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The effects of hot water dip treatments on the cold storage of Big Top nectarines

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Summary

Big Top nectarine fruits were subjected to hot water dip treatments at 45ºC, 50ºC or 55ºC for 2 or 3 min after harvest and kept at 0°C for 45 days and additional 4 days at 20°C to determine the effects of hot water dip treatments on storage and shelf life of Big Top nectarine fruits. The effects of hot water dip treatments on quality parameters (weight loss, skin color, flesh firmness, total soluble solids and titratable acidity) and incidence of chilling injury (CI) and fungal decay were assessed after 45 days of storage at 0°C and subsequent 2 days and 4 days at 20°C following cold storage. Hot water dip treatment at 45°C for 2 min reduced weight loss and CI, delayed color development and maintained fruit lightness, but insufficient to delay fruit softening. Incidence of fungal decay was low during storage and shelf life period. Our results indicated that hot water dip treatments had potential to maintain postharvest quality for Big Top nectarines.

Introduction

Postharvest fungicide treatments are required to control postharvest diseases in peaches and nectarines during storage. However, health and environment concerns lead to government regulations restricted postharvest use of fungicides in several fruits and vegetables. Iprodine was not labeled for peaches and nectarines in Europe and USA since 1996. Some fungicides (e.g. dichloran) are also ineffective in control of common postharvest diseases of peach and nectarines (Karabulut et al., 2002). Postharvest hot water treatments have been studied to control postharvest decay in peaches and nectarines (Wells, 1971; Margosan et al., 1997; Karabulut et al., 2002; Karabulut and Baykal, 2004). Peaches subjected to 46°C hot water treatment for 2-8 min were found to have substantially decreased their disease susceptibility (Margosan et al., 1997).

Postharvest life of nectarines is also limited by chilling injury (CI) or internal breakdown. Most nectarine cultivars develop CI if they are held for more than 2-3 weeks below 8°C (Lill et al., 1989). Storage life of most nectarine cultivars with low susceptibility to chilling injury varied from 4 to 6 weeks at 0°C. With CI-susceptible cultivars, the marketing life was reduced to 2-3 weeks at 0°C (Crisosto et al., 1999). Onset of CI symptoms such as internal and external browning, flesh breakdown, woolliness, reddish discoloration, loss of ability to ripen and increased incidence of decay (Lurie and Crisosto, 2005) determine storage/shipping potential because their development reduces consumer acceptance (Crisosto et al., 1999). Hot water treatments have been shown effective in reducing the CI susceptibility in citrus (Gonzalez-Aguilar et al., 1997; Schirra and D'Hallewin, 1997; Porat et al., 2000; Özdemir and Dündar, 2001), persimmon (Lay-Yee at al., 1997) and plum (Abu-Kpawoh et al., 2002).

Our previous study with Big Top nectarine (Çelik et al., 2006) showed that storage life of this cultivar is limited to 30 days with 2 days of shelf life due susceptibility of this cultivar to CI. CI also increased the incidence of decay. In this study, we aimed to extend storage life of Big Top nectarines by hot water dip treatments; we focused on the effects of hot water dip treatments on incidence of chilling injury and fungal decay and on some quality indices of Big Top nectarines after storage and shelf life.

Materials and Methods

Plant material

Nectarine cv. Big Top fruits were obtained from a commercial orchard in Mersin, Turkey. Big Top®-Zaitabo originates from Zaiger's Inc. (CA, USA) and was introduced into Europe around 1989. Fruit has intense red color on skin, firm yellow flesh and high levels of sugars but little acidity and aroma (Lavilla, 2002). Fruits were harvested from trees grafted on GF-677 rootstocks at firm-ripe stage and immediately transported via ventilated truck to cold storage facilities of Department of Horticulture, Faculty of Agriculture, Mustafa Kemal University where they were sorted and selected for medium size (58-65 mm), uniform maturity and appearance and freedom from defects.

Hot water dip treatments

Fruits were dipped in hot water at 45ºC, 50ºC or 55ºC for 2 or 3 min. Control fruits were dipped in water at 20°C for 2 or 3 min. Treatments were carried out in a tank fitted with heating elements (0-90ºC, 2 x 2000 watt), an electronic recirculation pump (400 watt). The tank contained 375 litres of water. 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 fruits were allowed to dry for about 6 h at room temperature, then packed into 10-12 kg commercial plastic boxes (52 cm x 36 cm x 18 cm) and kept at 0°C (±0.5) in 85-90% (±5%) relative humidity for 45 days. Each treatment was repeated three times using 5 fruits per replication that had been randomly selected from the same lot of fruit. Three replicates per treatment were removed from cold storage after 45 days and subsequently held at 20°C (±1.0) and 65-70% (±5%) relative humidity for 4 days to simulate shelf life.

Postharvest quality evaluation

Postharvest quality of fruits was assessed after 45 days of storage and additional 2 and 4 days at 20°C following cold storage. Fruits were numbered and individually weighted to determine weight loss. Weight loss was calculated as percentage loss of initial weight.

Flesh firmness was measured on two opposite sides of each fruit at the equatorial region, after the removal of a 1 mm thick disk of skin from each side of the fruit and the force in kg required to insert an Effegi penetrometer (model FT 327) fitted with an 8 mm diameter probe was recorded and expressed as Newton (N). Total soluble solids (TSS) content and titratable acidity (TA) were assessed in juice obtained from five fruits per replicate. TSS content was determined with a refractometer (Atago Model ATC-1E) and TA by titration of

5 ml of fruit juice with 0.1 N NaOH to pH 8.1 and expressed as g malic acid per 100 mL juice. Skin color was determined with a Minolta Chroma Meter CR-300 (Osaka, Japan). Color measurements were recorded using the CIE L*a*b* color space. From these values, hue angle was calculated as, $h° = \tan^{-1}(b^*/a^*)$. Color values for each fruit were computed as means of two measurements taken from opposite sides at the equatorial region of the fruit.

Incidence of fungal decay was determined by counting the number of decayed fruit in each replicate of treatments on the day removal from storage and after 2 and 4 days at 20°C.

Fruits were halved and examined visually for different manifestations of CI or internal breakdown such as lack of juiciness (mealiness or woolliness), flesh browning, flesh bleeding, and flesh translucency (gel breakdown) immediately after 45 days of storage and after 2 and 4 days at 20°C following 45 days of storage. The severity of CI as was assessed as described by FERNANDEZ-TRUJILLO and ARTES (1997) on a scale (1 to 5) where 1 = none, 2 = very slight, 3 = slight, 4 = moderately severe and 5 = severe.

Statistical analysis

The data were analyzed as a factorial experiment in a completely randomized block design by ANOVA using SAS software of SAS Institute, Cary, N.C. (SAS, 1990). Each treatment, consists of five fruits were replicated three times. Mean separation was performed by Fisher's Least Significance Test at P<0.05 level using SAS's Proc GLM procedure. Data for percent weight loss and incidence of chilling injury were arcsine transformed and analyzed by ANOVA and back transformed for reporting.

Results and discussion

Weight loss

Weight loss reached to about 11% after 45 days of storage (Tab. 1). An additional weight loss of about 5% and 9% occurred during 2 and 4 days at 20°C following 45 days of cold storage, respectively (Tab. 2). 45°C-2 min treatment resulted in lower weight loss than control and other treatments after 45 days of storage at 0°C (Tab. 1) and after additional 2 days and 4 days at 20°C following 45 days of cold storage (Tab. 2). In previous studies with peaches and nectarines, hot water treatments had no effect (MALAKOU and NANOS, 2005) or slight effect (ZHOU et al., 2002) on weight loss. However, 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; ÖZDEMIR and DÜNDAR, 2001; VICENTE et al., 2002).

Flesh firmness

Fruit softening occurred during 45 days of storage at 0°C (Tab. 1). After 45 days of storage at 0°C, Flesh firmness was at about 57 N. Fruit softening continued during shelf life period following cold storage (Tab. 2). Flesh firmness was about 54 N and 14 N after additional 2 days and 4 days at 20°C following 45 days of storage, respectively.

Flesh firmness of fruits from 2-min hot water dip treatments was lower or similar to that of control fruits during 45 day of storage at 0°C (Tab. 1). Fruits from 3-min hot water dip treatments were firmer than control fruits during 45 days of storage at 0°C (Tab. 1). Hot air /hot water treatments have been showed to delay fruit softening during storage in peaches and nectarines (ANTHONY et al., 1989; ZHOU et al., 2002; MALAKOU and NANOS, 2005). In other studies with peaches and nectarines, flesh firmness of fruits treated with hot air/ hot water was similar to control fruit (OBENLAND and AUNG, 1997; KARABULUT and BAYKAL, 2004; ZHANG et al., 2007). The delay of fruit softening might be due to inactivation of cell wall hydrolytic enzymes, mainly polygalacturonase (MALAKOU and NANOS, 2005) or associated to less ethylene production by heated fruits than control fruits (BUDDE et al., 2006). 50°C-3min treatment resulted in firmer fruits than other 3-min hot water dip treatments during 45 days of storage at 0°C (Tab. 1). Similarly, OBENLAND and AUNG (1997) reported that nectarine fruits treated with 50°C of hot water were firmer than those treated with 46°C of hot water which soften to the same extent as non-heated fruits. The little or no effect of hot water

Tab. 1: Effects of hot water treatments on postharvest quality, incidence of chilling injury (CI) and fungal decay in Big Top nectarine cultivars after 45 days of storage at 0°C.

Treatments	Weight Loss (%)	Flesh Firmness (N)	TSS (%)	TA (%)	Skin Color L*	Skin Color h°	CI (%)	Severity of CI[Z]	Decay (%)
At harvest	**-**	**71.69(a)** [Y]	**14.20(a)**	**0.56(a)**	**38.46(a)**	**36.10(a)**	**-**	**-**	**-**
45 days at 0°C									
Control-2min	11.87ab [X]	57.24bc	13.60	0.27b	36.08de	25.93f	13.33a	2.00bc	0.00a
45°C-2min	8.00e	55.44d	13.03	0.26b	43.25a	36.31a	0.00b	1.00c	0.00a
50°C-2min	11.51bcd	56.62c	13.10	0.30a	37.99cd	29.58cd	33.33a	3.67a	0.00a
55°C-2min	12.47a	53.84e	13.47	0.30a	37.84cd	28.58de	26.67a	2.33b	13.33a
Control-3min	11.71abc	55.57d	12.13	0.26b	40.44b	31.29c	0.00b	1.00c	0.00a
45°C-3min	10.85cd	57.57 b	13.00	0.27b	39.45bc	33.25b	0.00b	1.00c	0.00a
50°C-3min	10.65d	58.91a	13.73	0.31a	36.58de	26.83ef	13.33ab	2.00bc	13.33a
55°C-3min	11.97ab	56.72c	13.00	0.27b	35.78e	26.83ef	20.00ab	2.00bc	0.00a
Mean	**11.13**	**56.49(b)**	**13.13(b)**	**0.28(b)**	**38.43(a)**	**29.82(b)**	**13.33**	**1.75**	**3.33**

[X] Mean separation was performed by Fisher's Least Significance Test. Treatment means (n=3) followed by same letter within column are not significantly different at P<0.005.

[Y] Letters in parenthesis indicates comparison of means of storage time. Values represents mean of all treatments for each storage time.

[Z] Severity of CI as was assessed on a scale (1 to 5) where 1 = none, 2 = very slight, 3 = slight, 4 = moderately severe and 5 = severe.

Tab. 2: Effects of hot water treatments on postharvest quality, incidence of chilling injury (CI) and fungal decay in Big Top nectarine cultivars after 45 days of storage at 0°C and subsequent 2 days and 4 days at 20°C.

Treatments	Weight Loss (%)	Flesh Firmness (N)	TSS (%)	TA (%)	Skin Color		CI (%)	Severity of CI[Z]	Decay (%)
					L*	*h*°			
45 days at 0°C+ 2 days at 20°C									
Control-2min	5.72bc [X]	53.09a	15.07a	0.25a	37.85a	27.56a	0.00b	1.00b	0.00c
45°C-2min	2.75e	52.07a	14.13a	0.27a	38.68a	31.26a	0.00b	1.00b	0.00c
50°C-2min	3.76d	54.98a	14.80a	0.30a	36.41a	29.28a	26.67a	3.00ab	20.00ab
55°C-2min	3.89d	54.59a	15.40a	0.31a	36.20a	27.46a	13.33ab	1.67ab	0.00c
Control-3min	6.78ab	50.05a	15.80a	0.28a	35.57a	28.55a	26.67a	2.67ab	26.67a
45°C-3min	4.61cd	53.05a	14.40a	0.31a	39.01a	32.77a	0.00b	1.00b	0.00c
50°C-3min	4.79cd	54.59a	16.20a	0.27a	37.71a	30.20a	13.33ab	2.00ab	0.00c
55°C-3min	7.17a	55.80a	16.27a	0.27a	36.20a	29.74a	0.00b	1.00a	6.67bc
Mean	**4.82(b)** [Y]	**53.53(a)**	**15.26(a)**	**0.28(b)**	**37.20(a)**	**29.60(a)**	**10.00(b)**	**1.67(a)**	**6.67(a)**
45 days at 0°C+ 4 days at 20°C									
Control-2min	10.97a	11.70a	15.67a	0.30a	30.32a	27.80a	70.00a	2.33ab	26.67ab
45°C-2min	6.13d	14.19a	14.00a	0.30a	37.40a	31.49a	6.67c	0.67b	0.00c
50°C-2min	8.15c	19.12a	16.07a	0.30a	35.64a	28.07a	26.67b	2.33ab	13.33bc
55°C-2min	7.33cd	10.92a	14.33a	0.32a	34.30a	25.47a	26.67b	2.00ab	26.67ab
Control-3min	9.95ab	14.32a	14.13a	0.29a	37.78a	30.88a	80.00a	3.33a	26.67ab
45°C-3min	8.97bc	13.89a	15.53a	0.31a	36.13a	29.29a	6.67c	0.67b	0.00c
50°C-3min	8.82bc	13.66a	15.27a	0.26a	35.43a	27.55a	33.33b	2.67a	0.00c
55°C-3min	10.53ab	17.16a	15.20a	0.30a	35.27a	32.73a	33.33b	1.67ab	46.67a
Mean	**8.86(a)**	**14.37(b)**	**15.03(a)**	**0.30(a)**	**35.28(b)**	**29.16(a)**	**35.42(a)**	**1.96(a)**	**17.50(a)**

[X] Mean separation was performed by Fisher's Least Significance 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 shelf life period.
[Y]Letters in parenthesis indicates comparison of means of shelf life period. Values represents mean of all treatments for each shelf life period.
[Z]Severity of CI as was assessed on a scale (1 to 5) where 1 = none, 2 = very slight, 3 = slight, 4 = moderately severe and 5 = severe.

dip treatments was observed on flesh firmness during additional 2 days and 4 days at 20°C after cold storage (Tab. 2) which was consisted with the findings of MARGOSAN et al. (1997) on several peaches and nectarines cultivars kept at 20°C for 4 days following 2 weeks at 1°C. BUDDE et al. (2006) reported that when ethylene production is already triggered, heat treatments have no influence on fruit firmness, as evidenced in peaches harvested in a more advanced maturity, where heated and control fruit softened at the same rate during 3-day shelf life period at 20°C.

Total soluble solid content

Total soluble solid (TSS) content was not affected by hot water dip treatments during cold storage (Tab. 1) and during shelf life period after cold storage (Tab. 2) in agreement with previous reports on nectarines and peaches (MARGOSAN et al., 1997; OBENLAND et al., 1999; ZHOU et al., 2002). TSS content decreased significantly after 45 days storage at 0°C compared to TSS content at harvest (Tab. 1). TSS content did not change significantly during shelf life period (Tab. 2 and 3).

Titratable acidity

Titratable acidity (TA) declined significantly after 45 days storage at 0°C (Tab. 1). Previous studies showed that hot air/hot water treatments had no significant effect on TA in peaches and nectarines (ZHOU et al., 2002; MALAKOU and NANOS, 2005), mandarins (SCHIRRA and D'HALLEWIN, 1997) and apples (FALLIK et al., 2001) or reduced TA in nectarines (LAY-YEE and ROSE, 1994), strawberries (GARCIA et al., 1995; VICENTE et al., 2002) and apples (KLEIN and LURIE, 1990) and oranges (ÖZDEMIR and DÜNDAR, 2006) during storage and shelf life period. Fruits from 50°C-2min, 55°C-2min and 50°C-3min treatments maintained higher TA than control fruits during 45 days of storage (Tab. 1) in contrast to previous studies (SCHIRRA and D'HALLEWIN, 1997; FALLIK et al., 2001; ZHOU et al., 2002; MALAKOU and NANOS, 2005). During shelf life period, hot water treated fruits and control fruits had similar TA (Tab. 2) in agreement with previous studies (KLEIN and LURIE, 1990; VICENTE et al., 2002; ÖZDEMIR and DÜNDAR, 2006; ZHANG et al., 2007).

Skin color

Skin color parameters of L* (lightness) value did not significantly change, but hue angle (*h*°) value decreased after 45 days of storage at 0°C compared to initial values (Tab. 1). During shelf life period, skin color becomes darker (lower L*value) with slight reduction in *h*° values (Tab. 2).
The effects of hot water dip treatments on skin color parameters were significant during storage, but these effects was not observed after 2 days and 4 days at 20°C following 45 days of cold storage. 45°C-2min and 45°C-3min treated and Control-3min fruits showed higher L* values than fruits from other treatments after 45 days of cold storage. Lower L* values observed in fruits from other treatments might indicate skin browning associated with heat damage and chilling injury and combination of thereof (Tab. 1). LAY-LEE and ROSE (1994) reported that one of the main disorders associated with

heat treatment at 41-46°C for 24-48 hours was scald (external browning) in Fantasia nectarines. The incidence of scald increased with increasing temperature and the length of treatment during storage at 0°C for 3 weeks. Hot water treatment at about 45-50°C was not injurious to a number of nectarine and peach cultivars tested (WELLS, 1971; MARGOSAN et al., 1997; OBENLAND and AUNG, 1997; MALAKOU and NANOS, 2005). Our data showed that the hot water dip treatment at a temperature of >45°C for >2 min might result in heat damage on skin of Big Top nectarines as indexed by lower L* values. Control-2min fruits showing CI symptoms (Tab. 1) had also darker skin color (lower L* value). Chilling injured peach and nectarine fruits show darker skin due to development of scald on skin along with flesh scald (FERNANDEZ-TRUJILLO et al., 2000; LURIE and CRISOSTO, 2005).

45°C-2min and 45°C-3min treatment resulted in higher *h*° values than other treatments after 45 days of cold storage. Higher *h*° values might indicate the delay of red color development by 45°C hot water dip treatment. Previous studies showed that there is no or slight effect of hot air/hot water treatments on skin color of peaches and nectarines during storage and shelf life period (MARGOSAN et al., 1997; OBENLAND et al., 1999; OBENLAND et al., 2005; BUDDE et al., 2006). In peach and nectarine fruits, red color development is a result of anthocyanin accumulation (TOMAS-BARBERAN et al., 2001). There is no detailed study investigating the effect of hot air/hot water treatments on skin color in peaches and nectarines. With other fruits, delay of color development by hot air/hot water treatments was attributed to a diminution of PAL activity which brought to reduction of anthocyanin synthesis (CIVELLO et al., 1997; VINCENTE et al., 2002).

Incidence of chilling injury and fungal decay

Incidence of chilling injury (CI) was examined in fruits after removal from 45 days of cold storage and after 2 days and 4 days at 20°C following cold storage. A cultivar was determined to have reached the end of market life when ≥25% of fruit became mealy or leathery, had flesh browning or severe flesh bleeding (NANOS and MITCHELL, 1991). As in commercial practice, only moderate and severe levels were considered as losses, representing the intensity of CI (FERNANDEZ-TRUJILLO and ARTES, 1997). CI symptoms in susceptible peach and nectarine cultivars mainly develop during fruit ripening after cold storage (CRISOSTO et al., 1999). Therefore, the data from fruits kept at 4 days at 20°C following 45 days of storage might explain better the effects of hot water dip treatments on incidence of CI. Control fruits showed high incidence of CI with moderate and severe symptoms after 4 days at 20°C following 45 days of storage. 45°C-2min and 45°C-3min treatments with none or very slight CI symptoms on fruits reduced incidence of CI after additional 2 and 4 days at 20°C following cold storage (Tab. 2). Hot air/hot water treatments have been reported to alleviate chilling injury in peaches and nectarines (KERBEL et al., 1985; LI and HAN, 1998; MURRAY et al., 2007). 50°C and 55°C treatments did not reduce incidence of CI. Fruits dipped in hot water at 50°C or and 55°C for 2 min or 3 min showed moderate or severe CI symptoms more than 25% of fruits after 4 days at 20°C following 45 days of storage (Tab. 2). High-temperature forced-air treatment at about 50°C acted to accelerate development of mealiness, a major CI symptom in peach and nectarine fruits (OBENLAND and CARROLL, 2000). Authors suggested that too severe of a pre-stress may act as a damaging factor and overwhelm any positive benefit that is conferred by the heat treatment.

Incidence of fungal decay was low during cold storage (Tab. 1) and shelf life period following cold storage (Tab. 2). We observed infections caused by *Botrytis cinerea, Penicillium expansum, Rhizopus stolonifer, Monilinia fructicola* on fruits. Fruits from 45°C-2min and 45°C-3min treatments showed no visible fungal growth during storage and shelf life period following cold storage. Post-harvest hot water treatments have been shown to control postharvest decay in peaches and nectarines (WELLS, 1971; MARGOSAN et al., 1997; KARABULUT et al., 2002). However, it is not possible to reach conclusion for effects of hot water on fungal decay in Big Top nectarine fruits due to lower incidence of fungal decay.

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