Utilization of Hot Water Treatments for Reducing External Damage and Maintain Quality of Hass Avocado Fruits

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Abstract: Postharvest hot water treatments on external damage and fruit quality and ripening of Hass avocado were investigated. Avocado fruits were placed in hot water bath at 50°C for 5 or 10 min. prior to low temperature storage at 5°C, then ripened at 20°C for 3 days. Fruit characteristics were determined at removal from cold storage and subsequent ripening. Generally, long duration of HW treatments (10 min.) had better response in Hass fruit injury and quality than short duration (5 min). Hass fruits could withstand without external skin damage up to 9 days of storage either at 5 or 20°C in both HW durations. The least damage percent was recorded in fruits of HWT at 10 min. Fruit firmness had slight insignificant decline due to both HWTs progressed in the ripening period. Hot water treatments increased insignificantly the respiration rate of Hass fruits by expanding cold storage period compared to control fruits. Total acidity, vitamin C, and total phenols content significantly decreased in fruits received hot water treatments before storage at 5°C for 18 days with lower values at 10 min duration. Further slight reduction was noticed too after holding fruits at 20°C. Increasing in oil content due to HW treatments was observed without significant differences between storage periods and HW durations. Cellulose activity showed the greatest increase after cold storage and during holding at 20°C in HW treated fruits for 5 min. Moreover, pectinase activity had the opposite trend with minor role in the softening of avocado fruits.

Key words: Avocado, Hot water, External damage, Injury, Quality, Phenols, Firmness, Enzymes activity

INTRODUCTION

The avocado is a subtropical fruit sensitive to chilling injury (CI) when exposed to low but non-freezing temperatures. The main symptoms of CI are black spots on the peel and a gray or dark – brown discoloration of the mesocarp[1,2]. Exposure to high or low temperatures can be used as effective methods for non-chemical disinfections of fruit or as a means of reducing postharvest chilling injury (CI) at subsequent low temperatures[3]. In the past, disinfections treatments have been based on chemical fumigation and dips. However, many of these treatments have been withdrawn, and safer treatment, mainly using physical methods, are being developed. using physical methods, are being developed. These have focused on heat, cold, irradiation, controlled atmospheres, or combination of several of these[4,5,6]. Exposure to high or low temperatures can be used as effective methods for non-chemical disinfections of fruit or as a means of reducing postharvest chilling injury (CI) at subsequent low temperatures[3].

Tolerance to both low and high temperatures in avocados can be increased however, by pretreatments with hot air and hot water treatments[7,8]. An alternative to hot air HT is hot water treatment (HWT) and fruit response ha examined on a rage of crops[9]. Hot water treatments can be more easily applied commercially than hot air treatments, particularly if the duration of treatment is short[9]. Pretreatment with hot water in avocados showed almost completely eliminate external browning and reduce incidence of hard skin and a range of internal disorders[9]. Both hot air and hot water treatments (HWTs) can reduce external skin damage of Hass avocado caused by subsequent heat and cold treatments[7,9]. Thus, heat treatments have potential to reduce external damage of Hass avocados during cold disinfections.
The following experiments on Hass avocado fruits investigated the potential for hot water treatments to reduce and preventing its external skin damage development at otherwise injurious temperatures throughout cold storage and after ripening. These treatments were tested over two seasons.

**MATERIALS AND METHODS**

**Fruit Harvest and Handling:** Mature Hass avocado fruits (*Persea Americana Mill.*) were collected from a private orchard (Nemo) El Katta district, Giza Governorate. Trees were 20 years old grown in sand – loam soil and were similar in growth and received common horticulture practices. Fruit were harvested at the first of August of 2003 and 2004 graded, packed, and transported to the laboratory of ADS project in the Faculty of Agriculture, Cairo University. On arrival, undamaged fruits free from apparent pathogen infection and similar in shape, colour, and firmness were selected, washed, air dried, and used randomly at the day of harvest to hot water treatments. The initial quality measurements were determined (control).

**HW Treatments:** The hot water treatments were carried out in a stainless steel hot water bath (Sheldon VWR Instrument, model 13309 Oregon). Water distribution and temperature were uniform within the bath, and temperature was monitored and was accurate to ± 0.3°C. Hass and Fuerte fruits (15 and 30 fruits/treatment respectively) were placed into a hot water bath at 50 °C HWT durations were performed for 5 and 10 minutes. Following treatment, fruit were dipped in tap water and allowed to dry on mesh racks. After treatment, the fruits were placed in cardboard boxes at 5°C for 15 days. Control fruit were treated only with tap water and stored continuously at 20°C. At the end of treatments, the fruits were holed at 20 °C to ripen. Quality assessments and external damage were measured for HWTs and control fruits in three replicates for each treatment at 3 days intervals through storage period at 5°C (2 - 3 weeks) and after ripening for 3 days. The initial quality measurements after treatments were determined (Table 1).

**Quality Measurements:** External damage: was scored by estimating the percentage of skin damage observed as a blackening of the peel and nodule damage with black color. Each fruit was rated as having acceptable commercial external appearance, if there was less than 5% skin damage, and less than 5% of damaged nodules combined [10].

**Fruit firmness:** was determined using Ametek pressure tester, fitted with an 8 mm hemispherical probe (probe penetration 2 mm). Firmness of 5 fruits from each replicate was measured at two opposite points on the equator of each fruit after removing a thin slice of skin from each site [12].

**Respiration Rate:** Individual fruits for each treatment were weighed and placed in 2-liter jars. The jars were sealed for 24 hrs with a cap and a rubber septum. O2 and CO2 samples of the headspace were removed from a septum with a syringe and injected into Servomex Inst. Respiration rate was calculated as ml CO2 / kg -1 / hr -1 Model 1450C (Food Pack Gas Analyzer) to measure oxygen and carbon dioxide production, and respiration rate was calculated as ml CO2 / kg . / hr [13].

**Total Acidity:** Total acidity (expressed as oleic acid) was determined by titrating 5 – ml juice with 0.1N sodium hydroxide using phenolphthalein as an indicator [14].

**Ascorbic Acid (VC):** Ascorbic acid content was measured using 2, 5-6 dichlorophenol indophenols’ method described by [14].

**Oil Content:** The oil percentage in the dried flesh samples was extracted by means of soxhelt fat-extraction apparatus using hexane for the extraction according to [15].

**Total Phenols:** A procedure of folin ciocalteu [15], was adopted for determination of phenols in metabolic extract of fresh fruit. Total phenols were calculated as mg pyrogallol per 100 gm fresh weight.

**Pectinase and Cellulose Activities:** 0.5 ml of supernatant enzyme extraction were used and mixed in acetate and citrate buffer and incubated at 45 and 50°C for 10 min. for Pectinase and cellulose respectively. The reaction was stopped with 3 ml of 3, 5-dinitrosalicylic acid reagent, the color was obtained after heating for 10 min. and measured at wavelength of 570 nm and expressed as one unit of pectinase activity liberates 1 Mmol D-galactouronic acid in milliliter per min [16,17]. While cellulase color was measured at wavelength of 5 % nm with shimadzu UV-VIS spectrometer model UV-240 and expressed as one unit of cellulose activity liberates 1M mol glucose in milliliter per min [18,19].

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Experimental Design and Statistical Analysis: The design for this experiment was a Completely Randomized Design (CRD) with three replications. Data were analyzed with the Analysis of Variance (ANOVA) procedure of MSTAT-C program. When significant differences (P >0.05) were detected, treatment means were compared by Duncan's multiple range test at the level of probability in the two seasons experimentation.

RESULTS AND DISCUSSION

External Damage (%): Data illustrated in Figure 1 demonstrated that there were no fruits with external damage of Hass avocado during 9 days of storage at 5°C after previous HWTs at 50°C for 5 and 10 min periods. Thereafter, external damage percent appeared significant and gradual increase till the end of storage period.

The least damage percent (5.95 and 6.15 %) was recorded in fruits of HWT at 10 min; significantly followed by fruits of HWT for 5 min (7.65 and 7.23 %) for 18 days at 5°C in the two seasons respectively. Holding Hass fruits at 20°C for 3 days did not show any external damage for 9 days for both hot water treatments. Meanwhile, control fruits are still without damage only for 3 days at 20°C, in both seasons. Moreover, fruits treated with HW for 10 min, just before cold storage for 18 days had the least external damage percent (11.76 and 12.25 %) after holding at 20°C for 3 days compared with those of HWT for 5 min. (12.95 and 13.36 %) and control fruits for only 15 days at 20°C (14.85 and 15.13 %) with significant differences in the two seasons respectively.

In this concern,^{[9]} and^{[10]} reported that hot water treatments of Hass avocado fruits progressively reduced chilling injury and vascular browning severity but had no effect on mesocarp discoloration. Moreover,^{[3]} pointed out that longer HWT of Hass avocado fruits reduced external chilling injury than short treatment.

Fig. 1: External damage of Hass avocado fruits at removal from 5oC (A) and after holding at 20oC for 3 days (B) after HW treatments at 50oC for 5 or 10 min. The data (average of two seasons) represents percentage of fruits with visible skin damage. Acceptable commercial external appearance was 10 % skin and nodules damage combined. Values are the means of 3 replicates of five fruits each of 5 and 10 fruits. Significant differences at Duncan's multiple range comparison P > 0.05

Firmness (lb/Inch^2): Figure 2 illustrate Changes in fruit firmness of Hass avocado cultivar due to hot water treatments Hass fruits removed from storage at...
5°C resulted slight gradual and insignificant decline in fruit firmness in both HWTs throughout the considered period of storage.

Meanwhile, HWT treated fruits for 10 min recorded similar decrease percentage of fruit firm compared with fruits of 5 min HWT pre - storage treatments either storage period in the two seasons respectively. Holding Hass fruits at 20°C for 3 days, showed progressive decline in fruit firmness reached to the least firm (3.23 and 4.12) in HWT for 5 min., followed by those HWT for 10 min. (3.96 and 4.84) after 18 days. While control fruits kept at 20°C resulted fruit firmness 3.93 and 4.15 after 15 days in the 1st and 2nd seasons respectively. In this respect, [20] found in significant effect of hot water treatments on differences firmness of Keitt mangoes. Meanwhile hot water at 46.5°C for 45 min. had significantly lowest fruit firmness of Tommy Atkins mango compared with control.

**Respiration Rate (ml/kg/hr):** There was a progressive significant increase in respiration rate of Hass avocado fruits by expanding storage period at 5°C after hot water treatments as well as after holding at 20°C for three days as shown in Fig. 3 At removal of Hass avocado from cold storage at 5°C, fruits of HWT at 50°C for long duration (10 min) had the lowest rate of respiration (15.86 and 16.50) for 18 days storage. While, fruits of HWT for short duration (5 min) showed the highest value (17.65 and 17.93) in the two seasons respectively.

After holding Hass fruits at 20°C for 3 days, respiration rate appeared different trend than that at removal one. HWT fruits at 50°C for 5 min. reached its maximum rate in fruits previously cold stored for 9 days (46.96 and 50.82) compared with those treated
with HWT at 50°C for 10 min then cold stored for 12 days before holding (50.62 and 54.63). While control fruits had its highest value after 12 days (49.00 and 51.00) but it was significant less than that in HWTs. Thereafter, all treated and control fruits showed significant reduction in respiration rate. This reduction was parallel with expanding storage period.

Similarly, on papaya fruits found that respiratory climacteric occurred 2 days earlier in the injured Papaya fruits than in non-injured fruits that had been immersed in water at 49°C for only 30 min. Moreover, found that hot water treatment increased respiration rate in mature green Haden mangoes.

**Total Acidity:** According to Table 2 and 3 it is clear that Hass avocado fruits had gradual and significant decrease in total titratable acidity during storage at 5°C in the 1st and 2nd seasons. At removal, from cold storage Hass avocado fruits showed the minimum acid value after 18 days storage of received HWT for 10 min. (0.65 and 0.62) followed by those of HWT for 5 min. (0.68 and 0.70) at the two successive seasons respectively. In addition, Hass fruits holed at 20°C seemed to have further slight reduction in titratable acidity without significant differences between both HWT at only experimented period. Control fruits kept only at 20°C recorded the highest acid value (0.80 and 0.82) when compared with fruits of HWT(s) in both seasons of experiment. In this respect, observed that total acidity of papaya fruits was decreased during ripening under hot water treatment at 42°C for 30 min.

**Ascorbic Acid Content (VC):** Vitamin C content of Hass avocado fruits revealed significant and gradual decrease through storage at 5°C due to postharvest hot water treatments at 50°C for 5 and 10 min. as well as after holding at 20°C. The least ascorbic acid content of Hass fruits after 18 days of storage at 5°C was higher in fruits pre treated with hot water for 10 min. (14.90 and 15.23) compared with those received HWT for 5 min (13.75 and 14.15) at the two seasons respectively. Moreover, holding Hass fruits at 20°C recorded further reduction in VC content reached at the end of storage period to greater content in fruits of HWT for 10 min. (13.45 and 14.47) compared with control fruits (12.83 and 13.70) after 15 days and that of fruits received HWT for 5 min. (12.58 and 13.76) then cold storage for 18 days in both successive seasons of study respectively.

On the contrary, noticed that vitamin C was gradually increased till ripening of Solo papaya fruit after 9 days of hot water treatment at 42 °C for 30 min.

**Total Phenol Content:** From data presented in Tables 2 and 3 it can be stated that there was a gradual significant decrease in total phenols content (mg/100 gm FW) of Hass avocado fruits during storage at 5°C as effected by pre storage hot water treatments as well as after holding at 20°C in the two seasons of study. The lower significant total phenols (21.63 and 22.65) were obtained in fruits of HWT for 5 min. compared with those received HWT for 10 min. (22.93 and 23.48) at removal from cold storage by 18 days at the first and second seasons respectively.

In addition, holding Hass fruits for 3 days at 20°C showed further and significant decrease in total phenols content. The decline in phenols content was much greater in fruits of HWT for 5 min. than that of HWT for 10 min. Control fruits kept at 20°C for 15 days had the highest significant phenols content (21.23 and 22.34) compared with Hass fruits received HWT for 5 min. before storage at 5°C for 18 days then holding for 3 days (19.78 and 20.84 %) and those received HWT for 10 min (20.85 and 21.57%) at the first and second seasons respectively.

Similarly, on several mango cultivars found that total phenols % declined during storage and in course of ripening.

**Oil Content:** Data shown in Tables 2 and 3 indicated that the oil content of Hass avocado fruits had gradual and significant increase of the pre storage hot water treatments till 15 days of storage at 5°C as well as after holding at 20 °C for 3 days. At removal of Hass avocado fruits from cold storage, it was that the maximum oil content (53.63 and 55.42) was recorded in HWTs fruits for 10 min. then 15 days storage at 5°C. It was followed by fruits of 5 min HWT (52.88 and 54.67). However, there were no significant differences between fruits stored for 12, 15 and 18 days storage in both hot water treatments. In addition, after holding Hass fruits at 20°C there were further increase in oil content reached their greatest content (55.23 and 57.33) after 15 days cold storage of long HWT duration (10 min.). Although, oil increment was relatively high with long hot water duration. It was significantly equal to fruits received short hot water treatment (5 min) before cold storage. Control fruits also have gradual increase of oil content during holding at 20°C but significantly lower than fruits of HWTs in the two seasons. Similarly, found that oil content of Hass avocado fruits increased after cold storage at 4 and 9°C then 10 days at ambient temperature (18-20°C). also found that oil content of Hass avocado fruits increased with increasing cold storage temperature and with increasing storage duration.
### Table 2: Effect of Hot Water Treatments on Hass Avocado Fruits Quality at 5°C and after ripening at 20°C for 3 days in the season of 2003

<table>
<thead>
<tr>
<th>Hot water treatments in days</th>
<th>Storage</th>
<th>Total acidity (mg/100gm)</th>
<th>Vitamin C (mg/100g)</th>
<th>Oil content % (DW)</th>
<th>Total phenol (mg/100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>At removal</td>
<td>After holding</td>
<td>At removal</td>
<td>After holding</td>
<td>At removal</td>
</tr>
<tr>
<td>50°C (5 min.) 3</td>
<td>0.89 a 0.91 b c</td>
<td>18.32 bc 16.93 c</td>
<td>47.00 e 49.15 d</td>
<td>28.50 d 26.60 d</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>0.83 d 0.78 e f 17.68 cd 15.29 de</td>
<td>48.98 d 51.50 c</td>
<td>26.15 f 24.48 f</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>0.77 e f 0.72 gh 16.79 e 14.00 fg</td>
<td>51.39 b 53.76 ab</td>
<td>24.02 g 22.40 h</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>0.70 b 0.68 ghi 15.93 b 13.26 ghi 52.88 b 54.35 a</td>
<td>22.35 ij 20.50 ij</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>0.68 gh 0.67 hi 13.75 b 12.58 i</td>
<td>50.75 bc 53.65 ab</td>
<td>21.63 j 19.78 j</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 3: Effect of Hot Water Treatments on Hass Avocado Fruit Quality at 5°C and after ripening at 20°C for 3 days in the season of 2004

<table>
<thead>
<tr>
<th>Hot water treatments in days</th>
<th>Storage</th>
<th>Total acidity (mg/100gm)</th>
<th>Vitamin C (mg/100g)</th>
<th>Oil content % (DW)</th>
<th>Total phenol (mg/100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>At removal</td>
<td>After holding</td>
<td>At removal</td>
<td>After holding</td>
<td>At removal</td>
</tr>
<tr>
<td>50°C (5 min.) 3</td>
<td>0.89 a 0.91 b c</td>
<td>19.73 a 18.86 b</td>
<td>45.31 f 48.15 de</td>
<td>32.73 a 29.50 b</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>0.85 cd 0.79 e</td>
<td>19.13 ab 17.23 c</td>
<td>47.86 e 50.82 c</td>
<td>29.50 c 27.14 d</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>0.73 fg 0.69 ghi 17.03 de 15.10 d 52.89 a 54.00 a</td>
<td>25.78 f 23.65 g</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>0.69 gh 0.64 ij 16.38 ef 14.36 ef 53.63 a 55.23 a</td>
<td>23.65 gh 21.00 l</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>0.65 h 0.59 j</td>
<td>14.90 g 13.45 fggh 52.86 a 54.76 a</td>
<td>22.93 hi 20.85 i</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Control 3 - 0.94 ab - 18.26 b - 43.95 hi - 29.85 b

Data are means of three replicates of five fruits each, significant differences at Duncan's multiple range comparison *P >0.05*
Table 3: Continue

<table>
<thead>
<tr>
<th>Control</th>
<th>3</th>
<th>6</th>
<th>9</th>
<th>12</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.91 ab</td>
<td>0.89 abc</td>
<td>0.86 bede</td>
<td>0.84 cdef</td>
<td>0.82 def</td>
</tr>
<tr>
<td></td>
<td>17.86 d</td>
<td>16.75 ef</td>
<td>15.43 h</td>
<td>14.58 i</td>
<td>13.70 j</td>
</tr>
<tr>
<td></td>
<td>45.89 h</td>
<td>46.66 g</td>
<td>47.19 g</td>
<td>48.29 f</td>
<td>49.32 e</td>
</tr>
<tr>
<td></td>
<td>30.56 b</td>
<td>26.63 ef</td>
<td>25.80 g</td>
<td>23.45 l</td>
<td>22.34 j</td>
</tr>
</tbody>
</table>

Table 4: Effect of hot water treatments before storage at 5°C for 12 days and after holding for 3 days at 20°C on cellulase and pectinase activity (unit/gm FW, average of two seasons).

<table>
<thead>
<tr>
<th>Hot Water Treatments</th>
<th>Hass</th>
<th>Cellulase</th>
<th>Pectinase x10³</th>
</tr>
</thead>
<tbody>
<tr>
<td>At removal</td>
<td>After holding</td>
<td>At removal</td>
<td>After holding</td>
</tr>
<tr>
<td>5 min</td>
<td>15.41</td>
<td>43.64</td>
<td>5.842</td>
</tr>
<tr>
<td>10 min</td>
<td>13.30</td>
<td>40.58</td>
<td>7.637</td>
</tr>
<tr>
<td>At harvest</td>
<td>8.326</td>
<td>4.32</td>
<td></td>
</tr>
</tbody>
</table>

Data are means of three replicates of five fruits each. (average of two seasons).

**Cellulase and Pectinase Activity:** Table 4 showed that Hass avocado fruits had the greatest increase in cellulase activity reached 15.41 units/gm FW after 12 days of cold storage of short hot water duration (50°C for 5 min) followed by HWT for 10 min (13.3 units) and 43.64, 40.58 units respectively after holding at 20°C for 3 days compared with the initial value at harvest date (8.326 units). Meanwhile, pectinase activity decreased after storage at 5°C (5.842 x 10⁻¹, 7.637 x 10⁻³) as well as after holding (3.732 x 10⁻³, 5.976 x 10⁻³) respectively compared with the initial value at harvest date (4.32 units). In this concern[30] recorded that cellulase is involved in fruits softening of avocado fruits during ripening. In parallel our results,[29] showed that maximal cellulase activity was attained when avocado fruits was completely soft.[30] also stated that cellulase activity was low in the pre-climacteric Furete avocado fruits reached a level two times greater than edible soft stage. Results of[31] indicated a decrease in pectinesterase just prior to softening occurred, and became minimal for Lula cv. avocado fruits during ripening at 21.1 °C and 10 °C storage.

**Conclusion:** Long duration of hot water treatment (10 min.) before cold storage at 5 °C gave better results of keeping quality expressed as external damage, firmness, respiration rate and retarding Cellulase activity as compared with short HWT duration (5min) ;meanwhile control fruits had least quality attributes. Cellulase activity appeared to have major role in softening of avocado fruits; meanwhile Pectinase activity may have no effect in this concern.

**REFERENCES**


