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Full Length Research Paper

The effects of hot water treatments on chilling injury and cold storage of fuyu persimmons

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The aim of this study is to determine effects of hot water dips on chilling injury of non-astringent Fuyu persimmons. Fruits were subjected to hot water dips at 20, 45, 50 or 55°C for 10 or 20 min. Treated and untreated fruits were then kept at 0°C, 85 - 90% relative humidity for 5 months. Percentage weight loss, fruit flesh firmness (kg force), total soluble solids (%), pH, titratable acidity (g malic asid/100ml), fruit skin color (L* and *h*°), appearance (1 - 5) and incident of fungal decay and physiological disorders (skin and flesh browning) and drying calyx were determined at a month interval. During storage, fruit flesh firmness and titratable acidity decreased while weight loss and total soluble solid content increased. Physiological and fungal disorders were observed at 3rd month of storage. Hot water dips reduced incidence of chilling injury. 50°C for 10 or 20 min and 55°C for 10 min were the best treatments. Fuyu persimmon fruits could be stored for 4 months successfully.

Key words: Persimmon, fuyu, cold storage, hot water, chilling injury.

INTRODUCTION

China, Korea and Japan account for 90% of total production; Mediterranean countries account for less than 5% of world-wide production. In Mediterranean countries, the production is mostly exported (Llacer and Badenes, 2002). Recent expansion of persimmon cultivation is mostly in temperate and subtropical regions outside the major production areas. This has occurred in response to export market opportunities for 'out of season' fruit in traditional markets and 'exotics' in non-traditional markets (Mowat, 1995).

Persimmon fruits (*Diospyros kaki* L.) from climacteric fruits (Abeles, 1992) are divided into two groups according to their astringent degree at the harvest time as astringent fruits and non-astringent fruits (Zeng et al., 2006). Although non-astringent fruits are preferred, astringent cultivars production is also prevalent (Itamura et al., 2005).

It was reported that optimum storage temperature for persimmon fruits is 0°C (Kitagawa and Glucina, 1984; Mac-Rae, 1987; Pekmezci et al., 1995; Crisosto et al., 2006; Kaplankıran et al., 2008; Çandır et al., 2008a).

Postharvest life of some fruits is also limited by physiological disorders especially chilling injury (CI). Prestorage heat treatments have been shown effective in reducing the CI susceptibility in citrus (Schirra and D'hallewin, 1997; Gonzalez-Aguilar et al., 1997; Ozdemir and Dundar, 1999; Porat et al., 2000), persimmon (Lay-Yee et al., 1997; Woolf et al., 1997), peach (Margosan et al., 1997; Çandır et al., 2008b) and plum (Abu-Kpawoh et al., 2002). Heat treatments are a physical method for controlling insects, preventing pathogenic infection, improving resistance against chilling injury, delaying maturity and extending shelf life after harvest (Civello et al., 1997; Ketsa et al., 1998; Wang, 1998). Cowley et al. (1992) reported that heat applications on persimmon fruits reduce sensitivity against damages caused by cold.

Collins and Tisdell (1995) reported that Fuyu fruits are damaged at 10°C and the temperatures below it and especially at 5°C within 7 days. It was reported that the most important physiological deterioration seen in non-astringent persimmons during storage is peel discolorration called as peel browning (Park and Lee, 1997). Crisosto et al. (2006) reported that non-astringent cultivars like Fuyu are sensitive against chilling injury at the temperatures between 5 - 15°C, they show some indicators in the form of fruit flesh browning and softening.

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Woolf et al. (1997) examined the effects of hot air applications (0.5 and 10 h at 34 - 50°C) on chilling injury during storage in persimmon fruit and reported that the hot air application at 47°C for 0.5 - 3 h minimized chilling injury and peel browning. Lay-Yee at al. (1997) applied hot water around 47 - 54°C for 2.5 - 120 min and hot air at 20°C for 60 - 120 min on Fuyu cultivar and determined that the applications at 50°C for 30 and 45 min, at 52°C for 20 and 30 min and at 54°C for 20 min may be used for insect disinfestations without causing browning in fruit's flesh and peel.

It was reported that Fuyu persimmon cultivars are chilling injury during storage at cold, their fleshes seem semi-transparent and more studies are required for understanding Fuyu persimmons after harvest physiology better (Fagundes et al., 2006).

The aim of this study is to find the effect of hot water applications on preventing the chilling injury and quality losses during storage and to determine optimum hot water and time.

MATERIALS AND METHODS

Fruits cv. Fuyu, which were obtained from trees grafted on *Diospyros lotus* rootstock and planted 5 x 6 m in Dörtyol (Hatay) Research Station (36° 09' E, 36° 51' N, altitude 9 m) of Faculty of Agriculture, Mustafa Kemal University in 1998, were used as material in 2008. Dörtyol (Hatay) province has typical Mediterranean climate conditions with hot-dry summers and mild-rainy winters.

Thirty fruits of per replication of per treatments were dipped in hot water at 45, 50 or 55°C for 10 or 20 min. Control fruits were dipped in water at 20°C for 10 or 20 min. Treatments were carried out in a tank fitted with heating elements (0 - 90°C, 2 x 2000 watt), an electronic recirculation pump (400 watt). The tank contained 375 liter water and held two boxes of fruit (15 - 20 kg each) per run. Even water circulation, and temperature, within the baths was achieved by pumping water through perforated PVC tubing (25.4 mm i.d.). During each treatment, bath temperature was constantly maintained within ± 0.5°C of the required temperature by means of an electronic thermostat. Following treatment, the fruit were allowed to dry for about 2 h at room temperature and then As the bulk of the plastic boxes 60 x 40 x 30 cm dimensions were placed and stored at 0 ± 0.5°C and 85 - 90% relative humidity for 5 months. Three replicates of ten fruits per treatment were removed from cold storage after 1, 2, 3, 4 or 5 months.

The applications are 1) Control (intact fruits, nothing is applied on them), 2) 20°C for 10 min (dipping into tap water at 20°C for 10 min), 3) 20°C for 20 min (dipping into tap water at 20°C for 20 min), 4) 45°C for 10 min (dipping into hot water at 45°C for 10 min), 5) 45°C for 20 min (dipping into hot water at 45°C for 20 min), 6) 50°C for 10 min (dipping into hot water at 50°C for 10 min), 7) 50°C for 20 min (dipping into hot water at 50°C for 20 min), 8) 55°C for 10 min (dipping into hot water at 55°C for 10 min), 9) 55°C for 20 min (dipping into hot water at 55°C for 20 min).

The analyses done on the samples collected monthly are (1) Weight loss (%); 30 fruits were numbered and they were weighted by a laboratory balance with an accuracy of 0.01 g each month, the loss was calculated by subtracting the final weigh from the initial weigh in percent. (2) Physiological disorders (%); the fruits from the storage were examined each month and peel browning according to 0 - 3 scale of Mac Rea (1987) (0: none 1: less >25%, 2: moderate 50% and 3: severe >75%) and flesh browning and softening according to 0 - 5 scale (0: no gel 1: less gel, 2: 50% gel, 3: 75% gel, 4: The surface was covered by gel, 5:) were determined and also, disorders are calculated in percent. (3) Fungal decay (%); the fruits from the storage were examined each month and those deteriorated by fungi were detected and calculations were done in percent. (4) Total soluble solid (Tss) content (%); it was measured by hand refractometer (Atago Model ATC-1E) and calculated in percent (5) Titratable acidity (TA) content (%); it was measured by potensiometric method, 5 ml of juice sample collected from the fruit was diluted with distilled water to 100 ml and this sample was titrated with 0.1 N NaOH until the pH value of 8.1 was read on digital pH meter. The results were calculated as "g malic acid/100 ml juice" in percent. (6) pH was measured by digital pH-meter (WTW Innolab). (7) Fruit skin color (L* and *h*° angle values); in the fruits from storage each month for weigh losses, readings were done on previously marked regions on both sides of the fruit at the equator region of the fruit according to C.I.E. L*a*b* with the help of Minolta CR-300 Chromometer color measurement device. (8) Fruit flesh firmness (FFF) was measured with the help of a penetrometer (Effegi model FT 327) having a drilling head at a length of 8 mm after removed skin of the fruit with a diameter of approximately 1 cm on both sides of equator section in kg-f. (9) Appearance; A trained panel consisting of 25 people evaluated the appearance quality of the persimmons, initially and then weekly throughout the storage period. Persimmon appearance quality was evaluated on a scale of 1 - 5 (1 = very poor, 2 = poor, 3 = fair, 4 = high, 5 = very high). Each panelist was requested to evaluate overall acceptability. 10. Calix drying (%); the fruits from storage were examined at each month and those, which discolored from green to black more than 50%, were detected separately and calculated in percent.

Tests were based on a factorial experiment in a completely randomized block design and the data acquired were analyzed through SAS software (SAS Institute, Cary, N.C.) (SAS, 1990) and Tukey test was employed for comparison.

RESULTS AND DISCUSSION

Weigh losses increased as storage time extended and they reached 11.77% at the end of 5 months. The highest loss occurred in control fruits (8.38%) and the lowest loss occurred in the applications of 50°C for 10 min (6.42%). Hot water applications were considered as successful in reducing weigh losses (Table 1). It is reported that if the weight loss exceeds 10% of the product's total weigh, it will lose its marketable characteristic (Grierson and Wardowski, 1978; Ertürk et al., 2004; Çandır et al., 2008b). It is known that similar weigh losses occurred in many studies (Pekmezci et al., 1995; Öz, 2000; Salvador et al., 2004a). Fallik (2004) suggested that recrystallization or "melting" of the wax layer due to how water treatments sealed barely visible cracks in the cuticle through which water could escape and this sealing of cracks or natural openings significantly reduced weight loss. Consistent with our results, hot water treatments reduced weight loss in some fruits (Garcia et al., 1995; Ozdemir and Dundar, 1999; Vicente, et al., 2002).

Fungal deterioration occurred at very low degree during storage. It was seen in the control only at the end of 3 months (0.74%) and it reached 3.33% in the 5^{th} mount. The variations between applications were considered as statistically insignificant (Table 1).

Green Calix is an indicator for liveliness and attraction of the fruits. Calix converts from green into brown-black and

Table 1. Effects of hot water treatments on weight loss, fungal decay, drying of Calyx and physiological disorder (browning of skin and browning of flesh) in Fuyu persimmon cultivars during 5 months of storage at 0°C.

Factors	Weight loss (%)	Fungal decay (%)	Drying of Calyx (%)	Physiological disorder (%)	
				Browning of skin	Browning of flesh
Storage time (Months)					
1	2.91 e	0.00 b	0.00 d	0.00 c (0)	0.00 c (0)
2	4.77 d	0.00 b	0.00 d	0.00 c (0)	0.00 c (0)
3	7.02 c	0.74 b	5.06 c	0.86 c (1)	1.85 c (1)
4	9.37 b	0.99 b	8.89 b	3.46 b (2)	4.20 b (2)
5	11.77 a	3.33 a	16.79 a	25.06 a (3)	9.38 a (3)
Treatments					
Control	8.38 a	2.22 a[x]	7.11 bc	8.22 b (2)	8.44 a (5)
20°C - 10 min	6.81 de	0.67 a	4.00 de	9.56 a (3)	4.22 b (4)
20°C - 20 min	7.05 cd	1.33 a	5.78 bcd	8.67 ab (3)	4.67 b (4)
45°C - 10 min	7.77 b	2.00 a	1.33 e	6.89 bc (2)	3.11 bc (2)
45°C - 20 min	6.73 de	0.44 a	6.89 bc	6.89 bc (2)	3.78 b (3)
50°C - 10 min	6.42 e	0.44 a	10.89 a	3.11 d (1)	2.44 bc (1)
50°C - 20 min	6.82 de	0.44 a	7.78 b	0.22 e (0)	0.44 c (0)
55°C - 10 min	7.13 cd	1.11 a	6.67 bcd	3.56 d (1)	0.44 c (0)
55°C - 20 min	7.38 bc	0.44 a	4.89 cd	5.78 c (0)	0.22 c (0)

[x]Mean separation was performed by Tukey's Multiple Range Test. Treatment means (n = 3) followed by same letter within column are not significantly different at P < 0.005. Treatment means was compared separately for each storage time. Values represents mean of all treatments for each storage time.

dries during storage. Calix is completely green at the beginning. Discoloration and drying reached 5.06% in 3rd month, 8.89% in 4th month and 16.79% in 5th month during the storage (Table 1).

Indicators for physiological deterioration in persimmon fruits are in the form of discoloration. These are specific browning in the flower hole part of the fruit, peel and flesh, small stains on the peel, total or partial browning on the peel and flesh and small brown stains on the surface of the peel (Lee et al., 1999, 2000; Ahn et al., 2001; Lee, 2001). Chilling injury in 'Fuyu' persimmons was observed as darkening, gelling and softening of the fruit flesh as previously described by MacRae (1987). As the storage time extended, the physiological deteriorations in the form of peel browning, flesh browning and flesh liquefaction increased. Fruit peel browning increased as storage time extended similar to fruit flesh browning and softening. It was seen in the control fruits only at the end of 3 months (0.86%) and in those excluded out of the hot water applications only at the end of 4 months (3.46%) and became very severe and reached the 25.06% in the 5th month. The highest peel browning occurred in the control fruits and the applications at 45°C while the lowest peel browning occurred in the application at 50°C for 20 min (1.11%) (Table 1). Fruit flesh browning and softening increased as storage time extended and it was seen in the control fruits only at the end of 3rd months (1.85%) and in those excluded out of the applications at 50 and 55°C only at the end of 4th months (4.20%) and reached the 9.38% in 5th month. The highest fruit flesh browning and softening occurred in the control applications while the lowest fruit flesh browning and softening occurred in the applications at 50 and 55°C (Table 1). The applications especially at the applications at 50°C for 20 min and 55°C for 10 min were considered as successful in reducing chilling injury. Physiological deteriorations similar to those seen in Jiro and Fuyu cultivars were detected in the studies done by different researchers on cold storage on especially Fuyu cultivar also (Lay-Yee et al., 1997; Fagundes et al., 2006; Park and Lee, 2007).

As the storage time extended, FFF tented to decrease. Initial FFF was 8.91 kg-f and decreased to 4.81 kg-f after 5 months. The lowest decrease was seen in the applications at 55°C for 10 min (7.39 kg-f), at 50°C for 10 min (7.13 kg-f) and 50°C for 20 min (7.00 kg-f) and the highest decrease was seen in the control applications, which were 20°C for 20 min (5.70 kg-f) and 20°C for 10 min (5.74 kg-f). It may be said that hot water applications generally inhibit FFF loss (Table 2). It was reported that fruit flesh firmness of non-astringent persimmons should not fall below 4 lb-f (approximately 2 kg-f, 10 N) from the point of view of marketability of non-astringent persimmons (Ben-Arie, 1995; Salvador et al., 2004b; Crisosto et al., 2006). Hot water or hot air treatments have been showed to delay fruit softening during storage in several fruits including peaches and nectarines (Anthony et al., 1989; Malakou and Nanos, 2005), plums (Valero et al.,

Table 2. Effects of hot water treatments on firmness, Tss, TA, appearance and skin color (L* and *h*°) in Fuyu persimmon cultivars during 5 months of storage at 0°C.

Factors	Firmness (kg force)	Tss (%)	TA (%)	Appearance[y] (%)	Skin color L*	Skin color *h*°
Storage time (Months)						
0	8.91 a	15.67 c	0.26 a	5.00 a	61.65 a	81.03 a
1	7.81 b	16.73 bc	0.14 b	5.00 a	60.03 b	77.37 b
2	6.67 c	16.83 bc	0.13 b	5.00 a	59.53 bc	76.22 bc
3	6.02 cd	17.56 a	0.13 b	3.78 b	59.02 c	75.09 c
4	5.32 de	17.06 ab	0.11 c	2.65 c	58.00 d	72.44 d
5	4.81 e	17.33 ab	0.08 d	2.03 d	56.97 e	69.81 e
Treatments						
Control	6.25 ab	16.13 c	0.14 a[x]	3.57 f	59.10 bc	79.05 ab
20°C - 10 min	5.74 b	17.37 a	0.14 a	3.84 cd	59.48 ab	76.14 cd
20°C - 20 min	5.70 b	17.54 a	0.14 a	3.60 ef	58.29 cd	69.43 f
45°C - 10 min	6.41 ab	16.88 abc	0.14 a	3.94 bc	57.73 d	72.42 e
45°C - 20 min	6.82 ab	16.79 abc	0.13 a	4.06 b	59.68 ab	76.79 bc
50°C - 10 min	7.13 a	17.11 ab	0.14 a	4.08 b	59.22 b	68.92 f
50°C - 20 min	7.00 a	16.13 c	0.15 a	4.32 a	60.23 a	78.20 bc
55°C - 10 min	7.39 a	17.50 a	0.15 a	4.07 b	59.81 ab	80.93 a
55°C - 20 min	6.84 ab	16.32 bc	0.15 a	3.70 de	59.27 b	74.06 de

[x]Mean separation was performed by Tukey's Multiple Range Test. Treatment means (n = 3) followed by same letter within column are not significantly different at P < 0.005. Treatment means was compared separately for each storage time. Values represents mean of all treatments for each storage time. [y]Appearance was evaluated on a scale of (1 - 5) where 1 = very poor, 2 = poor, 3 = fair, 4 = high, 5 = very high.

2002), apples (Lurie and Nussinovitch, 1996; Lurie et al., 1998), strawberry (Vicente et al., 2002). The delay of fruit softening might be due to inactivation of cell wall hydrolytic enzymes, mainly polygalacturonase (Lurie, 1998).

Although fluctuations occurred in Tss content in the form of increases and decreases, increases occurred in all applications at the end of the storage time and the initial Tss of 15.67% reached 17.33% at the end of 5 months (Table 2). In some studies on persimmons, as storage time extended, Tss content increased (Öz, 2000; Ertürk et al., 2004; Ferri et al., 2004; Çandır et al., 2008b). As storage time extended, TA tended to decrease. The initial average TA value of 0.26% decreased to 0.08% at the end of 5 months. The variations between applications were considered as statistically insignificant (Table 2). In similar studies on persimmons, it was found that as the storage time extended, TA content decreased (Öz, 2000; Ertürk et al., 2004; Çandır et al., 2008b). Previous studies showed that hot air /hot water treatments had no significant effect on acidity in peaches and nectarines (Zhou et al., 2002; Malakou and Nanos, 2005), mandarins (Schirra and D'hallewin, 1997) and apples (Smith and Lay-Yee, 2000; Fallik et al., 2001) during storage. As the storage time extended, pH values increased. Initial average pH value of 5.40 reached after 5 months (Data no shown). Other authors reported similar results in which pH values increase (Öz, 2000; Ertürk et al., 2004; Fagundes et al., 2006).

According to the assessment of the panelist group consisting of 25 people, the appearance value, which was 5.00 initially, decreased as the storage time extended and reduced to 3.78 after 3 months and 2.03 after 5 months. The most preferred applications by the panelists are the applications at 50°C and least preferred applications by the panelists are the control applications (Table 2).

As the storage time extended, L* values decreased and the fruits lost a bit their brightness. The initial average L* value, 61.65, reduced to 56.97 after 5 months. The applications causing highest brightness losses are the applications at 45°C for 10 min (57.73) and the control application at 20°C for 20 min (58.29). The applications keeping brightness at most are the applications at 50°C for 20 min (60.23). It may be said that brightness loss is generally caused by physiological deteriorations, especially peel browning (Table 2). Similarly, Öz (2000), Perez-Gago et al. (2004) and Çandır et al., 2008b reported decreases in L* value during storage.

As the storage time extended, *h*° angle values decreased and the specific cultivar color converted from yellow to red more significantly. The initial *h*° angle value, 81.03, reduced to 69.81 after 5 months. The highest degree in color set off was seen at 20°C for 20 min (69.43) and 50°C for 10 min (68.92) while the lowest degree occurred at 55°C for 10 min (80.93) (Table 2).

Heat applications cause variations in fruit maturity as a result of inhibition of ethylene synthesis and cell wall destruction enzymes (Lurie, 1998; Fallik, 2004). Thus, it may be said that the reason for the lowest decrease in *h°* angle value at 55°C for 10 min is the fact that high temperature inhibits breaking off in the floor color. Similarly, Perez-Gago et al. (2004) and Çandır et al., 2008b reported that *h°* angle value reduced. Consisted with our results, heat-treated strawberry fruits showed higher *h°* angle and L* value than controls during storage (Vicente et al., 2002).

According to the findings, physiological and fungal deteriorations were seen from the 3rd month of the application. Hot water applications were considered as successful in preventing chilling injury, keeping flesh firmness, reducing weight loss and keeping the quality. However, it was determined that, the fruits may be stored for 3 months under 0°C of temperature and 85 - 90% of relative humidity without significant losses after they are kept at 45°C for 10 min, 45°C for 20 min and 55°C for 10 min and the fruits may be stored for 4 months under 0°C of temperature and 85 - 90% of relative humidity without significant losses after they are kept at 50°C for 20 min, 55°C for 10 min and 55°C for 20 min.

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