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Effect of different postharvest treatments on prolonging shelf life and maintaining quality of mandarin (*Citrus reticulata* Blanco.)

Pabitra Joshi, Bishnu Prashad Ojha and Arun Kafle

Abstract
This study was conducted during January to April 2018 to evaluate the effect of different postharvest treatments on maintaining quality and Shelflife of mandarin. Laboratory experiment was conducted under Complete Randomized Design (CRD) with four replications and seven treatments (T1 = Control i.e. dipped in distilled water, T2 = Cinnamomum oil @ 2%, T3 = Eucalyptus oil @2%, T4 = Calcium chloride @1%, T5 = Bavistin @0.1%, T6 = Paraffin Wax @10%, T7 = Paraffin Wax @ 10% + Bavistin @0.1%). Data were recorded in every 3 days interval and the last data was taken in 13 days interval because of the limited destructive sample. Postharvest treatment with wax @10% in combination with Bavistin @0.1% had minimum physiological loss in weight (6.61%) and maximum juice recovery percentage (43.72%) which was statistically at par wax (10%), Bavistin (0.1%), Cinnamomum oil (2%), Eucalyptus oil (2%) and Calcium chloride (1%) treated fruits. Also at the end of storage period the highest TSS content (15.45°Brix) was recorded in Calcium chloride (1%) treated fruits which were statistically at par with control, Eucalyptus oil (2%), Bavistin (0.1%) treated fruits. The pH was found non-significant throughout the storage period whereas postharvest life was found the maximum (73 Days) in fruits treated with wax (10%) in combination with Bavistin (0.1%) while it was only 46 days in control. The wax emulsion @10% in combination with Bavistin @0.1% was found better for maintaining quality and prolonging the shelf life of mandarin at the ambient room condition.

Keywords: Postharvest, cinnamomum, eucalyptus, paraffin wax, bavistin, shelf life

Introduction

Mandarin (*Citrus reticulata* Blanco.) is a group name for a class of oranges belonging to family Rutaceae with bright colored peel and pulp, excellent flavor, easy-to-peel rind and segments that separate easily, is believed to have originated in Southeastern Asia (Parashar, 2009) [11]. In Nepalthe total productive area, production and productivity of citrus are 24,854 hectare, 218,447 Metric tons and 8.79 Mt/haandmandarin orange has contributed to 16,248 hectare productive area, 146,690 Metric tons in production with productivity of 9.0 Mt /ha which is very low compared to the most citrus growing countries in the world(Statistical Year Book, 2015/16). Low productivity, decline in quality and heavy post-harvest losses are key hurdles faced by Nepalese fruit industry (Rokaya, 2017) [12].

Nearly 20-25 percent of mandarin fruits are wasted due to faulty postharvest management i.e.7% during harvesting, 25% during transportation, 3% while grading, 10% in packaging, 5% during marketing (Bhattarai, Rijal, & Mishra, 2013) [2]. Since Mandarin is a non-climacteric and perishable fruit, it cannot be kept for a long time during transportation and storage. Due to low adaptation of improved techniques during pre and post-harvest stage, both external and internal (TSS and TA) quality attributes are lost. The postharvest losses can be minimized by extension of shelf life through checking the rate of transpiration, respiration, microbial infection & protecting membranes from disorganization (Sahu, 2016) [13]. Among the different methods used to extend the shelf life alternative of low-cost technology i.e. the application of the edible coating (oil, wax, chemical) to fruit has received attention worldwide as these coatings are maintaining quality even under ordinary storage condition (Bisen, Pandey, & Patel, 2012) [3].

Edible coating of fruits can result in the creation of a modified atmosphere due to ineffective blockage of the pores within the fruits, reducing respiration rate and improving postharvest quality (Kader, 2005) [7]. Considering the above facts this study was carried out with the general objective of evaluating the effect of different postharvest treatments to increase shelf life and maintaining the quality of mandarin under room condition.

Methodology

Khoku Variety (local mandarin of Dhankuta) with uniform size, healthy, greenish yellow and well matured from the private orchard of Udayapur district (Katari Municipality, Katunje,one of the potential districts for citrus cultivation in Nepal) were selected and harvested by clipper keeping with small pedicel intact of fruit and collected in crates from the orchard on Poush 25, 2017. The collected fruits were sorted and graded on the basis of size and maturity for treatments. The fruits were stored under an ambient condition at Beteni lab (PMAMP Citrus Zone) which is located 1300masl at Udayapur District, Nepal. The experiment was conducted from January to April, 2018 which was laid out in CRD with 7 treatments each replicated 4 times. The treatments applied were T_1: Control (distilled water), T2: Cinnamomum oil@2%, T3: Eucalyptus oil @2%, T4: Calcium Chloride ($CaCl_2$)@1%, T5: Bavistin @0.1%, T_6: Wax emulsion @10%, T7: Wax (10%) in combination with Bavistin (0.1%). Different Essential oils (*Cinnamomum* oil, *Eucalyptus* oil) at concentration (2 %) was prepared. The fungicidal solution of Bavistin @ 0.1 % was prepared by dissolving1g of Bavistin (amorphous) 1000 ml of distilled water. This emulsifier wax solution was prepared as a procedure outlined by (Rokaya, 2017) [12]. Fruits from each treatment separately dipped for 2 minutes in each prepared solution in a bucket and were dried for 5 minutes under the shed over the newspaper. After the treatment completion, 10 fruits from each treatment were allocated in the plastic tray as a destructive sample and 5 fruits of each treatment were allocated in each tray as the non-destructive sample under the ambient condition 12.42±0.28^{0}C mean temperature, 68.56±1.46% RH for 41days.Observations were recorded in 2 days interval up to 27days and final observation was taken at 41 day (because of limited sample).Following parameters were evaluated during the storage period.

Physiological Loss in weight (%)

Weight loss was recorded twice a day in the same 5 fruits. A digital sensitive balance was used to determine fruit weight. The weight loss was calculated according to the formula:

$$W_1 = [(W_0 - W_t) / W_0] \times 100\ \%$$

Where W_1 is the percentage weight loss,
W_0 is the weight of the initial fruit and
W_t is the weight of the fruits at the designated time.

Total Soluble Solid (^{0}Brix)

Total soluble solids (^{0}Brix) was determined with the help of Erma hand-held refractometer.

Titrable acidity (TA)

The acidity of the fruits from each treatment was estimated as per standard procedures of AOAC (2005). 10 ml of the clear homogenized juice of a fruit from each treatment was taken and titrated against standard 0.1 N of sodium hydroxide (NaOH) solution using phenolphthalein as an indicator. Then the titrable acidity of the fruit was expressed in percentage using the following formula:

$$\text{Titrable Acidity} = \frac{\text{ml of NaOH used x acid factor}}{\text{Volume (ml) of Juice used}} \text{ x } 100$$

TSS/TA

TSS /TA ratio was calculated by dividing the TSS content by titrable acidity of each treatment and average was recorded. Following formula was used to calculate TSS/TA ratio:

$$\text{TSS /TA} = \frac{\text{Total soluble solids}}{\textit{Titrable acidity}}$$

pH of the juice

pH of the juice was measured with the help of digital pH meter.

Temperature & RH

Temperature and RH were recorded each day during the experimental Periodusing thermo-hygrometer.

Juice content

Juice was extracted by squeezing by hands. The volume of juice was measured (ml/fruit) by beaker. Average juice percentage per fruit was obtained from the following formula:

$$\text{Juice (\%)} = \frac{\text{Juice weight per fruit}}{\text{Individual fruit weight}} \text{ x } 100$$

Statistical method

The data pertaining to various parameters were collected at different stages and intervals and tabulated in an Excel sheet for analysis as mentioned by Gomez and Gomez (1984). All routine statistical analysis was carried out using Genstat software 15th Edition. This software was used to generate (LSD) test at 0.05 ($p<=0.05$) by Analysis of Variance (ANOVA) to determine the significant difference among the treatment means.

Results and Discussions

Physiological loss in weight (PLW)

The physiological loss in weight (PLW) was significantly increased in all the treatments with the advancement of the storage period and the increasing trend in the weight loss percentage was found the maximum in control up to 41 days of storage. Minimum percentage of PLW was observed in the fruits treated with wax in combination with Bavistin during the whole storage period and the losses ranged from 0.90% in 6th day to 6.61% in 41th day whereas maximum weight loss was recorded in the fruits with untreated as control (1.59% to 18.09%) which was statistically at par with the findings of Calcium chloride (1%), Eucalyptus oil (2%) and Bavistin (0.1%) during the storage (Table 1).

This minimum weight loss in the wax-treated fruits was might be due to retardation in the process of transpiration and respiration by the closing of lenticels and stomata of the cell wall of the fruits. Thus wax emulsion might have been an effective treatment to reduce weight loss by checking the stomata and lenticels of the cell wall of fruits which reduces the rate of transpiration and respiration. Wax coated fruits retained better glossiness and fresh appearance being a moisture barrier in the study carried by (Mahajan, Dhatt, & Sandhu, 2005) [8]. A study in tangerine citrus var. Siam Banjar showed that the application of wax coatings in combination with low-temperature storage proves effective in reducing the percentage weight loss (Hassan, Lesmayati, Qomariah, & Hasbianto, 2014) [5]. The findings were in consonance with the findings of the (Ahmad & Siddiqui, 2013) [1] in Kinnow fruit, (Rokaya, 2017) [12] in Mandarin, (Sahu, 2016) [13] in custard apple, who found minimum weight loss in the fruits treated with a wax emulsion.

Table 1: Effect of postharvest treatments on physiological weight loss (%) of mandarin fruit during storage at ambient condition (12.42±0.28^{0}C mean temperature, 68.56±1.46% RH), Udayapur, Nepal, (2017-18)

Treatments	The physiological loss in weight (%) on days indicated									
	6 day	9 day	12 day	15 day	18 day	21 day	24 day	27 day	30 day	41 day
Control	1.59^{abc}	3.81^a	6.03^a	6.98^a	8.25^a	9.21^a	10.79^a	12.06^a	14.29^{ab}	18.09^a
Cinnamon Oil (2%)	1.25^{bcd}	2.19^b	4.70^{bc}	5.95^{ab}	6.89^{ab}	7.52^{ab}	9.09^{ab}	9.71^{bc}	10.28^c	12.70^b
Eucalyptus oil (2%)	1.56^{abc}	2.81^{ab}	4.06^c	5.01^b	5.94^b	6.88^b	7.82^b	9.07^c	12.20^{bc}	14.38^{ab}
$CaCl_2$ (1%)	2.17^{ab}	3.41^a	6.19^a	6.81^a	7.74^a	8.67^{ab}	10.22^a	11.15^{ab}	15.17^a	17.03^a
Bavistin (0.1%)	2.23^a	3.51^a	5.73^{ab}	6.05^{ab}	7.32^{ab}	8.28^{ab}	10.51^a	11.47^{ab}	14.97^a	17.83^a
Wax (10%)	0.60^d	0.90^c	2.09^d	2.09^c	2.40^c	2.99^c	3.89^c	4.19^d	6.58^d	11.98^b
Wax (10%) + Bavistin (0.1%)	0.90^{cd}	1.20^c	1.80^d	2.10^c	3.01^c	3.01^c	3.91^c	3.91^d	5.41^d	6.61^c
S.Em (±)	0.293	0.293	0.326	0.354	0.532	0.458	0.592	0.539	0.759	1.227
LSD (=0.05)	0.862	0.959	1.042	1.564	1.347	1.743	1.584	1.721	2.232	3.608
CV, %	39.8	25.6	16.2	21.3	15.4	17.8	13.4	13.3	13.5	17.4
P-value	0.005	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Grand mean	1.47	2.55	4.37	5.00	5.94	6.65	8.03	8.79	11.27	14.09

LSD = Least Significant Difference, SEM = Standard Error of Mean, and CV = Coefficient of variation, ns = non-significant

Juice content

Table 2 shows that the juice recovery percentage was decreased with time during the storage in all the treatments but was not significantly lower. Wax + Bavistin treated fruits recorded the maximum juice recovery percentage (43.72%) which was statistically at par with the findings of Wax 10%,Bavistin 0.1%,Eucalyptus oil (2%), Cinnamon oil (2%) and Calcium chloride 1% at 41thday of storage whereas the minimum juice recovery percentage (33.89%) was observed in control fruits.

The trend of decrease in juice percentage during the storage was might be due to loss of moisture from the surface of the fruits. The wax treated fruits in combination with Bavistin showed a low reduction in juice content during storage as compared to control or other essential oils. This might be due to the fact that the wax acted as a barrier which had checked the losses of the moisture from the fruit surface. Ahamad, & Siddiqui (2013) [1] reported higher juice recovery percentage in PE-packed fruits (T10) followed by the fruits with 100% Sta-Fresh 960 (T4) which might be due to less water loss in PE-packaging and waxing treatments as the combination acts as a barrier to moisture loss. The minimum decrease in juice percentage was observed in the fruits treated with wax 10% plus Bavistin 0.1% from the 1st week (49.56%) to the 4th week (43.81%) followed by wax 10% from the 1st week (49.49%) to the 4th week (43.45%) as against control from the 1st week (47.26%) to the 4th week (34.65%). Rokaya *et al*. (2017) [12] reported that the fruits treated with wax and in combination with Bavistin showed low reduction in juice content during storage as compared to other chemically treated fruits and control which might be due the fact that the wax acted as a barrier which had checked the losses of the moisture from thefruit surface. These results are in line with (Mahajan, Dhillon, & Kumar, 2013) [9] in Kinnow fruit, (Bisen, Pandey, & Patel, 2012) [3] in Kagzi lime.

Table 2: Effect of postharvest treatments on juice recovery (%) of mandarin fruit during storage at ambient condition (12.42±0.28^{0}C mean temperature, 68.56±1.46% RH), Udayapur, Nepal, (2017-18)

Treatments	Juice recovery % of fruit on days indicated									
	Day 3	Day 6	Day 9	Day 12	Day 15	Day 18	Day 21	Day 24	Day 27	Day 41
Control	46.60	45.89	44.61	44.26	43.72	42.27	41.02	39.82	38.00	33.89^b
Cinnamon Oil (2%)	46.81	46.47	46.33	44.60	44.56	43.83	42.43	41.52	40.61	37.07^{ab}
Eucalyptus oil (2%)	48.23	47.67	47.64	46.95	45.70	45.50	44.81	44.80	38.62	37.80^{ab}
$CaCl_2$ (1%)	45.61	45.57	45.12	44.97	44.41	43.87	43.30	42.68	41.93	41.47^a
Bavistin (0.1%)	46.69	45.65	45.23	44.56	44.49	43.62	42.72	42.68	42.45	41.86^a
Wax (10%)	48.22	47.79	47.09	45.09	45.34	44.33	43.30	43.16	42.89	42.04^a
Wax (10%) + Bavistin (0.1%)	48.23	47.07	46.37	46.05	45.62	45.00	44.66	44.35	44.27	43.72^a
SEm (±)	1.731	1.933	1.855	1.282	2.044	1.133	1.565	1.807	1.869	2.173
LSD (=0.05)	ns	ns	ns	ns	ns	ns	ns	ns	ns	6.390
CV, %	7.3	8.3	8.1	5.7	9.1	5.1	7.2	8.5	9.1	10.9
P-value	0.896	0.961	0.897	0.759	0.991	0.550	0.653	0.534	0.225	0.048
Grand mean	47.20	46.59	46.06	45.21	44.83	44.06	43.18	42.71	41.25	39.69

LSD = Least Significant Difference, SEM = Standard Error of Mean, and CV = Coefficient of variation, ns = non-significant

Total soluble solutes (TSS)

TSS content is one of the major indicators that determine the quality of mandarin orange. As shown in Table 3, TSS content increased with the increasing period of storage in all the treatments and the increasing trend is higher in untreated (control), Eucalyptus and calcium chloride treated fruits than the fruits treated with other coatings. Fruits treated with calcium chloride showed the maximum TSS content during the storage period and ranged from 12.30°brix during 3rd day to 15.45°brix during 41st day which was statistically at par with untreated fruits &Eucalyptus treated fruits and minimum TSS content was recorded in the fruits treated with wax 10% from 3rd day of storage (11.83°brix) to 41st day of storage (13.35°brix) which was statistically at par with wax 10% in combination with Bavistin 0.1% from 3rd day to 41st day of storage. The trend showed that wax treated fruits was significantly superior because of the gradual increment in the TSS change whereas in calcium chloride treated and control it was increased at a faster pace. The faster rate in the TSS increment in the calcium chloride treated and untreated fruits were might be due to faster metabolic activities through respiration and transpiration than in the other coatings. Rokaya *et al*. (2017) [12] reported that untreated (control) fruits showed the maximum TSS content during the storage and ranged from the 1st week (10.92˚ Brix) to the 4th week (12.88˚ Brix) and minimum TSS was recorded in the fruits treated with wax 10% from the 1st week (10.35˚ Brix) to the 4th week (11.51˚ Brix) which was at par with wax 10% in combination with Bavistin 0.1% from the 1st week (10.39˚ Brix) to the 4th week (11.65˚ Brix). Similarly, the results are in line with the results of (Bisen, Pandey, & Patel, 2012) [3] in Kagzi lime, (Waskar & Gaikwad, 2005) [16] in Keshar mango, (Jholgiker & Reddy, 2007) [6] in Sugar apple (*Annona squamosa* L.) fruits, (Shahid & Abbasi, 2011) [14] in sweet orange, (Hassan, Lesmayati, Qomariah, & Hasbianto, 2014) [5] in tangerine citrus.

Table 3: Effect of postharvest treatments on total soluble solids (TSS) of mandarin fruit during storage at ambient condition (12.42±0.28^{0}C mean temperature, 68.56±1.46% RH), Udayapur, Nepal, (2017-18)

Treatments	TSS of fruits on days indicated									
	Day 3	Day 6	Day 9	Day 12	Day 15	Day 18	Day 21	Day 24	Day 27	Day 41
Control	11.85	12.23	12.55	13.00	13.18	13.70	13.93	14.23^a	14.25^a	15.35^a
Cinnamon Oil (2%)	11.80	11.83	12.60	12.75	12.85	13.50	13.53	13.60^{abc}	13.63^{ab}	14.05^{bc}
Eucalyptus oil (2%)	12.50	12.65	12.90	13.03	13.08	13.50	13.62	13.63^{abc}	13.65^{ab}	14.53^{ab}
$CaCl_2$ (1%)	12.30	12.38	13.28	13.30	13.33	13.60	13.68	14.03^a	14.13^a	15.45^a
Bavistin (0.1%)	12.00	12.20	12.63	12.73	12.88	13.70	13.73	13.90^{ab}	13.95^a	14.60^{ab}
Wax (10%)	11.83	11.95	12.10	12.30	12.40	12.65	12.78	13.03^{bc}	13.10^b	13.35^c
Wax (10%) + Bavistin (0.1%)	11.93	12.00	12.33	12.50	12.68	12.83	12.90	13.00^c	13.08^b	13.12^c
S.Em (±)	0.663	0.389	0.370	0.318	0.286	0.390	0.416	0.276	0.251	0.347
LSD (=0.05)	ns	ns	ns	ns	ns	ns	ns	0.811	0.738	1.021
CV, %	11.0	6.4	5.9	5.0	4.4	5.8	6.2	4.0	3.7	4.8
P-value	0.984	0787	0.417	0.376	0.342	0.332	0.394	0.030	0.016	<0.001
Grand mean	12.03	12.18	12.63	12.80	12.91	13.35	13.45	13.63	13.68	14.35

LSD = Least Significant Difference, SEM = Standard Error of Mean, and CV = Coefficient of variation, ns = non-significant

Titrable Acidity

As data presented in Table 4 Titrable acidity of different treatments was significant at the end of the storage period. The TA was significantly decreased with the advancement of the storage period. Higher acidity was recorded in the fruits treated with wax 10% along with Bavistin 0.1% which was 0.0303 at 3rd day of storage and 0.55 on 41th day of storage period whereas there was a significant decrease in the TA content of the fruits left untreated which was 0.66 on 3rd day of storage and 0.40 on 41st day of storage period. The decreasing trend of titrable acidity during the storage period was probably due to the utilization of acid in the tricarboxylic acid cycle in the respiration process. The higher acidity in wax treated fruits was might be due to less utilization of the acids in the respiration process during the storage whereas untreated fruits had minimum acids was due to faster utilization of the acids in the respiration process during storage. Rokaya (2017) [12] recorded maximum TA in the fruits treated with wax 10% plus Bavistin 0.1% against control at the end of the storage. Similarly, the results are in line with (Bisen, Pandey, & Patel, 2012) [3], (Ahmad & Siddiqui, 2013) [1] in Kinnow fruit, (Hassan, Lesmayati, Qomariah, & Hasbianto, 2014) [5] tangerine citrus var. Siam Banjar.

Table 4: Effect of postharvest treatments on titrable acidity (TA) of mandarin fruit during storage at ambient condition (12.42±0.28^{0}C mean temperature, 68.56±1.46% RH), Udayapur, Nepal, (2017-18)

Treatments	Titrable acidity on days indicated (%)									
	Day 3	Day 6	Day 9	Day 12	Day 15	Day 18	Day 21	Day 24	Day 27	Day 41
Control	0.66	0.63	0.61	0.60	0.57	0.54	0.50	0.47	0.42^b	0.40^c
Cinnamon Oil (2%)	0.68	0.67	0.65	0.64	0.62	0.60	0.59	0.58	0.51^a	0.48^{abc}
Eucalyptus oil (2%)	0.68	0.67	0.63	0.62	0.60	0.58	0.56	0.54	0.53^a	0.50^{abc}
$CaCl_2$ (1%)	0.67	0.64	0.61	0.58	0.56	0.55	0.52	0.50	0.49^{ab}	0.47^{abc}
Bavistin (0.1%)	0.67	0.66	0.64	0.58	0.56	0.54	0.51	0.49	0.46^{ab}	0.43^{bc}
Wax (10%)	0.69	0.66	0.64	0.62	0.60	0.59	0.56	0.55	0.54^a	0.52^{ab}
Wax (10%) + Bavistin (0.1%)	0.68	0.66	0.64	0.63	0.62	0.60	0.58	0.57	0.56^a	0.55^a
S.Em (±)	0.0303	0.0543	0.0431	0.0280	0.0382	0.0357	0.0653	0.0343	0.0290	0.0330
LSD (=0.05)	ns	ns	ns	ns	ns	ns	ns	ns	0.0852	0.0970
CV, %	9.0	16.6	13.6	9.2	13.0	12.5	24.0	13.0	11.5	13.8
P-value	0.989	0.998	0.989	0.683	0.827	0.724	0.929	0.199	0.030	0.067
Grand mean	0.68	0.66	0.63	0.61	0.59	0.57	0.54	0.53	0.50	0.48

LSD = Least Significant Difference, SEM = Standard Error of Mean, and CV = Coefficient of variation, ns = non-significant

TSS/TA Ratio

TSS/TA ratio of mandarin fruit as influenced by a different combination of treatments is depicted in Table 5. The effect of treatment was significant with respect to TSS/TA ratio. At the beginning of the storage period from 3rd day to 21st day no significant differences were observed among the treatments. From 24th day to 41st day of storage significant differences among the treatments were observed. Onthe41st day of storage, the significantly maximum ratio was observed with untreated fruits (38.06) while the minimum ratio was observed with wax 10% in combination with Bavistin 0.1%(24.73).

Table 5: Effect of postharvest treatments on TSS/TA ratio of mandarin fruit during storage at ambient condition (12.42±0.28^{0}C mean temperature, 68.56±1.46% RH), Udayapur, Nepal, (2017-18)

Treatments	TSS/TA on days indicated									
	Day 3	Day 6	Day 9	Day 12	Day 15	Day 18	Day 21	Day 24	Day 27	Day 41
Control	17.78	19.44	20.68	22.00	23.46	25.72	28.36	30.68^a	34.35^a	38.06^a
Cinnamon Oil (2%)	17.37	18.13	19.66	19.93	20.88	22.96	23.08	23.38^b	27.26^{bc}	30.17^{bc}
Eucalyptus oil (2%)	18.78	19.12	20.49	21.20	22.32	23.48	26.14	25.78^{ab}	25.89^a	29.01^{bcd}
$CaCl_2$ (1%)	18.40	19.39	21.97	22.90	24.33	24.88	26.42	27.85^{ab}	29.28^{abc}	33.44^{ab}
Bavistin (0.1%)	18.07	18.80	20.04	21.92	23.24	25.93	28.68	28.99^{ab}	30.30^{ab}	34.00^{ab}
Wax (10%)	17.17	18.91	19.51	19.80	21.00	21.79	24.90	24.45^b	24.40^{bc}	25.90^{cd}
Wax (10%) + Bavistin (0.1%)	17.68	18.31	19.33	19.89	20.55	21.56	22.69	23.35^b	23.47^c	24.73^d
S.Em (±)	1.098	1.303	1.360	1.068	1.476	1.484	2.67	1.901	1.939	1.673
LSD (=0.05)	ns	ns	ns	ns	ns	ns	ns	5.590	5.702	4.921
CV, %	12.3	13.8	13.4	10.1	13.3	12.5	20.7	14.4	13.9	10.9
P-value	0.946	0.987	0.838	0.279	0.450	0.241	0.598	0.073	<0.001	<0.001
Grand mean	17.89	18.87	20.24	21.09	22.25	23.76	25.75	26.35	27.85	30.76

LSD = Least Significant Difference, SEM = Standard Error of Mean, and CV = Coefficient of variation, ns = non-significant

p^H of the fruit

None of the treatment had any significant effects on pH of fruits as shown in table 6. Fruits that were untreated showed maximum (3.73 to 4.48) pH followed by Calcium chloride (1%) (4.05 to 4.43) which were statistically at par with Bavistin (0.1%) treated fruits (4.05 to 4.43) up to 41 days of storage. When the storage period was increased, the pH value of Mandarin fruits was also increased gradually under all the treatments. It may be due to the conversion and utilization of different acids in the respiration process. While the minimum pH value was retained by the fruits those were coated with paraffin wax 10% in combination with Bavistin 0.1% which might be due to the slower process of respiration and utilization of organic acids present in mandarin fruits which were statistically at par with cinnamon oil 2% treated fruits.

Table 6: Effect of postharvest treatments on p^H of mandarin fruit during storage at ambient condition (12.42±0.28^{0}C mean temperature, 68.56±1.46% RH), Udayapur, Nepal, (2017-18)

Treatments	pH of fruit juice on days indicated									
	Day 3	Day 6	Day 9	Day 12	Day 15	Day 18	Day 21	Day 24	Day 27	Day 41
Control	3.73^b	3.88	3.95	4.13	4.15	4.23	4.35	4.38	4.43	4.48
Cinnamon Oil (2%)	3.98^a	4.08	4.10	4.10	4.10	4.18	4.18	4.28	4.38	4.10
Eucalyptus oil (2%)	3.93^{ab}	3.98	4.20	4.20	4.25	4.25	4.30	4.35	4.38	4.38
$CaCl_2$ (1%)	4.05^a	4.10	4.13	4.15	4.20	4.23	4.25	4.35	4.40	4.43
Bavistin (0.1%)	4.05^a	4.08	4.13	4.20	4.23	4.23	4.28	4.30	4.40	4.43
Wax (10%)	4.13^a	4.13	4.15	4.23	4.25	4.25	4.25	4.28	4.28	4.30
Wax (10%) + Bavistin (0.1%)	3.90^{ab}	4.00	4.10	4.10	4.13	4.13	4.13	4.13	4.18	4.18
S.Em (±)	0.0748	0.0815	0.1173	0.1795	0.1356	0.997	0.959	0.940	0.899	0.1654
LSD (=0.05)	0.2200	ns	ns	ns	ns	ns	ns	ns	ns	ns
CV, %	3.8	4.0	5.7	8.6	6.5	7.2	7.3	7.4	6.9	7.6
P-value	0.025	0.368	0.847	0.997	0.972	0.997	0.959	0.940	0.899	0.635
Grand mean	3.96	4.03	4.11	4.16	4.19	4.21	4.25	4.29	4.35	4.33

LSD = Least Significant Difference, SEM = Standard Error of Mean, and CV = Coefficient of variation, ns = non-significant

Table 7: Postharvest life

Treatments	Storage up to (Days)
T_1: Control (distilled water)	46days
T_2: Cinnamomum oil@2%	53 Days
T_3: Eucalyptus oil @2%	51 Days
T_4: Calcium Chloride ($CaCl_2$)@1%	60 Days
T_5: Bavistin @0.1%	62 Days
T_6: Wax emulsion @10%	71 Days
T_7: Wax (10%) in combination with Bavistin (0.1%)	73 Days

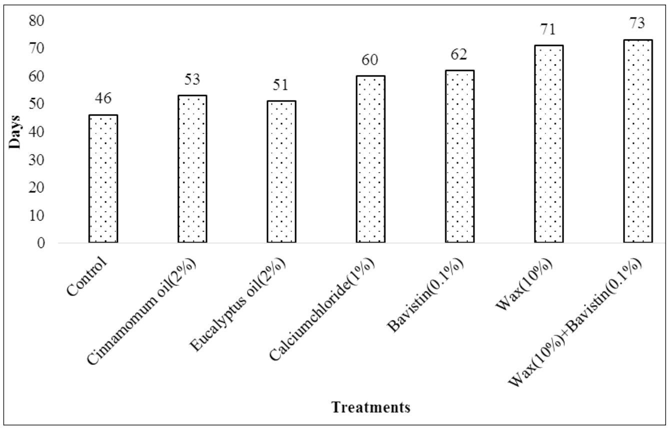

Fig 1: The Postharvest life of different treatments under ambient room condition

Conclusion

Prolongation of shelf life, as well as the quality of mandarin fruit, could be retained with the use of different surface coatings than without using them. By maintaining prolonged shelf life of mandarin fruits, it can be made available in markets for a longer duration as well as can be exported to other countries. To enhance the storage quality, shelf life, and other physiochemical parameters fruits after harvest it is better to treat with Wax (10%) in combination with Bavistin (0.1%) so that fruits could be kept in normal condition for long duration.

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