EFFECTS OF HOT WATER TREATMENTS AND STORAGE DURATIONS ON THE PHYSICOCHEMICAL COMPOSITION OF SWEET ORANGE (Cv. SALOTIANA)

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ABSTRACT: *An experiment was conducted to evaluate the effects of hot water treatments and storage durations on the physicochemical composition of sweet orange Cv. Salotiana. After HWT, the fruits of sweet orange were stored at room storage conditions for 60 days. The experiment was laid out in completely randomized design with two factors i.e. hot water dipping time (0, 5, 10, and 15 Min) and storage durations (0, 15, 30, 45 and 60 Days). Data were recorded on disease incidence, weight loss, total soluble solids (TSS), fruit juice pH, TSS/acid ratio and total sugar content at 15 days intervals. The HWT reduced significantly the increase in TSS, pH, disease incidence, weight loss, TSS/acid ratio and total sugar content with increasing storage period. The HWDT of 15 minutes (At a temperature of 45 °C) was found to be the most suitable for preserving the postharvest quality of sweet orange. It can be concluded that HW treated fruits of sweet orange can be stored commercially up to 2 months at room storage conditions (10 ± 2 °C temperature and 75-85% RH). HWT can serve as a dynamic means of retaining postharvest quality of sweet orange fruits during the long term storage with cost-effective benefits.*

Key Words: Hot water dipping time (HWDT), Hot water treatment (HWT), Hot water (HW), Cultivar (Cv.) Fruit weight loss (FWL), Completely randomize design (CRD), Total soluble solids (TSS).

1. INTRODUCTION

The orange belongs to family Rutaceae, genus Citrus and species Sinensis. To distinguish it from the related Citrus × aurantium (sour orange), it is also called sweet orange. The orange is a hybrid between pomelo (Citrus maxima) and mandarin (Citrus reticulata) which has genes that are ~25% pomelo and ~75% mandarin; however, it is not a simple backcrossed BC1 hybrid, but hybridized over multiple generations [1].

In Chinese literature, sweet oranges were mentioned in 314 BC. Orange trees were observed to be the most cultivated fruit trees in the world in 1987. Orange trees are extensively grown for their sweet fruit in subtropical and tropical climates. Sweet oranges were accounted for about 70% of the total citrus production in the world in 2012. Orange fruit can be eaten fresh, or processed for its juice or aromatic rind [2]. Pakistan has 194.5 thousand hectares area under citrus orchards with 1982.25 thousand tons per year production [3]. Decreases in sugar content and weight loss are common in orange fruits during storage. After harvest, the fruits continuously lose moisture, which results in loss of fruit weight during storage. The total soluble solids generally increase during storage in citrus fruits. The increased TSS and decreased acidity results increase in TSS/acid ratio with increased storage duration [4].

Postharvest heat treatments are applied to many types of fruits to prevent disease incidence and maintaining quality during storage [5]. A major benefit of hot water treatments is the non-existence of chemical remains on the fruit. HW is a heat transfer medium, which is more effective than the hot air [6]. Hot water dipping even for a few minutes, control fungal pathogens successfully [10]. Tolerance to chilling injury in seedling radicals has been reportedly induced by hot water treatments. Tolerance against abiotic stresses and heat shock proteins are also induced by hot water treatments reported [8]. An experiment was therefore initiated to evaluate the impacts of hot water treatments and storage durations on the physicochemical composition of sweet orange Cv. Salotiana.

2. MATERIALS AND METHODS

Fruit material

The fruits of Salotiana sweet orange of almost similar maturity and size were taken from the orchards of Citrus Research Institute Sargoda, Pakistan in 2013. The fruits had light yellow color and thick juicy flesh. The selected fruits were free from any visual and physical symptoms. The fruits were washed carefully with distilled water and then dried with dry and clean cloth. Fresh weight of all fruits was noted with the help of electronic balance (Seed buro Equipment Company Chicago Model 8860) before the hot water treatment.

Hot water treatments and storage conditions

The temperature of water was raised to 45 °C in water bath. The fruits were randomly distributed into 4 groups for hot water treatments. The fruits of first, second and third groups were dipped in HW for 5, 10 and 15 minutes respectively. The fourth group was considered as control. The fruits were then placed in wooden shelves. The fruits were stored at room storage conditions (10 ± 2 °C temperature and 75-85% RH) for 2 months. Fruit samples were taken at 15 days intervals and various chemical and physical analyses were performed on the fruits. Analyses were performed for each group after each storage interval with 25 fruits per group in each replication. The 1st data were recorded on the 1st day of storage.

Disease incidence (%)

Disease incidence (%) was identified by counting the attacked fruits in each treatment and then its percentage was measured against the total stored fruits.

$$\text{Percent Disease incidence} = \frac{\text{Diseased fruits}}{\text{Total fruits}} \times 100$$

Weight loss (%)

The fruit weight of the randomly selected twenty-five fruits per group in each replication was recorded by electronic balance (Seed buro Equipment Company Chicago Model 8860) after each storage interval. To calculate weight loss (%) the following formula was used.

$$\text{Weight loss } (\%) = \frac{(\text{A} - \text{B})}{\text{A}} \times 100$$

A = Fresh fruit weight

B = fruit weight after each storage interval

Total soluble solids

The total soluble solids of the randomly selected twenty-five fruits per group in each replication were observed with the help of hand refractometer (Kernco Instruments Co. Texas).

Fruit juice pH

Electric pH meter (Model# INOLAB pH-720) was used for pH determination of randomly selected 25 fruits per group in each replication.

TSS/acid ratio

TSS /acid ratio was calculated according to AOAC [7] by the following formula.

$$\text{TSS/acid ratio} = \frac{\text{TSS}}{\text{Titratable acidity}}$$

Total sugars content (%)

Total sugars content was measured by Fehling's solution method according to AOAC [7].

Statistical analysis

The data were statistically subjected to analysis of variance (ANOVA) technique through STATISTIX (version 8.1) software. The means were evaluated further in such cases where significant differences were found through Least Significant Difference test as stated by Jan et al [9].

3. RESULTS AND DISCUSSIONS

Disease incidence (%)

Hot water treatments and storage durations significantly affected the disease incidence in sweet orange. According to Fig. 1, the disease incidence was increased rapidly in fruits having HWDT of 0 and 5 minutes from 15th to 60th day of storage. The rapid increase in disease incidence was significantly reduced by the application of hot water. The highest disease incidence, i.e. 7.40% was recorded in control fruits at the end of storage, while no diseases incidence was found in fruits having hot water dipping time of 10 and 15 minutes from 0 to 30 days of storage, but after 30 days, comparatively low disease incidence was recorded. With increasing storage duration disease incidence in fruits usually increases [10]. Postharvest rotting of 3 to 6% in citrus fruit was reported [11]. If conditions are favorable for the pathogens, the disease incidence should be increased to 50% [12, 13]. The heat treatments have been found to increase injury repairing in citrus fruits by enhancing the synthesis of lignin like compounds [14] that act as physical obstructions to pathogen penetration [15] or by increasing scoparone synthesis that could have antifungal properties [16]. Heat treatments also stimulate heat shock protein syntheses [17, 18] which assist in procurement of thermo tolerance [19]. However exposure to high temperature for more than 15 minutes increased disease incidence by damaging the waxy layer and rind tissues probably [20, 21] or increased cuticle cracks [12] which could serve as routes for pathogen.

Fruit weight loss (%)

The interaction between HWT and storage duration on weight loss is shown in Fig. 2. After 60 days of storage, maximum weight loss (32.34%) was recorded with the control group, followed by 31.23% in fruits dipped in hot water for 5 minutes. The lowest weight loss (0%) was recorded in fresh fruits of all groups. Throughout the storage, the significant decrease in FWL was observed in sweet oranges treated at different HWDT (5 min, 10 min, and 15 min). The decrease in weight of sweet orange fruits was might be due to moisture loss as a result of postharvest respiration. Fruit weight loss decreased significantly with increasing hot water dipping time. But weight loss increased significantly when storage duration increased. Hot water dipping time and storage durations significantly affected the weight loss of citrus fruits. These results are similar to the results of Rab et al [4] who claimed that by increasing the storage duration a continuous increase in weight loss occurred. They also reported that the weight loss increased significantly from a minimum of 0% on day 0 to 11.26% on day 15th of storage and further increased to 13.61% on 30th day of storage and finally reached to maximum value (43.54%) at 75th day at room temperature.

Total soluble solids (°Brix)

The effects of hot water treatments and storage durations on total soluble solids (TSS) of sweet orange were found statistically significant ($P \leq 0.05$) during storage of 60 days at room temperature. By prolonging the storage duration, the TSS (°Brix) of sweet orange exhibited an increase. The total soluble solids were increased from 11.10 °Brix at harvest to 11.44, 12.03, 12.71 and 13.43 °Brix after 15, 30, 45 and 60 days respectively. The application of hot water retarded the rapid increase in TSS significantly. At the end of storage, the total soluble solids in hot water treated fruits were lower compared to control fruits. The total soluble solids of control and hot water treated fruits having HW dipping time of 5, 10 and 15 minutes were respectively 12.67, 12.18, 11.99 and 11.73 Brix° (Table 1). The TSS in citrus fruits generally increased during storage due to the breakdown of complex carbohydrates [6, 22 and 23]. It also has been reported that heat treatments delayed the fruit ripening due to which the increase in total soluble solids was delayed [24, 25 and 26]. The TSS increase in citrus fruits during storage seems a normal ripening associated change [26]. These results resembles with that of Khan et al [27] who evaluated the impacts of wet heat treatments and room storage conditions on the quality attributes of sweet orange, reported that the minimum TSS were found in fruits having storage period of 15 days which was non-significant as compared to fresh fruits. They further stated that when storage duration increased, a gradual TSS increase was occurred, so that the highest total soluble solids were noted at 75th day of storage, followed by 60th day.

Fruit juice pH

The pH showed increasing trend from start to the end of storage. The highest pH (4.71) was recorded in fruits having storage period of 60 days, whereas the minimum pH (3.95) was noted in fresh fruits. The pH increasing rate with increasing storage duration was reduced by hot water treatments. The maximum fruit juice pH (4.59) was recorded in control treatment, whereas the minimum (4.28) was recorded in fruits having HWDT of 15 min (Table 1). pH of sweet orange increases due to decrease in acidity with increasing storage duration. pH also increases when ascorbic acid content decreases. As we know that the fruits are perishable commodities, so with increasing storage duration, the ascorbic acid (vitamin c) content and titratable acidy of fruits decrease due to post harvest respiration which is the main reason of fruit juice pH increase [28]. Similarly Ansari and Hossein [29] also reported that with increasing storage duration pH of sweet orange increased because the organic acids present in orange fruit juice were consumed for energy during the process of postharvest respiration.

Total soluble solids/acid ratio

Total soluble solids/acid ratio is critical for taste of sweet orange. Hot water treatment significantly reduced the TSS/acid ratio. With regard to hot water dipping time, the highest TSS/acid ratio (8.78) was observed in control group, while the lowest of 8.28 was found in hot water treated fruits having hot water dipping time of 15 minutes. The TSS/acid ratio was continuously increased with increasing storage period. The highest total soluble solids/acid ratio was found in fruits having storage period of 60 days, while the lowest was recorded in fresh fruits (Table 1). The total soluble solids/acid ratio is a function of acidity and TSS. Decrease in acidity and increase in TSS during storage gave rise to a significant increase in total soluble solids/acid ratio. Paul and Chen [2] identified that the TSS/acid ratio was significantly affected by wet heat treatments so that its value decreased from highest in control fruits to lowest in fruits received WHT of 5 minutes. But with regard to wet heat treatment durations, the difference in the values of TSS/acid ratio was not much significant [4]. Similar results were obtained by Rab *et al* [4] who reported that when storage duration increased, TSS/acid ratio also significantly increased from a lowest value on day 1^{st} to highest on 75^{th} day of storage at room temperature.

Total sugars content (%)

According to figure 3, the total sugar content was increased significantly with increasing storage duration, so that it increased from 4.13% in fresh fruits of control group to 6.80% in fruits stored for 60 days. HWT had a significant effect on total sugar content of sweet orange fruits. The rapid increase in total sugar content with increased storage duration was reduced by HWT. The sugar content of fruits having HWDT of 15 min increased from 4.15% at harvest to 5.43% at 60^{th} day of storage. In control fruits it increased from 4.13% in fresh fruits to 6.80% in fruits stored for 60 days. Hence the increase in sugar content of hot water treated fruits was very low as compared to control group (Fig. 3). The starch hydrolyzed to sugars during storage [30]. The starch to sugars conversion continues during storage [31] which is the cause of increase in total sugars content with increasing storage duration [32]. The increase in sugars during storage is therefore in line with the observations of Crouch [32] on decrease in starch content during storage period.

Table 1: Disease incidence, weight loss, TSS, pH, TSS/acid ratio and total sugar content of sweet orange (Cv. Salotiana) as affected by hot water treatments and storage durations

HW dipping time (Minutes)	Disease incidence (%)	Weight loss (%)	TSS (°Brix)	pH	TSS/acid ratio	Sugar content (%)
0	3.59 a	15.25 a	12.67 a	4.59 a	8.78 a	5.37 a
5	2.31 b	13.97 b	12.18 b	4.46 ab	8.61 b	5.23 b
10	0.21 c	12.36 c	11.99 b	4.42 bc	8.40 c	5.10 c
15	0.20 c	10.95 d	11.73 c	4.28 c	8.28 c	4.80 d
LSD α 0.05	**1.21**	**0.1939**	**0.1939**	**0.1420**	**0.1551**	**0.0155**
Storage intervals (Days)						
Fresh	0.00 e	0.00 e	11.10 e	3.95 c	7.16 e	4.14 e
15	0.44 d	7.19 d	11.44 d	4.38 b	7.52 d	4.72 d
30	1.37 c	12.21 c	12.03 c	4.48 b	8.12 c	5.06 c
45	2.65 b	17.30 b	12.71 b	4.67 a	9.05 b	5.44 b
60	3.44 a	28.96 a	13.43 a	4.71 a	10.74 a	6.27 a
LSD α 0.05	**0.42**	**0.7380**	**0.2167**	**0.1587**	**0.1734**	**0.0174**

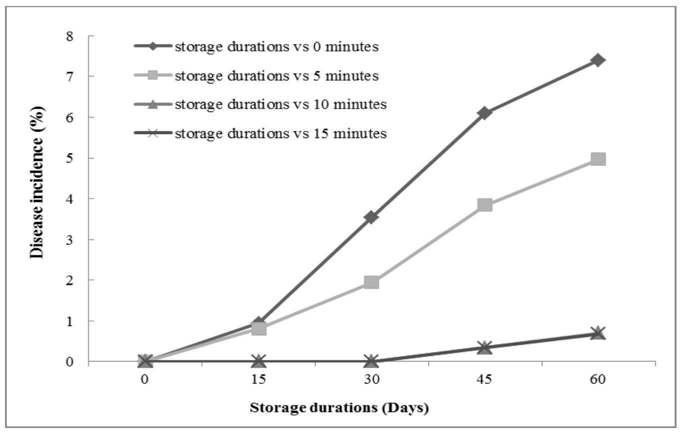

Figure 1: Disease incidence of sweet orange Cv. Salotiana as affected by HWT × Storage durations

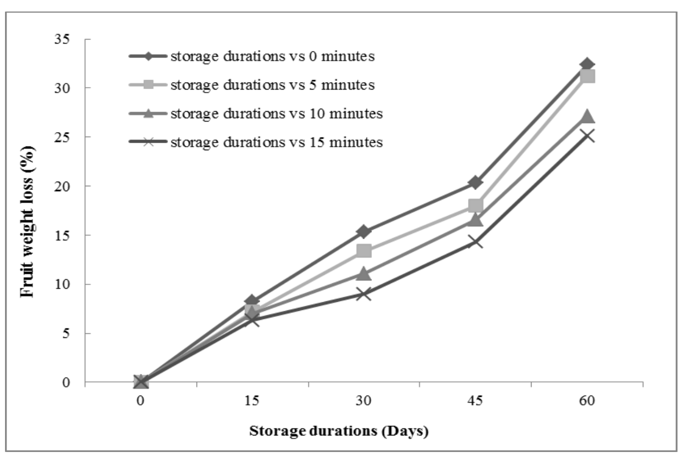

Figure 2: Fruit weight loss (%) of sweet orange Cv. Salotiana as affected by HWT × Storage durations

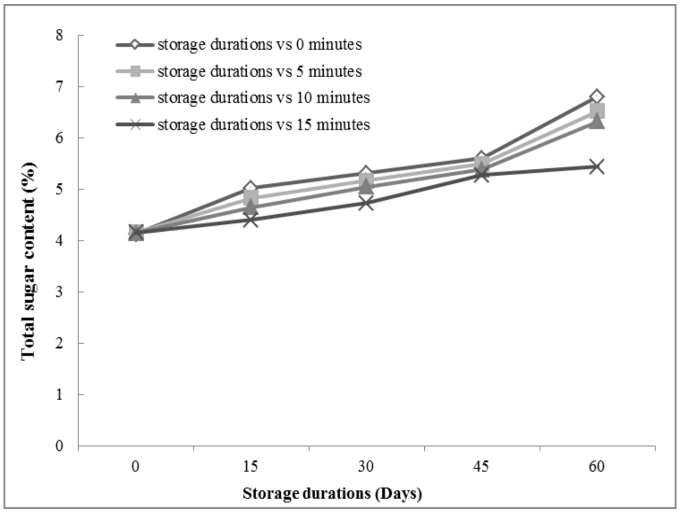

Figure 3: Total sugar content (%) of sweet orange Cv. Salotiana as affected by HWT × Storage durations

4. CONCLUSIONS

According to the experimental results, it can be concluded that hot water treatments significantly retarded the rapid increase in disease incidence, weight loss, total soluble solids, juice pH, TSS/acid ratio and sugar content of sweet orange fruits. Application of hot water treatments made possible the storage of Salotiana sweet orange up to 2 months at room storage conditions (8 ± 2 °C storage temperature and 70 - 80% RH) with cost-effective benefits. The hot water dipping time of 15 minutes with heating temperature of 45 °C was determined to be the most appropriate treatment for maintaining the postharvest quality of Salotiana sweet orange during storage.

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