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Effect of Different Post-harvest Treatments on Shelf Life and Quality of Sweet Orange (*Citrus sinensis* Osbeck.) Fruit#

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ABSTRACT

Background: Several post-harvest treatments are used for extension of storage life of sweet orange fruits. The present investigation was carried out at Department of Horticulture, MPKV, Rahuri, during 2019-20 and 2020-21 in order to study the effect of different packaging materials and storage conditions on quality and shelf life of fresh fruit of sweet orange cv. Phule Mosambi.

Methods: The experiment consists of six types of packaging materials *viz*., P_1- Plyethylene bags (150 gauge), P_2- PE paper coating bags, P_3- LDPE (200 gauge), P_4- Cotton bags, P_5- Aluminum foil bags, P_6- Nano silver-based bags and untreated control under two storage conditions *viz*., S_1- Room temperature (RT) and S_2- Cold storage (CS, 12±2°C and 90% RH) in Factorial Completely Randomized Design (FCRD) with three replications.

Result: The data revealed that, the sweet orange fruits packed in nano silver-based bags and stored at cold storage *i.e.* P_6S_2 recorded significantly lowest PLW (7.81%) and spoilage (4.18%) with highest firmness (10.87 N), juice content (46.59%) and overall acceptability (8.73) at the end of storage life of 60 days.

Key words: Packaging materials, Quality, Shelf life, Storage conditions, Sweet orange.

INTRODUCTION

Sweet orange (*Citrus sinensis* Osbeck.) belongs to family Rutaceae and considered as most vital fruit crop of citrus group with their healthful nature multifold nutrition and its medicinal properties have made them so important. The total area under sweet orange cultivation was 209.19 and 61.8 thousand hectares area with the production of 3497.35 and 543.0 thousand metric tons of fruits with average productivity of 16.7 and 8.8 MT/ha in India and Maharashtra, respectively during 2019 (Anonymous, 2020). The cultivars such as Nucellar Mosambi, Phule Mosambi *etc*. are grown in Maharashtra while Phule Mosambi is one of the popular and leading cultivars grown in Maharashtra and adjoining states. Several post-harvest treatments like use of wax 6%, cellophane, packed in perforated polyethylene bags and use of growth regulators are reported to extend the storage life of fruits by storing them under cold storage conditions (Kumar and Chauhan, 1990). In India, post-harvest handling losses of fruit account for 20 to 40% at different stages of handling such on storage, transport and marketing of fresh produce. This is a great bottle neck in exploiting the full potential of fruit crops in increasing their production which is one of the major constraints in improving the rural income, employment opportunity and nutrition value. Packaging technology can contribute to maintenance of appropriate postharvest quality of fresh produce. Nano silver-based bags, punnet and polypropylene bags have been successfully used to maintain postharvest quality and to prolong the storage life of fruits. By creating higher CO_2 and lower O_2 concentrations in the surrounding atmosphere of the commodities, decay, respiration rate, ethylene production and enzymatic activity can be controlled, resulting in improved maintenance of postharvest quality (Dar and Nayik, 2022). The lot of work has been carried out regarding the post-harvest treatments for improving the shelf life sweet orange fruits; however no research work has been reported so far on *cv.* Phule Mosambi a leading cultivar grown in Maharashtra state. In this context, the present study was planned to find out the most suitable packaging material and storage condition for enhancing the shelf life of fresh fruit of sweet orange *cv.* Phule Mosambi.

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MATERIALS AND METHODS

The present investigation was carried out at Department of Horticulture, MPKV, Rahuri, during 2019-20 and 2020-21 for this purpose, the fruits of sweet orange cv. Phule Mosambi of *ambia bahar* were harvested from 20 years old orchard of Department of Horticulture, MPKV, Rahuri at colour break stage and brought to the Post-harvest Technology Laboratory, Department of Horticulture, MPKV., Rahuri and used for further investigation. All the chemicals and packaging materials used for present investigation were obtained from local market of Rahuri, Ahmednagar. The selected fruit were washed under running tap water to remove the adherent dirt material and then allowed to dry in shade. The fruits were dipped for one minute in 6% wax solution coupled with 0.1% Bavistin and packed in different packaging materials as per treatments combinations such as Polyethylene bags (150 gauge) + Room temperature (T_1), Polyethylene bags (150 gauge) + Cold storage (T_2), PE paper coating bags + Room temperature (T_3), PE paper coating bags + Cold storage (T_4), LDPE (200 gauge) + Room temperature, (T_5), LDPE (200 gauge) + Cold storage (T_6), Cotton bags + Room temperature (T_7), Cotton bags + Cold storage (T_8), Aluminum foil bags + Room temperature (T_9), Aluminum foil bags + Cold storage (T_{10}), Nano silver based bags + Room temperature (T_{11}), Nano silver based bags + Cold storage (T_{12}), Untreated control + Room temperature (T_{13}) and Untreated control + Cold storage (T_{14}). The following observations were recorded at five days interval during storage period by following the standard procedures as described below:

Physiological loss in weight (%)

The weight of the fruits was recorded on every five day and subtracted from the initial weight. The loss of weight in grams in relation to initial weight was calculated and expressed as percentage.

$$\text{PLW (\%)} = \frac{\text{Initial weight of fruit - Subsequent day weight of fruit}}{\text{Initial weight of fruit}} \times 100$$

Fruit firmness (N)

Firmness of fresh sweet orange fruit was measured using an Instron Universal Testing Instrument (Make: Shimadzu, Japan; Model: AX-G). Different probe assemblies were used for different tests. Machine was connected to computer via software, this software coverts received signals, collects the data and converts it in graphical representation (texture profile) and prepare the reports of individual tests. The machine was fitted with1kN load cell and an 8 mm diameter compressive probe. The probe was positioned at zero force contact with the surface of the Sweet orange fruit. Probe penetration was set at 10 mm at a crosshead speed of 20 mm/min and readings were taken at 3 equidistant points on the equatorial region of the fruit. The force (N) required to penetrate the fruit surface up to a specific depth (mm) was recorded (Ergun and Huber, 2004).

Juice content (%)

The juice percentage was expressed on weight basis per unit weight of the fruit.

$$\text{Juice content (\%)} = \frac{\text{Weight of juice extracted}}{\text{Weight of fruit}} \times 100$$

Spoilage (%)

Each fruit was thoroughly examined for any visible symptoms of infection *i.e.* disease on every third day during storage. Fruit showing any sign of rot or mould was considered as100% spoilage. The spoilage % was calculated by using following formula,

$$\text{Spoilage (\%)} = \frac{\text{Number of fruits decayed}}{\text{Total no. of fruits}} \times 100$$

Storage life (Days)

The shelf life of fruit was determined by recording the number of days the fruits remained in good condition during storage without spoilage. When the spoilage (Softening, skin browning and rotting) of fruits under different treatments exceeded 50% it was considered as the end of storage period, which was judged by visual observations.

Sensory evaluation score

The organoleptic or the sensory evaluation of sweet orange fruits was done by a panel of five semi-trained judges on the basis of nine-point hedonic scale (9-Like Extremely., 8-Like Very much; 7-Like Moderately; 6-Like Slightly; 5-Neither Like Nor Dislike; 4-Dislike Slightly; 3-Dislike Moderately; 2-Dislike Very Much; 1-Dislike Extremely) for fruit appearance and colour, flavour, texture and taste (Amerine *et al*., 1965). The average of all the above characters was calculated and expressed as overall acceptance. A score of 5.5 and above is considered acceptable for consumer appeal of sweet orange fruits.

The data generated through the present investigation was analyzed by following two factorial Analysis of Variance (ANOVA) using OPSTAT program. Differences were considered statistically significant at P<0.01 (Panse and Sukhatme, 1985).

RESULTS AND DISCUSSION

Physiological loss in weight (%)

The physiological loss in weight PLW (%) of sweet orange fruits was found to be influenced by the use of different packaging materials storage conditions which showed an increasing trend throughout the storage period irrespective of packaging materials and storage conditions (Table 1). It was noticed that, the treatment combination of P_6S_2 *i.e.* Nano silver-based bags + cold storage recorded the lowest PLW (4.33 and 7.81%) on 45 and 60 days of storage followed by P_1S_2 (6.34 and 10.72 %, respectively). This is mainly because of continuous water evapotranspiration from fruit and partly because of increased degradation process with time and high temperature and low humidity. Packaging material *i.e.* nano silver-based bags not only protect the stored fruits but also provide the delivery of bioactive compounds, improves external appearance by giving extra shine to fruit surface, edible coatings are being developed using organic Nano-materials which are effective in maintaining post-harvest quality and controlling fruit loss as reported by Dar and Nayik

Table 1: Effect of different treatments on PLW (%), juice content (%), firmness (N) and spoilage (%) of sweet orange fruit during storage.

Treatment	PLW (%)				Juice content (%)					Firmness (N)					Spoilage (%)			
	5 day	30 days	45 days	60 days	Initial day	5 day	30 days	45 days	60 days	Initial day	5 day	30 days	45 days	60 days	5 day	30 days	45 days	60 days
A. Packaging																		
P_1	0.58	3.91	6.84	10.72	51.89	51.14	48.96	47.53	45.70	24.16	23.74	17.46	15.63	10.60	0.00	0.00	0.00	5.40
P_2	0.55	3.68	6.66	-	51.89	51.09	48.72	47.36	-	24.16	23.81	16.56	14.43	-	0.00	5.41	1.56	-
P_3	0.69	3.79	7.26	-	51.89	51.02	48.98	47.52	-	24.16	23.79	17.46	14.21	-	0.00	0.00	0.00	-
P_4	0.66	3.88	6.84	-	51.89	50.59	48.55	46.99	-	24.16	23.82	16.18	13.21	-	0.00	6.05	1.46	-
P_5	0.57	3.72	7.54	-	51.89	51.22	48.93	47.18	-	24.16	23.88	16.85	14.00	-	0.00	0.00	3.29	-
P_6	0.39	2.51	5.40	7.81	51.89	51.18	48.95	47.60	46.59	24.16	23.94	18.19	13.55	10.87	0.00	0.00	1.14	2.09
P_7	1.02	7.09	-	-	51.89	50.52	47.48	-	-	24.16	23.97	13.61	-	-	0.00	9.46	-	-
S.Em. (±)	0.11	0.20	0.12	0.09	-	0.19	0.15	0.09	0.05	-	0.07	0.44	0.37	0.08	0.00	0.25	0.11	0.08
CD at 1%	NS	0.75	0.44	0.32	-	NS	0.57	0.35	0.18	-	NS	1.65	1.38	0.29	0.00	0.95	0.43	0.29
B. Storage																		
S_1	0.77	4.51	7.44	-	51.89	50.56	48.21	46.92	-	24.16	23.82	15.74	10.90	-	-	9.46	14.92	-
S_2	0.51	3.65	10.67	18.53	51.89	51.37	49.09	47.39	46.14	24.16	23.88	17.49	14.61	10.73	-	0.00	3.11	7.49
S.Em. (±)	0.06	0.11	0.06	0.05		0.10	0.08	0.05	0.03	-	0.04	0.23	0.20	0.04	0.00	0.13	0.06	0.04
CD at 1%	0.23	0.40	0.24	0.17		0.38	0.31	0.19	0.10	-	NS	0.88	0.74	0.15	0.00	0.51	0.23	0.15
A × B																		
P_1S_1	0.84	4.34	-	-	51.89	50.70	48.30	-	-	24.16	23.66	16.95	-	-	0.00	0.00	-	-
P_1S_2	0.32	3.48	6.34	10.72	51.89	51.58	49.62	47.53	45.70	24.16	23.83	17.97	15.63	10.60	0.00	0.00	0.00	10.80
P_2S_1	0.52	3.99	-	-	51.89	50.63	48.07	-	-	24.16	23.81	15.60	-	-	0.00	5.41	-	-
P_2S_2	0.57	3.36	6.66	-	51.89	51.55	49.38	47.36	-	24.16	23.80	17.52	14.43	-	0.00	0.00	3.13	-
P_3S_1	0.81	4.13	-	-	51.89	50.74	48.71	-	-	24.16	23.76	17.03	-	-	0.00	0.00	-	-
P_3S_2	0.56	3.45	6.81	-	51.89	51.30	49.25	47.52	-	24.16	23.82	17.89	14.21	-	0.00	0.00	0.00	-
P_4S_1	0.80	4.26	-	-	51.89	50.05	48.19	-	-	24.16	23.82	15.19	-	-	0.00	6.05	-	-
P_4S_2	0.53	3.50	6.84	-	51.89	51.14	48.91	46.99	-	24.16	23.83	17.17	13.21	-	0.00	0.00	2.92	-
P_5S_1	0.87	4.15	-	-	51.89	50.85	48.57	-	-	24.16	23.81	16.53	-	-	0.00	0.00	-	-
P_5S_2	0.27	3.28	6.90	-	51.89	51.58	49.29	47.18	-	24.16	23.94	17.17	14.00	-	0.00	0.00	3.29	-
P_6S_1	0.46	2.87	6.46	-	51.89	50.85	48.75	47.45	-	24.16	23.92	17.23	10.90	-	0.00	0.00	2.28	-
P_6S_2	0.32	2.15	4.33	7.81	51.89	51.52	49.14	47.74	46.59	24.16	23.97	19.15	16.21	10.87	0.00	0.00	0.00	4.18
P_7S_1	1.07	7.86	-	-	51.89	50.11	46.91	-	-	24.16	23.94	11.64	-	-	0.00	9.46	-	-
P_7S_2	0.98	6.32	-	-	51.89	50.92	48.05	-	-	24.16	24.00	15.59	-	-	0.00	0.00	-	-
S.Em. (±)	0.16	0.28	0.17	0.12	-	0.26	0.21	0.13	0.07	-	0.10	0.62	0.52	0.11	-	0.36	0.16	0.11
CD at 1%	0.64	1.10	0.62	0.46	-	NS	0.80	0.50	0.25	-	NS	NS	1.95	0.40	-	1.34	0.61	0.41

P_1- Polyethylene bags (150 gauge); P_2- PE paper coating bags; P_3- LDPE (200 gauge); P_4- Cotton bags; P_5- Aluminum foil bags; P_6- Nano silver based bags; S_1- Room temperature; S_2- Cold storage.

(2022). The results of present findings are in close conformity with the finding reported by Waskar *et al.* (1999) in pomegranate, Jawandha *et al.* (2014) in Baramasi lemon and Rokaya *et al.* (2016) also reported a significant reduction in weight loss with HDPE packed fruits of mandarin.

Juice content (%)

The juice content was found to be decreased progressively with increase in storage period irrespective of packaging materials and storage conditions; however, the rate of decrease in juice content was faster under ambient temperature as compared cold storage conditions (Table 1). On 5th day of storage, the packaging materials and storage conditions showed non-significant influence on juice content of fruits. The highest juice content was recorded in the treatment combination of P_6S_2 *i.e.* packed with Nano silver-based bags + cold storage (47.74 and 46.59%) followed by P_1S_2 *i.e.* polyethylene bags + cold storage (47.53 and 45.70%) on 45 and 60 days of storage, respectively. The might be due to loss of moisture from the surface of sweet orange fruit packed in different packaging materials and stored under cold storage conditions showed a low reduction in juice content during storage as compared untreated control under room temperature where polyethylene acted as a barrier which had checked the losses of the moisture from the fruit surface (Dar and Nayik, 2022). The results of present findings are in parallel with results reported by Ahmad *et al.* (2013) in sweet orange, Dhumal *et al.* (2008) in aonla, Thapa *et al.* (2020) in sweet orange and Isnaini and Purbiati (2021) in tangerine.

Firmness (N)

The fruit firmness was found to be decreased in all treatments during storage period irrespective of packaging materials and storage conditions (Table 1). On 5th and 30th day of storage, the packaging materials and storage conditions showed non-significant influence on firmness of fruits. The fruit firmness of 24.16 N recorded initially which was decreased and maximum firmness recorded in P_6S_2 *i.e.* packed with Nano silver-based bags + cold storage (16.21 and 10.87 N) closely followed by P_1S_2 *i.e.* Nano silver-based bags + cold storage (15.63 and 10.60 N) on 45 and 60 days of storage, respectively. The decrease in firmness of sweet orange fruit might be due to loss in moisture content during storage. Softening of fruits is caused either by the breakdown of insoluble proto-pectins into soluble pectin or by hydrolysis of starch (Mattoo *et al*., 1975). The coating of mandarin fruits resulted in higher fruit firmness, during storage, which might be due to reduction in moisture loss and respiratory activity and thus maintained the turgidity of the cells (Rokaya *et al.,* 2016). The results of present findings are in line with results reported by Bisen *et al.* (2012) in Kagzi lime and Poudel *et al.* (2021) in acid lime fruits.

Spoilage (%)

The spoilage was found to be increased in all treatments during storage period irrespective of packaging materials and storage conditions (Table 1). There was no spoilage of sweet orange fruits recorded under any of the treatment up to 25th day of storage. The maximum spoilage was recorded by P_5S_2 *i.e.* packed with aluminum foil bags + cold storage (3.29%) which was at par with P_2S_2 (3.13%) and P_4S_2 (2.92%) *i.e.* PE paper coating bags + cold storage and cotton bags + cold storage on 45 days of storage. It was also noticed that, the treatment combination of P_6S_2 *i.e*. Nano silver-based bags + cold storage revealed slower changes in spoilage during storage and recorded the lowest spoilage of 4.18% at the end of storage life 60 days. Packaging material *i.e.* Nano silver-based bags not only protect the stored fruits but also provide the delivery of bioactive compounds, improves external appearance by giving extra shine to fruit surface, edible coatings are being developed using organic Nano-materials which are effective in maintaining post-harvest quality and controlling fruit loss. The spoilage of fruits may be caused due to condensation of water in the bags which creates congenial conditions for the development of micro-organisms and also low levels of oxygen favours fermentation process which might cause the formation of the acetaldehyde and off flavor which may cause spoilage. The most explored nanoparticles in fruits are zinc oxide, silver and chitosan, considering their high antimicrobial activity and stability (Dar and Nayik, 2022 and Kondle *et al*., 2022). The results of present findings are in agreement with the results reported by Mahajan *et al.* (2006) found that Kinnow mandarin washed in chlorine solution followed by individually seal packaged in HDPE bags showed minimum spoilage at the end of 60 days of storage. Similar results are reported by Nasrin *et al*. (2018) in mandarin and Poudel *et al.* (2021) acid lime fruits.

Storage life (Days)

The data presented in Fig 1 clearly indicated that, the shelf life of sweet oranges was found to be influenced by different packaging materials and storage conditions. The highest shelf life of 60 days was recorded when the fruits packed in P_6S_2 *i.e*. Nano-silver based bags + cold storage followed by (P_1S_2) *i.e.* Polyethylene bags (150 gauge) + cold storage (58.50 days) whereas minimum of 28 days noticed in untreated control. The wax emulsion covered the stomatal openings on the fruit surface and formed a physical barrier to the internal gaseous diffusion into the external atmosphere which prevented transpiration, suppressed initial respiration and decreased the rate of biochemical degradation (Chaudhary and Kumar, 2019). Similar results were also reported by Rathnayake *et al.* (2022) who observed that, the wax coating treatment for lime fruits under low temperature storage proved to have better performance compared with all other treatments. Similarly, Joshi *et al.* (2020) reported that, the post-harvest life *Citrus reticulata* Blanco could be extended up to 73 days when treated with wax (10%) in combination with Bavistin (0.1%) while it was only 46 days in control.

Sensory evaluation score

The organoleptic score for overall acceptability was found to be decreased during storage period irrespective of packaging materials and storage conditions (Fig 2). The

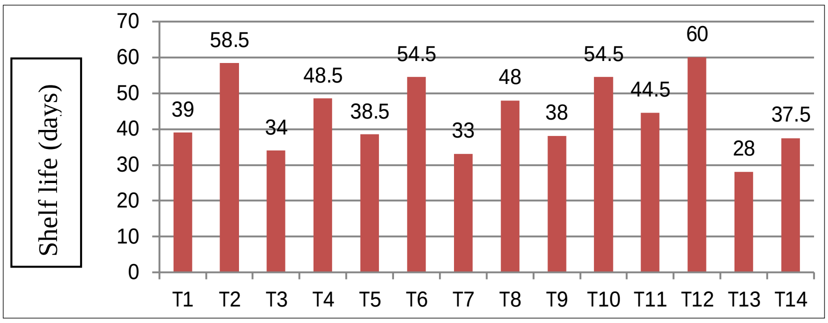

Fig 1: Effect of different treatments on shelf life of sweet orange fruit under different storage conditions.

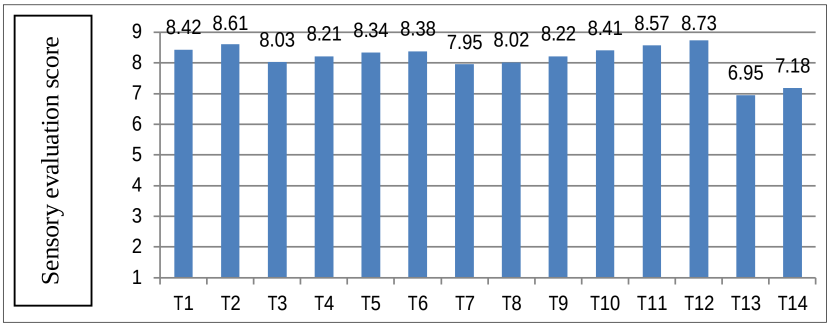

Fig 2: Effect of different treatments on sensory evaluation score of sweet orange fruit at the end of storage life.

highest score for overall acceptability was noticed in P_6S_2 *i.e.* T_{12}-Nano silver-based bags + cold storage (8.73) followed by P_1S_2 *i.e.* T_2-polyethylene bags + cold storage (8.61) on 60th day of storage. The treatment P_6S_2 (Nano silver-based bags 2% vent in cold storage) was found the best packaging material followed by P_1S_2 (150 gauge polyethylene bags with 2% vent in cold storage) while minimum organoleptic quality parameters recorded in untreated control. Since consumer buy fruits with their eyes, a commodity that exhibits a better visual quality will be perceived by a consumer superior over rest of the treatments. The results of present findings are in the line of results reported by Nasrin *et al*. (2018) in mandarin, Haque *et al.* (2020) in Willow leaf mandarin and Kinnow mandarin and Thapa *et al.* (2020) in sweet orange.

CONCLUSION

The physiological loss in weight (%) and spoilage (%) of fresh fruits of sweet orange cv. Phule Mosambi were found minimum in the treatment combination of P_6S_2 *i.e.* packed in nano silver-based bag coupled with cold storage (12±2°C and 90% RH) recorded the maximum firmness, juice content (%) and overall acceptability at the end of shelf life. The shelf life of fruits of sweet orange could be extended up to 44.5 days at room temperature and 60 days at cold storage (12±2°C and 90% RH) when treated with 6% wax coupled with 0.1% Bavistin and packed in nano silver-based bags whereas the untreated control recorded the shelf life of 28 days at room temperature.

Conflict of interest: None.

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