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Postharvest treatments for preserving quality of 'Kinnow' fruit under different storage conditions

M.S. Ahmad*[(1)], K.S. Thakur, M.W. Siddiqui***

* *Department of Food Science and Technology, Bihar Agricultural University, Sabour, Bhagalpur (Bihar), India.*

** *Department of Food Science and Technology, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan (HP), India.*

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Abstract: 'Kinnow' mandarin is an attractive and nutritious fruit available only for a short period due to its poor shelf life. The effect of different postharvest treatments and storage conditions on the postharvest quality of 'Kinnow' up to 60 days was examined. With progression of the storage period, TSS and total sugars tended to increase whereas acidity, ascorbic acid, juice content, and overall acceptability decreased. Fruits stored at low temperature (4±1°C, RH 85-95%) and Zero Energy Cool Chamber (ZECC) (12-22°C, RH 85-95%) showed a slower rate of physico-chemical changes compared to ambient conditions (18-32°C, RH 45-65%). Both waxing and PE-packaging maintained the external appearance of fruits irrespective of storage systems. However, off-flavour development was noticed in PE-packed fruits after 15 days at room temperature and 40 days in cold storage and ZECC. Waxing of 'Kinnow' mandarin with undiluted Sta-fresh 960 along with low temperature and low cost storage (ZECC) may be recommended to extend the availability of fruits.

1. Introduction

'Kinnow' mandarin occupies a prime position amongst the citrus fruits grown in India. It can be used for processing into a variety of beverages, as well as industrial and medicinal uses due to its attractive colour, distinctive flavour and rich source of vitamin 'C', vitamin 'B', β-carotene, calcium and phosphorous (Sogi and Singh, 2001). Despite its attributes and commercial importance, 'Kinnow' cannot be enjoyed for long periods due to its poor shelf life. The aggregate post-harvest losses from orchards to consumers in 'Kinnow' range from 15 to 22% (Gangwar *et al.,* 2007). Storage at low temperature is one of the potential options to extend the avaibility of many fruits and vegetables (Lei *et al*., 2012). However refrigeration facilities are not generally within the reach of a majority of growers and pathological disease occurrence in 'Kinnow' is very high in cold storage (Singh and Jain, 2004). Edible coatings are promising postharvest treatments to extend the self-life of many fruits as reported in mango (Abbasi *et al.,* 2011; Singh *et al.,* 2012), strawberry (Del Valle *et al*., 2005), custards apple (El-Monem and El-Mayeed, 2003) and sweet orange (Shahid and Abbasi, 2011). Both Semperfresh ™ and Sta-Fresh 960 are commercial edible coating materials, the former is a sucrose-fatty acid ester-based wax while the later is a paraffin polyethylene-based wax. Another important technology used for extending shelf-life of fresh fruits and vegetables is Modified Atmosphere Packaging (MAP) (Ladaniya, 2001; Wasker and Gaikward, 2005; Sharma *et al.,* 2012). Also in 'kinnow' various postharvest treatments such as waxing (Ahmad *et al.,* 2005), MAP packaging (Ahmad *et al.,* 2005; Jawandha *et al.,* 2012), Bavistin dip (Sonkar *et al.,* 2008) and a combination of these treatments are reported to extend the shelf-life during storage and transportation. However, there are few works on edible coating, MAP packaging and low cost storage systems such as Zero Energy Cool Chamber (ZECC) for 'kinnow' fruits and the subject calls for further investigation. Other workers have reported that ZECC may be an alternative low cost storage system (Roy and Khurdiya, 1986; Pal *et al*., 1997) however the treatments must be hazard free and eco-friendly (Siddiqui and Dhua, 2010). Considering these factors, in the present study 'kinnow' fruits were treated with different coating materials to evaluate their performance under ambient, ZECC and cold storage conditions.

2. Materials and Methods

Raw material and treatments

Mature 'kinnow' fruits were procured from the Regional Horticulture Research Station, Dhaulakuan (HP) and brought to the Postharvest Technology Laboratory, UHF, Nauni, Solan immediately after harvest. Sound and unblemished fruits were treated with different waxing

[1] Corresponding author: shamsher73@gmail.com

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materials as follows: T_1= Semperfresh (0.5%), T_2= Semperfresh (1.0%), T_3= Semperfresh (1.5%), T_4= Sta Fresh 960 (100%), T_5= Sta Fresh 960 (50%), T_6= Rice Starch (3%)+Bavistin (0.05%), T_7= Rice Starch (6%)+Bavistin (0.05%), T_8= Rice Starch (3%)+Bavistin (0.05%)+Guar gum (2%), T_9= Rice Starch (6%)+Bavistin (0.05%)+Guar gum (2%), T_{10}= Bavistin (0.05%)+ packing of four fruits in a 150 gauze Polyethylene film, T_{11}= Control.

Storage conditions

Treated and air-dried fruits from all treatments with their replications were divided into three lots and stored in plastic crates with paper moulded trays under ambient (18-32°C, RH 45-65%), Zero Energy Cool Chamber (12-22°C, 80-95% RH) and Cold store (CS, 4±1°C, 80-90% RH) conditions.

Chemical analysis

Different biochemical parameters of the juice were analyzed at fortnightly intervals. Total soluble solids (TSS) were estimated by hand refractometer (0-32°B). The readings obtained were calibrated against a standard temperature at 20°C as per the International Temperature Correction Table and expressed as °Brix. Acidity and ascorbic acid were determined by standard method (AOAC, 1990) and results were expressed as percentage citric acid and mg/100 ml of juice respectively. Total sugars were estimated by the Lane and Eynon volumetric methods (AOAC, 1990).

Physical analysis

The juice was extracted with the help of an electrically operated citrus juice extractor. The fruits were first weighed and then cut into halves and the cut portion of each half was placed on the revolving ridge knob of the extractor till only the skin part remained and all the segments were crushed and pressed; the juice was collected in the bottom of the juice extractor.

Sensory evaluation

Sensory evaluation of samples was conducted by a panel of judges (consisting of teachers, students, and staff) at periodic intervals of storage. The judges were given coded samples consisting of whole and cut fruits for evaluation regarding overall acceptability of the fruits on the basis of appearance, color, taste and defects if any. The evaluation consisted of a 9-point hedonic scale for each attribute (Wills *et al.*, 1980).

Statistical analysis

Interactions among treatments, storage conditions and biochemical attributes were assessed by Completely Randomized Design whereas, sensory attributes were assessed by the Randomized Block Designed using the STATISTICA v. 8.0 (Stat Soft, Tulsa, OK, USA) package.

3. Results and Discussion

Total soluble solids (TSS)

It was observed that TSS in general increased as the storage period progressed under all treatments and storage conditions (Table 1). Among the fruits kept at ambient temperature, the highest mean TSS contents (14.04°B) were recorded in T_{11} (control), whereas the lowest mean TSS contents (12.84°B) were found in treatment T_4 (100% Sta-Fresh 960), which was closely followed by T_{10} and T_5, respectively. The control fruits also exhibited the maximum increase of TSS under ZECC and cold storage conditions, whereas it was usually minimum in response to T_4 followed by T_{10}.

Table 1 - Effect of postharvest treatments on Total soluble solids* (B) of 'Kinnow' fruits under different storage systems during 60 days of storage

Storage systems (S)	Treatments (T)	Storage intervals (days)				
		15	30	45	60	Mean
Room temperature (18-32°C, RH 45-65%)	T_1	11.90	12.59	13.82	14.69	13.25
	T_2	11.84	12.59	13.57	14.10	13.02
	T_3	11.84	12.36	13.41	14.45	13.01
	T_4	11.76	12.31	13.22	14.09	12.84
	T_5	11.78	12.35	13.29	14.49	12.98
	T_6	12.04	12.87	14.18	15.81	13.72
	T_7	12.02	12.84	14.09	15.37	13.58
	T_8	12.00	12.79	14.05	15.50	13.58
	T_9	11.98	12.73	14.92	15.33	13.49
	T_{10}	11.77	12.31	13.16	14.15	12.85
	T_{11}	11.12	13.46	14.45	16.15	14.04
	Mean	11.91	12.65	13.74	14.92	13.03
Zero energy cool chamber (12-22°C, RH 80-95%)	T_1	11.53	11.82	12.12	12.43	11.98
	T_2	11.50	11.80	13.23	13.24	12.44
	T_3	11.49	11.84	12.62	13.25	12.30
	T_4	11.45	11.65	12.06	12.88	12.01
	T_5	11.48	11.87	12.61	13.15	12.28
	T_6	11.57	12.10	12.95	13.40	12.50
	T_7	11.56	11.88	12.20	12.53	12.04
	T_8	11.55	11.86	12.18	12.92	12.13
	T_9	11.54	11.95	12.13	12.83	12.20
	T_{10}	11.46	11.68	11.91	12.84	11.97
	T_{11}	11.59	12.94	13.30	14.68	13.12
	Mean	11.52	11.98	12.48	13.10	12.31
Cold storage (4±1°C, RH 85-95%)	T_1	11.49	11.73	12.00	12.30	11.88
	T_2	11.48	11.72	12.23	12.23	11.82
	T_3	11.46	11.67	12.15	12.15	11.80
	T_4	11.40	11.56	11.91	11.91	11.65
	T_5	11.47	11.67	11.94	11.94	12.04
	T_6	11.54	11.89	12.47	12.47	12.01
	T_7	11.53	11.80	12.41	12.41	11.96
	T_8	11.51	11.78	12.35	12.35	11.92
	T_9	11.51	11.77	12.32	12.32	11.91
	T_{10}	11.42	11.58	11.93	11.93	11.67
	T_{11}	11.65	11.96	12.62	12.62	12.13
	Mean	11.50	11.73	11.98	12.23	

$CD_{0.05}$ Storage systems (S)- 0.10, SxT- 0.33, SxI- 0.19, SxTxI- 0.66.
*Initial Total Soluble Solids (TSS) of 'Kinnow' = 11.35°B.

The TSS content increased due to hydrolysis of insoluble polysaccharides into sugars at a faster rate at high temperature (ambient) and at a slower rate at lower temperatures, i.e. in cold storage and in ZECC (Siddiqui, 2008; Siddiqui *et al.,* 2011; Jawandha *et al.,* 2012). The higher value of TSS in control fruit might be due to a higher concentration of sugars because of higher transpiration losses as these fruits were not covered, which could impede the movement of water out of the fruits. On the other hand, waxing and PE-packing might have reduced moisture losses to a maximum extent as the combination offers excellent moisture barrier properties (Ben-Yehoshua, 1985). Waxing treatments can act as an additional barrier to moisture loss but are less effective because waxes are more permeable to moisture and gases. However, it is a well established fact that wax materials are capable of delaying ripening process by maintaining slow degradation of polysaccharides as observed in mango (Abbasi *et al.,* 2011) and Kinnow mandarin (Chaudhary *et al.,* 2004). Shahid and Abbasi (2011) also reported less change compared to control in TSS in stored sweet orange fruits treated with bee's wax and paraffin wax coatings throughout the storage period. Manzano and Diaz (2001) and Hayat *et al.* (2005) found the similar results in apple after PE-packing and waxing treatments.

Titratable acidity

A gradual decline in titratable acidity contents (Table 2) was observed with an increase in storage duration under all three storage conditions during the entire 60-day storage period. 100% Sta-Fresh 960 (T_4) retained the highest mean TA (0.93%) under ambient conditions whereas T_4 and T_3 presented the maximum values under ZECC (1.02%) and CS followed by T_{10}. At the same time, the control treatment (T_{11}) had the lowest mean titratable acidity (0.64, 0.91, and 0.93%) under ambient, ZECC and CS conditions, respectively.

The faster rate of decline in acidity at room temperature could be due to faster metabolic reactions leading to earlier senescence at higher temperature. Among metabolic reactions in fruits, respiration is an important process which may utilize organic acids as substrate for the production of energy resulting in a decrease in acidity during prolonged storage (Sharma *et al.,* 2012). The organic acids involved in the respiratory process are not oxidized at a faster rate at lower temperature, and therefore their levels remained high. Furthermore, polyethylene and wax materials slow down the metabolism of fruits and vegetables as these have been reported to maintain higher Co_2 and lower O_2 inside the coated/PE-packed fruits (Kader *et al.,* 1989): this might explain the higher acid levels in waxed and PE-packed fruits. These findings are further supported by the findings of Bisen and Pandey (2008) and Siddiqui (2008) in guava and mango, respectively.

Total sugars

Total sugar increased significantly (Table 3) throughout the storage period with the increase being faster under ambient storage and slower under cold storage. Under ambient conditions, T_4 (100% Sta-Fresh 960) proved to be the most effective in delaying the increase in total sugars up to 60 days, whereas, under the other two storage conditions T_{10} proved to be the best during the same period. At the end of the study period, the mean maximum total sugar contents (7.74%) was found in treatment T_{11} (control) whereas the minimum average sugar contents were recorded for treatments T_4 and T_{10} (6.93% and 6.96%, respectively).

Table 2 - Effect of postharvest treatments on titratable acidity* (as % citric acid) of 'Kinnow' fruits under different storage systems during 60 days of storage

Storage systems (S)	Treatments (T)	Storage intervals (days)				
		15	30	45	60	Mean
Room temperature (18-32°C, RH 45-65%)	T_1	1.00	0.86	0.79	0.63	0.82
	T_2	1.00	0.96	0.84	0.68	0.84
	T_3	1.01	0.95	0.88	0.67	0.88
	T_4	1.03	0.98	0.93	0.76	0.93
	T_5	1.00	0.95	0.90	0.70	0.89
	T_6	0.96	0.87	0.74	0.74	0.83
	T_7	0.98	0.88	0.53	0.53	0.78
	T_8	1.00	0.87	0.54	0.54	0.79
	T_9	1.00	0.89	0.54	0.54	0.81
	T_{10}	1.01	0.96	0.72	0.72	0.89
	T_{11}	0.80	0.64	0.60	0.52	0.64
	Mean	0.98	0.89	0.80	0.64	0.82
Zero energy cool chamber (12-22°C, RH 80-95%)	T_1	1.04	1.02	0.99	0.96	1.01
	T_2	1.04	1.02	1.00	0.97	1.01
	T_3	1.04	1.03	1.01	0.98	1.02
	T_4	1.04	1.03	1.01	0.96	1.02
	T_5	1.02	1.02	1.01	0.98	1.00
	T_6	1.02	0.96	0.91	0.85	0.94
	T_7	1.02	0.99	0.95	0.90	0.92
	T_8	1.03	1.00	0.97	0.93	0.98
	T_9	1.03	1.00	0.98	0.94	0.98
	T_{10}	1.04	1.02	1.01	0.98	1.01
	T_{11}	1.00	0.94	0.87	0.82	0.91
	Mean	1.03	1.00	0.95	0.93	0.98
Cold storage (4±1°C, RH 85-95%)	T1	1.04	1.02	1.00	0.97	1.01
	T2	1.04	1.02	1.01	0.99	1.02
	T3	1.04	1.03	1.02	1.00	1.03
	T4	1.04	1.03	1.02	1.01	1.03
	T5	1.03	1.03	1.02	1.00	1.02
	T6	1.02	0.98	0.95	0.91	0.97
	T7	1.02	1.00	0.97	0.93	0.98
	T8	1.03	1.01	0.99	0.96	0.99
	T9	1.04	1.02	1.00	0.97	1.00
	T10	1.04	1.03	1.02	1.01	1.02
	T11	1.01	0.96	0.91	0.85	0.93
	Mean	1.03	1.01	0.99	0.96	1.00

$CD_{0.05}$, Storage systems (S) 0.007, SxT- 0.02, SxI- 0.01, SxTxI- 0.05.
*Initial Titratable acidity (%) of 'Kinnow' = 1.05%.

Table 3 - Effect of postharvest treatments on Total sugar* (%) of 'Kinnow' fruits under different storage systems during 60 days of storage

Storage systems (S)	Treatments (T)	Storage intervals (days)				
		15	30	45	60	Mean
Room temperature (18-32°C, RH 45-65%)	T_1	6.81	7.37	8.27	9.87	8.08
	T_2	7.10	7.25	7.95	9.25	7.88
	T_3	6.71	7.11	7.71	8.70	7.55
	T_4	6.76	7.07	7.49	8.19	7.37
	T_5	6.69	7.17	7.84	8.85	7.63
	T_6	6.90	7.81	9.07	10.65	8.60
	T_7	6.87	7.80	8.91	10.35	8.48
	T_8	6.84	7.75	8.75	10.35	8.42
	T_9	6.81	7.71	8.75	10.45	8.43
	T_{10}	6.72	7.17	7.67	8.40	7.49
	T_{11}	7.00	8.30	10.49	11.60	9.34
	Mean	6.83	7.50	8.44	9.69	8.11
Zero energy Cool Chamber (12-22°C, RH 80-95%)	T_1	6.68	6.75	6.82	6.97	6.80
	T_2	6.67	6.72	6.80	6.93	6.78
	T_3	6.66	6.71	6.78	6.86	6.75
	T_4	6.66	6.72	6.75	6.82	6.73
	T_5	6.65	6.68	6.76	6.84	6.73
	T_6	6.69	6.85	6.95	7.09	6.89
	T_7	6.71	6.81	6.93	7.06	6.87
	T_8	6.70	6.80	6.92	7.04	6.86
	T_9	6.68	6.76	6.90	7.02	6.84
	T_{10}	6.64	6.68	6.74	6.81	6.71
	T_{11}	6.73	6.86	7.03	7.21	6.95
	Mean	6.67	6.76	6.81	6.90	6.77
Cold storage (4±1°C, RH 85-95%)	T_1	6.66	6.73	6.80	6.90	6.77
	T_2	6.64	6.70	6.78	6.86	6.74
	T_3	6.65	6.69	6.74	6.80	6.72
	T_4	6.64	6.67	6.71	6.75	6.69
	T_5	6.64	6.68	6.74	6.80	6.71
	T_6	6.70	6.80	6.91	7.03	6.86
	T_7	6.70	6.79	6.85	7.00	6.83
	T_8	6.46	6.68	6.88	6.98	6.75
	T_9	6.68	6.76	6.86	6.96	6.81
	T_{10}	6.63	6.66	6.70	6.75	6.68
	T_{11}	6.72	6.84	6.99	7.15	6.92
	Mean	6.64	6.72	6.81	6.90	6.77

$CD_{0.05}$, Storage systems (S)- 0.01, SxT- 0.06, SxI- 0.03, SxTxI- 0.12.
*initial Total sugar content of the fruit = 6.51%.

The greater increase in sugar contents under ambient conditions may be due to rapid hydrolysis of insoluble polysaccharides into sugars (Siddiqui *et al.,* 2011; Jawandha *et al.,* 2012). The great content of sugars in control fruit might be due to greater transpiration losses. PE-packing and waxing have been reported as excellent moisture barriers which reduced moisture losses in fruits. Moreover, both PE-packing and waxing can produce modified atmosphere by increasing CO_2 and decreasing O_2 concentration.

Ascorbic acid

The ascorbic acid content showed a general declining trend in all treatments and storage conditions. However, the decrease was more pronounced under ambient conditions as compared to the other two storage systems (Table 4). The slow degradation rate and consequently higher retention of ascorbic acid under cold storage condition

Table 4 - Effect of postharvest treatments on Ascorbic acid contents (mg/100 ml juice) of 'Kinnow' fruits under different storage systems during 60 days of storage

Storage systems (S)	Treatments (T)	Storage Intervals (days)				
		15	30	45	60	Mean
Room temperature (18-32°C, RH 45-65%)	T_1	24.78	24.31	23.84	23.35	24.07
	T_2	24.79	24.33	23.84	23.35	24.08
	T_3	24.81	24.37	23.93	23.49	24.15
	T_4	24.84	24.43	24.02	23.61	24.23
	T_5	24.80	24.35	23.90	23.45	24.12
	T_6	24.65	24.05	23.45	22.82	23.74
	T_7	24.69	24.13	23.57	23.04	23.86
	T_8	24.66	24.07	23.48	22.88	23.77
	T_9	24.65	24.05	23.45	22.85	23.75
	T_{10}	24.85	24.45	23.72	23.65	24.17
	T_{11}	24.64	24.03	23.42	22.78	23.72
	Mean	24.74	24.23	23.69	23.21	23.96
Zero energy cool chamber (12-22°C, RH 80-95%)	T_1	25.08	24.78	24.53	24.27	24.66
	T_2	25.10	24.79	24.55	24.30	24.68
	T_3	25.10	24.82	24.59	24.35	24.71
	T_4	25.15	24.91	24.74	24.55	24.84
	T_5	25.11	24.84	24.62	24.39	24.74
	T_6	25.01	24.66	24.35	24.03	24.51
	T_7	25.05	24.72	24.44	24.15	24.59
	T_8	25.03	24.71	24.38	24.07	24.55
	T_9	25.03	24.69	24.40	24.11	24.56
	T_{10}	25.16	24.94	24.76	24.56	24.85
	T_{11}	25.02	24.64	24.29	24.94	24.47
	Mean	25.08	24.77	24.51	24.25	24.52
Cold storage (4±1°C, RH 85-95%)	T_1	25.12	24.86	24.65	24.43	24.76
	T_2	25.12	24.90	24.71	24.51	24.81
	T_3	25.14	24.94	24.77	24.54	24.86
	T_4	25.16	24.98	24.83	24.67	24.91
	T_5	25.18	24.90	24.71	24.51	24.82
	T_6	25.16	24.82	24.59	24.35	24.71
	T_7	25.10	24.86	24.65	24.43	24.76
	T_8	25.12	24.84	24.62	24.39	24.74
	T_9	25.11	24.80	24.56	24.31	24.69
	T_{10}	25.09	25.00	24.86	24.71	24.94
	T_{11}	25.19	24.76	24.49	24.21	24.63
	Mean	25.07	24.88	24.68	24.46	24.78

$CD_{0.05}$, Storage systems (S)- 0.01, SxT- 0.06, SxI- 0.03, SxTxI- 0.12.
*initial Ascorbic acid content of the fruit = 25.25 mg/100 ml.

and in cool chamber might be due to a reduced metabolic rate at lower temperature. Greater ascorbic acid content under low temperature might be due to a reduced rate of fruit metabolic activities, mainly respiration. These results are in accordance with the findings of Wills *et al.* (2007) and Worawaran *et al.* (2013). Among the treatments, PE-packed fruits (T_{10}) and undiluted Sta-Fresh 960 (T_4) had the highest average ascorbic acid during the 60-day storage. The better retention of ascorbic acid in fruits of both the treatments might be due to modifications in the atmosphere immediately surrounding the fruits. PE packing and waxing have been reported to retain higher ascorbic acid (Bayindirli *et al.,* 1995; Kaushal and Thakur, 1996).

Juice content

The juice content of 'Kinnow' fruit was highest in ZECC (Table 5) followed by CS; the lowest juice content was found in fruits kept under ambient conditions. In the present study it was also observed that the juice content (initially 40.18%) increased under all treatments and storage conditions at the early sampling dates and then declined as the storage period progressed. Maximum juice contents (43.51%) were recorded in treatment T_{10} followed by T_5 and T_4, in comparison to the control fruits which yielded only 40.05 percent at 60 days storage.

These findings might be due to a greater moisture loss at higher temperature coupled with the lower humidity conditions under ambient conditions than ZECC and CS. Among the treatments, higher juice recovery was recorded in PE-packed fruits (T_{10}) followed by the fruits with 100% Sta-Fresh 960 (T_4). This might be due to less water loss in PE-packaging and waxing treatments as the combination acts as a barrier to moisture loss. Similar results were also obtained by Chaudhary *et al. (*2004) in Kinnow mandarin and Bisen and Pandey (2008) in Kagzi lime.

Sensory quality

A perusal of data in Table 6 indicates that the storage temperature had a profound influence on the overall acceptability of the fruits. Cold-stored fruits were the most acceptable after 60 days storage, followed by fruits from ZECC while those stored at ambient conditions were the least acceptable. Up to 60 days storage, fruits from T_4 outscored all other treatments under all three storage conditions, followed by 50% Sta-Fresh 960 (T_5) fruits. At the end of the storage period (60-days), the maximum acceptability (8.01, 7.90 and 6.70) was observed in response to T_4 followed by T_5 (7.85, 7.65 and 6.50), T_3 (7.85, 7.65 and 6.05), T_2 (7.70, 7.45 and 5.90) and T_{10} (7.67, 7.35 and 5.82) in cold store, ZECC and under room temperature respectively.

Better acceptability of cold-stored fruits is understandable as low temperature storage of 'Kinnow' fruit helps maintain storage quality, thereby increasing acceptability. PE packing and waxing creates beneficial effects and these conditions are more effective in retaining fruit quality at higher temperature (Kader *et al.,* 1989; Ladaniya and Sonkar, 1997; Ladaniya, 2007). The fruits treated with Sta-Fresh 960 (T_4) registered overall good acceptability at the end of 60 days. The present results show similarity with the findings of Ladaniya (2001) who demonstrated that taste scores were highest in 'Musambi' sweet orange (*Citrus sinensis*) fruits treated with Sta-fresh 451 wax, and Wang *et al.* (2004) who revealed that due to the waxing, eating quality was good without an unpleasant taste in fruits of Jincheng orange variety. Similar results were also reported by Mahajan *et al. (*2005) in 'Kinnow' fruits.

Table 5 - Effect of postharvest treatments on juice content* (%) of 'Kinnow' fruits under different storage systems during 60 days of storage

Storage systems (S)	Treatments (T)	Storage intervals (days)				
		15	30	45	60	Mean
Room temperature (18-32°C, RH 45-65%)	T_1	44.68	46.02	39.54	35.59	41.47
	T_2	43.01	43.01	40.17	36.17	40.59
	T_3	43.78	41.76	40.11	36.11	40.44
	T_4	40.44	44.20	44.30	43.01	42.98
	T_5	42.88	44.47	42.82	38.82	42.24
	T_6	44.45	45.24	37.12	33.12	39.98
	T_7	42.95	42.17	39.75	35.72	40.14
	T_8	40.41	45.43	36.77	32.94	38.89
	T_9	43.24	43.17	35.78	32.94	38.78
	T_{10}	40.92	42.16	46.70	42.70	43.12
	T_{11}	40.73	39.16	35.43	29.76	36.27
	Mean	42.68	43.34	38.96	36.08	40.44
Zero energy cool chamber (12-22°C, RH 80-95%)	T_1	41.45	43.76	44.02	44.79	43.50
	T_2	41.38	41.78	43.69	44.14	42.74
	T_3	40.98	40.07	44.07	48.11	43.31
	T_4	40.35	42.00	44.50	44.45	42.85
	T_5	40.75	43.20	45.00	48.82	44.44
	T_6	42.08	47.12	46.05	43.12	44.59
	T_7	40.18	42.15	42.17	43.75	42.06
	T_8	42.90	41.75	43.75	40.94	42.33
	T_9	40.05	43.75	45.55	41.76	42.78
	T_{10}	40.28	43.15	45.15	46.68	43.82
	T_{11}	40.30	44.75	42.15	40.76	41.99
	Mean	40.97	43.04	43.39	44.30	43.08
Cold storage (4±1°C, RH 85-95%)	T_1	41.75	43.22	40.75	44.75	42.62
	T_2	42.48	41.78	41.78	49.70	43.93
	T_3	40.35	41.20	40.80	49.43	42.94
	T_4	41.78	41.83	42.65	44.45	42.68
	T_5	41.08	41.35	43.33	48.30	43.52
	T_6	40.47	42.35	41.25	44.10	42.04
	T_7	40.70	40.80	42.80	44.80	42.27
	T_8	41.25	42.15	43.25	48.55	43.80
	T_9	40.25	41.19	42.25	45.50	42.45
	T_{10}	41.20	42.45	44.35	46.48	43.63
	T_{11}	40.75	40.35	42.25	44.25	41.90
	Mean	41.09	41.69	42.12	46.14	42.88

$CD_{0.05}$, Storage systems (S)- 0.37, SxT-1.23, SxI- 0.74, SxTxI- 2.47.
* Initial juice content of fruit = 40.18%.

Table 6 - Effect of postharvest treatments on overall acceptability* of 'Kinnow' fruits under different storage systems during 60 days of storage

Storage systems (S)	Treatments (T)	Storage intervals (days)				
		15	30	45	60	Mean
Room temperature (18-32°C, RH 45-65%)	T_1	6.80	5.80	5.40	3.80	5.45
	T_2	7.20	6.20	5.60	4.60	5.90
	T_3	7.20	6.40	6.00	4.60	6.05
	T_4	7.60	7.20	6.80	5.20	6.70
	T_5	7.40	6.80	6.40	5.40	6.50
	T_6	7.80	5.00	3.80	2.80	4.60
	T_7	7.20	5.60	4.60	4.00	5.35
	T_8	7.00	5.40	4.20	3.40	5.00
	T_9	6.80	5.00	3.80	2.40	4.50
	T_{10}	8.00	6.40	5.70	3.20	5.82
	T_{11}	6.00	4.80	3.00	1.80	3.90
	Mean	7.18	5.87	5.03	3.75	5.43
Zero energy cool chamber (12-22°C, RH 80-95%)	T_1	8.20	7.60	7.20	6.60	7.40
	T_2	7.80	7.80	7.40	6.80	7.45
	T_3	8.00	7.80	7.60	7.20	7.65
	T_4	8.20	8.00	7.80	7.60	7.90
	T_5	8.00	7.80	7.60	7.20	7.65
	T_6	7.80	7.60	7.00	6.40	7.20
	T_7	7.80	7.80	7.20	6.60	7.35
	T_8	7.80	7.60	7.00	6.60	7.25
	T_9	7.60	7.00	5.80	5.60	6.50
	T_{10}	8.60	8.40	6.80	5.60	7.35
	T_{11}	7.60	6.40	5.80	5.40	6.30
	Mean	7.95	7.62	7.02	6.51	7.27
Cold storage (4±1°C, RH 85-95%)	T_1	8.20	8.00	7.80	7.20	7.80
	T_2	8.20	7.80	7.60	7.20	7.70
	T_3	8.20	8.00	7.80	7.40	7.85
	T_4	8.40	8.20	8.00	7.80	8.10
	T_5	8.20	8.00	7.80	7.40	7.85
	T_6	8.00	8.00	7.60	7.00	7.65
	T_7	8.00	7.80	7.40	6.80	7.50
	T_8	7.80	7.80	7.20	7.00	7.45
	T_9	7.80	7.40	6.80	6.40	7.10
	T_{10}	8.80	8.60	7.10	6.20	7.67
	T_{11}	7.80	7.40	7.00	6.40	7.15
	Mean	8.12	7.90	7.46	6.98	7.62

$CD_{0.05}$, Storage systems (S)- 0.09, SxT- 0.31, SxI- 0.18, SxTxI- 0.62.
*Initial score for overall acceptability = 8.60.

4. Conclusions

The result of this investigation showed that using eco-friendly edible coating along with Zero Energy Cool Chamber, the shelf life of 'Kinnow' fruits can be increased substantially. Among the treatments, waxing with undiluted Sta-fresh 960 along with low temperature storage and ZECC has been found the best and may be recommended to extend the availability of fruits.

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