Environment and Ecology 37 (3A) : 843—847, July—September 2019
Website: environmentandecology.com ISSN 0970-0420

Influence of Different Chemicals and Paraffin Wax on the Post-Harvest Quality of Mandarin Orange (*Citrus reticulata* Blanco) Fruits

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Received 16 February 2019; Accepted 21 March 2019; Published on 12 April 2019

Abstract Mandarin orange (*Citrus reticulata* Blanco) fruits were subjected to various post-harvest treatments such as Control (T_1) ; Calcium chloride 1% (T_2); Oxalic acid 5mM (T_3); Salicylic acid 5 mM (T_4); Sodium nitroprusside 5 mM (T_5); Paraffin wax (T_6); Paraffin wax with Bavistin 1% (T_7) and Paraffin wax with Calcium chloride 1% (T_8), and were stored in ambient temperature. Observations on TSS, titratable acidity, total sugar and ascorbic acid content were taken at the end of shelf life. Physiological loss in weight (PLW) and decay percentage were recorded at 5 days interval, and average shelf life of the fruits recorded. Observations reveal that among different treatments, Control (T_1) showed highest levels of TSS, Total sugar and Ascorbic acid content after storage of mandarin orange, and T_4 (Salicylic acid 5 mM) showed lowest levels of TSS, Titratable acidity and Total sugar contents. The PLW and decay loss (%) increases with storage of mandarin orange, and the treatments containing paraffin wax (T_6, T_7 and T_8) showed significantly lower levels of PLW as compared to all other treatments. T_8 resulted in lowest PLW and decay percentage at different stages of storage. Longest shelf life of 27.67 days was obtained with T_8. These results indicate that the treatment of Paraffin wax with Calcium chloride 1% (T_8) is effective in reducing PLW and decay percent as well as increasing shelf life of mandarin orange fruits in storage.

Keywords Calcium chloride, Mandarin orange, Paraffin wax, Post-harvest quality, Shelf life.

Introduction

Mandarin orange (*Citrus reticulata* Blanco) cv Khasi mandarin belonging to the family Rutaceae, is one of the most popular fruits having excellent fruit quality with high juice content and is grown in tropical and sub-tropical regions of India. The fruits are generally consumed raw, although processed products such as juice are also made but on a very small scale. Fresh fruits have poor shelf life and can be enjoyed only for a short period in their season. Mandarin orange also faces big loss due to improper post-harvest treatments and lack of proper post-harvest handling, and a suit-

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able means for storage is needed for exploring wider market i.e. for exporting them to the outside markets. It is of utmost importance to develop techniques for extending the shelf life of mandarin orange at ambient temperature by reducing the post-harvest decay and maintaining the physico-chemical qualities of fruit.

Different treatments have different effect on the storage of mandarin. Shelf life can be extended with post-harvest treatments of edible coatings in many fruits such as in mango (Abbasi et al. 2011, Singh et al. 2012) and sweet orange (Shahid and Abbasi 2011). Sonkar et al. (2008) reported extending shelf life of Kinnow mandarin with Bavistin dip in combination with waxing. The present investigation was thus taken up to study the effect of certain post -harvest treatments in a view to extent the shelf life and maintain the quality of mandarin orange fruit at room temperature.

Materials and Methods

Matured fruits of mandarin orange (*Citrus reticulata*) from Khawlailung village were harvested in the morning and transferred to the Laboratory of the Department of HAMP, Mizoram University. Sound and unblemished fruits of approximately equal sizes were selected and subjected to different post-harvest treatments such as T_1 (Control); T_2 (Calcium chloride 1%); T_3 (Oxalic acid 5 mM); T_4 (Salicylic acid 5 mM); T_5 (Sodium nitroprusside 5mM); T_6 (Paraffin wax). T_7 (Paraffin wax with Bavistin 1%); T_8 (Paraffin wax with Calcium chloride 1%). The treatments were laid down in a completely randomized design with 3 replications. The treated fruits were then stored in ambient conditions, and observations taken for their various post-harvest quality. Different biochemical observations on the fruits were taken at the end of their respective shelf life. TSS was estimated by hand refractometer. Titratable acidity and total sugars were determined by standard method (AOAC 1990) and the result expressed in percentage. Ascorbic acid was also determined by standard method (AOAC 1990) and the result expressed in mg/100 g. Physiological loss in weight and decay loss were determined and calculated on the basis of percent weight loss and percent decayed fruits. Shelf life was determined by physical observation and recorded for each treatment.

Table 1. Effect of post-harvest treatments on TSS, acidity, total sugar and ascorbic acid content of mandarin orange fruits.

Treatments	TSS (^{0}Brix)	Acidity (%)	Total sugar (%)	Ascorbic acid (mg/100 g)
T_1	10.50	0.45	5.11	38.40
T_2	10.33	0.51	4.57	24.00
T_3	10.43	0.45	4.46	24.60
T_4	10.37	0.94	4.79	30.00
T_5	10.00	0.62	4.22	22.80
T_6	9.00	0.45	4.52	20.40
T_7	9.00	1.07	4.12	22.80
T_8	8.33	0.36	4.10	22.20
CD (0.05)	NS	0.38	NS	NS

Results and Discussion

Total soluble solids (TSS), titratable acidity, total sugar and ascorbic acid

As indicated in Table 1, total soluble solid content of mandarin orange fruits after storage differ with different post-harvest treatments. Among the different treatments, T_1 (Control) showed highest TSS (10.50 ^{0}Brix) whereas lowest TSS content (8.33 ^{0}Brix) was with T_8 (Paraffin wax with Calcium chloride 1%). Lower levels of TSS were obtained in fruits after storage with treatments that contain Paraffin wax such as T_6 (Paraffin wax), T_7 (Paraffin wax with Bavistin 1%) and T_8 (Paraffin wax with Calcium chloride 1%), as compared to those treatments that does not contain Paraffin wax. Similar results were reported by Rokaya et al. (2016) where mandarin orange fruits of untreated (control) showed maximum TSS during storage among different post-harvest treatments, and fruits treated with wax 10% showed minimum TSS in storage from 1st week to the 4th week.

Highest levels of titratable acidity after storage of mandarin orange fruits were obtained with T_7 (Paraffin wax with Bavistin 1%) at 1.07%, which was-significantly higher than all other treatments, except for T_4 (Salicylic acid 5 mM) having 0.94%. On the other hand, T_8 (Paraffin wax with Calcium chloride 1%) showed lowest titratable acidity of 0.36%, which was followed by T_1 (Control), T_3 (Oxalic acid 5 mM) and T_6 (Paraffin wax) having 0.45% each. The higher acidity in the Paraffin wax plus Bavistin treated fruits

Table 2. Effect of post-harvest treatments on physiological loss in weight and decay percentage on mandarin orange fruits. DAT = Days after treatment.

Treatments	Physiological loss in weight (%)				Decay (%)			
	5 DAT	10 DAT	15 DAT	20 DAT	5 DAT	10 DAT	15 DAT	20 DAT
T_1	4.07	7.95	11.91	18.13	3.00	3.67	5.33	10.33
T_2	3.00	7.06	11.09	20.94	1.33	2.67	5.33	8.00
T_3	3.99	6.82	10.35	17.55	2.33	4.33	7.67	11.00
T_4	3.76	7.39	11.14	18.94	2.00	3.33	6.00	10.67
T_5	3.85	7.97	11.84	18.54	2.67	4.00	7.33	11.00
T_6	0.30	0.56	0.82	2.68	0.33	1.33	4.33	9.00
T_7	2.43	2.69	2.90	3.85	2.67	5.67	10.00	23.33
T_8	0.18	0.34	0.48	4.28	0.67	1.33	3.33	4.67
CD (0.05)	1.83	2.10	2.11	5.46	1.50	NS	NS	NS

might be due to lesser utilization of the acids in the respiration process during storage. The results are in line with the findings reported by Sonkar et al. (2009) in Kinnow mandarin, and Deka et al. (2006) in Khasi mandarin. Salicylic acid is also observed to be effective in maintaining titratable acidity, ascorbic acid, and antioxidant activity in plum fruits during storage at 4^0C (Davarynejad et al. 2013).

The total sugar content of mandarin orange fruits after storage were also highest (5.11%) with T_1 (Control) followed by T_4 (Salicylic acid 5 mM) having 4.79%, whereas T_8 (Paraffin wax with Calcium chloride 1%) with total sugar content of 4.10% was the lowest record for all the treatments. The higher content of sugars in control fruit might be due to greater transpirational loss of water. The greater increase in sugar content under ambient conditions may be due to rapid hydrolysis of insoluble polysaccharides into sugars (Siddiqui et al. 2011, Jawandha et al. 2012).

The ascorbic acid content was also highest with Control (38.40 mg/100 g) followed by T_4 (Salicylic acid 5 mM) at 30.00 mg/100 g, and the lowest reading of ascorbic acid with 20.40 mg/100 g was obtained with T_6 (Paraffin wax). However, earlier findings reported that wax treated fruits retained maximum vitamin C content in Kinnow mandarin fruits (Sonkar et al. 2009) and wax 10% in combination with 0.1% Bavistin recorded maximum vitamin C content of mandarin after storage (Rokaya et al. 2016).

Physiological loss in weight (PLW)

The physiological loss in weight percent (PLW) of mandarin orange fruits showed an increasing trend during storage, and the different post-harvest treatments showed significant effects on the PLW of mandarin orange fruits during different days of storage (Table 2). At 5 days after treatment (DAT), highest PLW of 4.07% was obtained with T_1 (Control), followed by that of T_3 (Oxalic acid 5 mM) with 3.99%, and these were higher at 0.05 level of significance compared with T_8 (Paraffin wax with Calcium chloride 1%) and T_6 (Paraffin wax), having PLW of 0.18% and 0.30% respectively.

At 10 days after treatment, the PLW of mandarin orange fruits was highest (7.97%) with Sodium nitroprusside 5 mM (T_5) and Control (T_1) with 7.95%, whereas lowest PLW of 0.34% was obtained in treatment of Paraffin wax with Calcium chloride 1% (T_8), followed by 0.56% in Paraffin wax (T_6). The treatments containing Paraffin wax i.e., T_6, T_7 and T_8 showed significantly lower levels of PLW compared to all other treatments, indicating that Paraffin wax treatment significantly lower the physiological loss in weight of mandarin orange at 10 days of storage. Similar trend was observed at 15 DAT, where the highest PLW was obtained with Control (11.91%) and Sodium nitroprusside 5 mM (T_5) at 11.84%, and the lowest PLW (0.48%) was recorded with T_8 (Paraffin wax with Calcium chloride 1%) and 0.82% with T_6 (Paraffin wax). Again the treatments of T_6, T_7 and T_8 showed significantly lower levels of PLW compared to all other treatments. The data on PLW at 20 days after treatment also showed significant effects in which the treatments T_6, T_7 and T_8 were lower at 0.05 level of significance when compared to all other treatments. Highest PLW of 20.94% was with T_2

Calcium chloride 1%) and the lowest PLW of 2.68% was obtained with T_6 (Paraffin wax).

Increase in physiological loss in weight (PLW) of mandarin orange with the advancement of storage period was also reported by Rokaya et al. (2016), who showed maximum weight loss percentage with untreated (control) fruits, and minimum PLW with fruits treated with wax in combination with Bavistin. Yadav et al. (2010) also reported minimum weight loss in Kinnow mandarin fruits treated with wax emulsion. On the other hand, earlier reports showed Oxalic acid (10%) treatment reduced the physiological weight loss in litchi fruits (Pandey and Lal 2014) and Sodium nitroprusside treatment on mango fruits reduced ethylene production and respiration rate and reduced fruit weight loss (Linh et al. 2015).

Fruit decay percent

The decay percent of mandarin orange fruits as indicated in Table 2, showed increasing trend with increase in storage time. At 5 days after treatment, Control (T_1) showed highest percentage of decay (3.00%) followed by T_5 (Sodium nitroprusside 5 mM) and T_7 (Paraffin wax with Bavistin 1%) with 2.67% each, whereas lowest percentage of decay was with T_6 (Paraffin wax) and T_8 (Paraffin wax with Calcium chloride 1%) having 0.33% and 0.67% respectively. As storage time increases, the decay percent was highest (5.67%) in T_7 (Paraffin wax with Bavistin 1%) at 10 days after treatment, and lowest level of 1.33% recorded with both T_6 (Paraffin wax) and T_8 (Paraffin wax with Calcium chloride 1%). At 15 days after treatment, T_7 (Paraffin wax with Bavistin 1%) again showed highest percentage of decay (10.00%) of mandarin orange fruits, and lowest amount of 3.33% recorded with T_8 (Paraffin wax with Calcium chloride 1%), followed by 4.33% in T_6 (Paraffin wax). Paraffin wax with Bavistin 1% (T_7) again showed highest percentage of decay of 23.33% at 20 days after treatment, whereas the lowest level (4.67%) was again obtained with T_8 (Paraffin wax with Calcium chloride 1%). This showed that with the advancement of storage period, Paraffin wax with Bavistin 1% (T_7) treatment resulted in highest decay percent whereas T_8 (Paraffin wax with Calcium chloride 1%) treatment resulted in lowest percent of decay.

Table 3. Effect of post-harvest treatments on average shelf life of mandarin orange fruits.

Treatments	Shelf life (days)
T_1	20.67
T_5	22.67
T_6	23.67
T_7	22.67
T_8	21.00
T_2	24.67
T_3	20.33
T_4	27.67
CD (0.05)	NS

Similar results were observed by Yadav et al. (2010) in Kinnow mandarin, where minimum decay loss occurred in treatments of wax and wax like safe fungicide during storage, and also observed that the minimum decay loss could be due to interaction effect of wax coating as a microbial inhibitor as well as moisture inhibitor. Rokaya et al. (2016) also observed increase in decay with increase in storage, but they reported minimum decay loss in bavistin and wax treated fruits of mandarin orange in storage.

Shelf life

As shown in Table 3, the shelf life of mandarin orange fruits differs with different post-harvest treatments. Among the treatments in this experiment, T_8 (Paraffin wax with Calcium chloride 1%) resulted in longest shelf life of 27.67 days followed by T_6 (Paraffin wax) with 24.67 days, T_7 (Paraffin wax with Bavistin 1%) resulted in shortest shelf life of 20.33 days followed by T_1 (Control) with 20.67 days. Rokaya et al. (2016) reported that mandarin orange fruits treated with wax and bavistin can be stored upto four weeks at a temperature of 14^0C to18^0C and relative humidity of 45% to 73%. Post-harvest losses can be minimized by treating mandarin fruit with different fungicides to prolong shelf life and enhance fruit quality. Hajilou and Fakhimrezaei (2013) reported post-harvest treatment with Salicylic acid or $CaCl_2$ also prolonged the storage of apricot fruit.

Conclusion

Observation reveal that among different treatments, Control (T_1) showed highest levels of TSS, Total sugar

and Ascorbic acid content after storage of mandarin orange, and T_4 (Salicylic acid 5 mM) showed lowest levels of TSS, Titratable acidity and Total sugar contents. The PLW increases with storage of mandarin orange, and the treatments containing Paraffin wax (T_6, T_7 and T_8) showed significantly lowest levels of PLW compared to all other treatments. T_8 (Paraffin wax with Calcium chloride 1%) resulted in lowest PLW at all stages. From 10 DAT onwards, the decay percent was also highest with T_7 (Paraffin wax with Bavistin 1%), and lowest with T_8. Longest shelf life of 27.67 days was obtained with T_8 (Paraffin wax with Calcium chloride 1%). These results indicate that the treatment of Paraffin wax with Calcium chloride 1% is effective in reducing PLW and decay percent as well as increasing shelf life of mandarin orange fruits in storage.

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