resulted in the lowest L*, C* and h° values after 10 days in all cultivars (Tables 1-3). Soluble and insoluble tannin, fruit flesh firmness, and TSS data indicated a higher degree of ripening of persimmon fruit from this treatment than control and other treatments. The results were consistent with higher taste scores above the acceptability limit obtained by this treatment.

Soluble tannin content decreased while insoluble tannin content increased during the shelf-life period in all cultivars (Tables 1-3). Soluble tannin concentration decreased to the level of 0.03% (0.03 ± 0.05 g 100 mL-1) at which time fruits became non-astringent based on the scale described by Orihuel Iranzo et al. (2003). Other studies suggested that fruits were considered as slightly astringent at 0.2% of soluble tannin content and they were non-astringent when the soluble tannin content decreased to below 0.1% (Kato, 1990; Ben-Arie and Sonego, 1993). In all cultivars, only fruits from HW 40°C-5 h treatment became non-astringent based on soluble tannin content after 7 days. Insoluble tannin content was highest in this treatment than control and other treatments. Other treatments were not effective in the removal of astringency in all cultivars since soluble tannin content was above the limit of non-astringency. After 5 days, fruits from HW 40°C-5 h treatment were slightly astringent, but panelists did not detect astringency of these fruits and rated with acceptable taste scores. In agreement with our results, Ben-Arie and Sonego (1993) found that immersion of Triumph persimmons into the water at HW 40°C-5 h was effective in astringency reduction without high CO2 treatments while the treatment at 20°C lead to astringency reduction if combined with 80% CO2 for 48 h. Dipping of persimmon fruits in water to remove astringency has been used non-commercially (Ben-Arie and Sonego, 1993). When the water temperature is 40°C, this process is accelerated (Taira et al., 1989). Mechanism of removal of astringency by hot water treatment includes the production of acetaldehyde by the heat-sensitive enzymes followed by chemical reaction between acetaldehyde and oligomeric soluble tannin, producing an insoluble tannin polymer (Matsuoa and Itoo, 1977).

In conclusion, HW 40°C-5 h could be used for artificial removal of astringency. It should be noted that persimmon fruit subjected to this treatment became edible after 7 days of shelf life at 20°C without adverse effect on firmness.

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