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 45°C, 50°C or 55°C 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 (Crisostro 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 Crisostro, 2005) determine storage/shipping potential because their development reduces consumer acceptance (Crisostro 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 Dundar, 2001), persimmon (Lay-Yee et al., 1997) and plum (Abu-Kwah et al., 2002).

Our previous study with Big Top nectarine (Celik 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-rripe 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 45°C, 50°C or 55°C 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 (0-90°C, 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 replications 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, $h^* = \tan^{-1} \left( \frac{b^*}{a^*} \right)$. 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 wooliness), 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 Dundar, 2001; Vicente et al., 2002).

### 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.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Weight Loss (%)</th>
<th>Flesh Firmness (N)</th>
<th>TSS (%)</th>
<th>TA (%)</th>
<th>Skin Color</th>
<th>CI (%)</th>
<th>Severity of CI</th>
<th>Decay (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>At harvest</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>45 days at 0°C</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control-2min</td>
<td>11.87ab</td>
<td>57.24bc</td>
<td>13.60</td>
<td>0.27b</td>
<td>36.08de</td>
<td>25.93f</td>
<td>13.3a</td>
<td>2.00bc</td>
</tr>
<tr>
<td>45°C-2min</td>
<td>8.00e</td>
<td>55.44d</td>
<td>13.03</td>
<td>0.26b</td>
<td>43.25a</td>
<td>36.31a</td>
<td>0.00b</td>
<td>1.00c</td>
</tr>
<tr>
<td>50°C-2min</td>
<td>11.51bcd</td>
<td>56.62d</td>
<td>13.10</td>
<td>0.30a</td>
<td>37.99cd</td>
<td>29.58cd</td>
<td>33.33a</td>
<td>3.67a</td>
</tr>
<tr>
<td>55°C-2min</td>
<td>12.47a</td>
<td>53.84e</td>
<td>13.47</td>
<td>0.30a</td>
<td>37.84cd</td>
<td>28.58de</td>
<td>26.67a</td>
<td>2.33b</td>
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<tr>
<td>Control-3min</td>
<td>11.71abc</td>
<td>55.57d</td>
<td>12.13</td>
<td>0.26b</td>
<td>40.44b</td>
<td>31.29c</td>
<td>0.00b</td>
<td>1.00c</td>
</tr>
<tr>
<td>45°C-3min</td>
<td>10.85cd</td>
<td>57.57b</td>
<td>13.00</td>
<td>0.27b</td>
<td>39.45bc</td>
<td>36.31a</td>
<td>0.00b</td>
<td>1.00c</td>
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<tr>
<td>50°C-3min</td>
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<td>58.91a</td>
<td>13.73</td>
<td>0.31a</td>
<td>36.58de</td>
<td>26.83ef</td>
<td>13.33ab</td>
<td>2.00bc</td>
</tr>
<tr>
<td>55°C-3min</td>
<td>11.97ab</td>
<td>56.72c</td>
<td>13.00</td>
<td>0.27b</td>
<td>35.78e</td>
<td>26.83ef</td>
<td>20.00ab</td>
<td>2.00bc</td>
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<tr>
<td>Mean</td>
<td>11.13</td>
<td>56.49(b)</td>
<td>13.13</td>
<td>0.28(b)</td>
<td>38.43(a)</td>
<td>29.82(b)</td>
<td>13.33</td>
<td>1.75</td>
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</tbody>
</table>

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.

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

X 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.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Weight Loss (%)</th>
<th>Flesh Firmness (N)</th>
<th>TSS (%)</th>
<th>TA (%)</th>
<th>Skin Color</th>
<th>CI (%)</th>
<th>Severity of CI (%)</th>
<th>Decay (%)</th>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>L*</td>
<td>h*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>45 days at 0°C+ 2 days at 20°C</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Control-2min</td>
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<td>27.56a</td>
<td>0.00b</td>
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<tr>
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<td>14.13a</td>
<td>0.27a</td>
<td>38.68a</td>
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<td>0.00b</td>
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<tr>
<td>50°C-2min</td>
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<td>14.80a</td>
<td>0.30a</td>
<td>36.41a</td>
<td>29.28a</td>
<td>26.67a</td>
<td>3.00a</td>
</tr>
<tr>
<td>55°C-2min</td>
<td>3.89d</td>
<td>54.59a</td>
<td>15.40a</td>
<td>0.31a</td>
<td>36.20a</td>
<td>27.46a</td>
<td>13.33b</td>
<td>1.67b</td>
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<tr>
<td>Control-3min</td>
<td>6.78ab</td>
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<td>15.80a</td>
<td>0.28a</td>
<td>35.57a</td>
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<tr>
<td>45°C-3min</td>
<td>4.61cd</td>
<td>53.05a</td>
<td>14.40a</td>
<td>0.31a</td>
<td>39.01a</td>
<td>32.77a</td>
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<td>1.00c</td>
</tr>
<tr>
<td>50°C-3min</td>
<td>4.79cd</td>
<td>54.59a</td>
<td>16.20a</td>
<td>0.27a</td>
<td>37.71a</td>
<td>30.20a</td>
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<td>2.00b</td>
</tr>
<tr>
<td>55°C-3min</td>
<td>7.17a</td>
<td>55.80a</td>
<td>16.27a</td>
<td>0.27a</td>
<td>36.20a</td>
<td>29.74a</td>
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<tr>
<td>Mean</td>
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<td>53.53(a)</td>
<td>15.26(a)</td>
<td>0.28(b)</td>
<td>37.20(a)</td>
<td>29.60(a)</td>
<td>10.00(b)</td>
<td>1.67(a)</td>
</tr>
<tr>
<td>45 days at 0°C+ 4 days at 20°C</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Control-2min</td>
<td>10.97a</td>
<td>11.70a</td>
<td>15.67a</td>
<td>0.30a</td>
<td>30.32a</td>
<td>27.80a</td>
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<td>2.33ab</td>
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<tr>
<td>45°C-2min</td>
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<td>14.19a</td>
<td>14.00a</td>
<td>0.30a</td>
<td>37.40a</td>
<td>31.49a</td>
<td>6.67c</td>
<td>0.67c</td>
</tr>
<tr>
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<td>19.12a</td>
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<td>35.64a</td>
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<td>26.67b</td>
<td>2.33ab</td>
</tr>
<tr>
<td>55°C-2min</td>
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<td>10.92a</td>
<td>14.33a</td>
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<td>34.30a</td>
<td>25.47a</td>
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<td>2.00ab</td>
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<tr>
<td>Control-3min</td>
<td>9.95ab</td>
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<td>30.88a</td>
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<tr>
<td>45°C-3min</td>
<td>8.97bc</td>
<td>13.89a</td>
<td>15.53a</td>
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<td>36.13a</td>
<td>29.29a</td>
<td>6.67c</td>
<td>0.67c</td>
</tr>
<tr>
<td>50°C-3min</td>
<td>8.82bc</td>
<td>13.66a</td>
<td>15.27a</td>
<td>0.26a</td>
<td>35.43a</td>
<td>27.55a</td>
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<td>2.67a</td>
</tr>
<tr>
<td>55°C-3min</td>
<td>10.53ab</td>
<td>17.16a</td>
<td>15.20a</td>
<td>0.30a</td>
<td>35.27a</td>
<td>32.73a</td>
<td>33.33b</td>
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</tr>
<tr>
<td>Mean</td>
<td>8.86(a)</td>
<td>14.37(b)</td>
<td>15.03(a)</td>
<td>0.30(a)</td>
<td>35.28(b)</td>
<td>29.16(a)</td>
<td>35.42(a)</td>
<td>1.96(a)</td>
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</table>

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 Dhallewin, 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 Dundar, 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 Dhallewin, 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 Dundar, 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 after 45 days of storage at 0°C and subsequent 2 days and 4 days at 20°C.
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 Criostiso, 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 (Criostiso et al., 1999). Therefore, the data from fruits kept 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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