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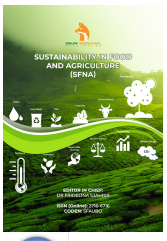

RESEARCH ARTICLE

EFFECT OF DIFFERENT POSTHARVEST TREATMENTS ON PROLONGING SHELF LIFE AND MAINTAINING QUALITY OF SWEET ORANGE (*Citrus sinensis* Osbeck.)

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ABSTRACT

An experiment was conducted to evaluate the effect of different postharvest treatments on maintaining quality and shelf life of sweet orange from Feb-Apr 2019 under completely randomized (CRD) with four replications and five treatments (T1= Aloe vera gel @100%, T2= Paraffin wax @100%, T3= Corn Starch @4%, T4=Tragacanth Gum @4%, T1=Control i.e. untreated fruits) at ambient room condition (15.15±0.33ºC, 58.16±1.69% RH). The parameters recorded were Physiological loss in weight (PLW), total soluble solid(TSS), titratable acidity(TA), Shrinkage, Juice content, Marketability, Disease Incidence and Shelf life in every 5 days' interval till 40th day. Minimum percentage of PLW was observed in the fruits treated with paraffin wax (5.83% in 40th day) which was statistically at par with the findings of all other coated fruits. Corn starch showed minimum shrinkage (4.27%) which was statistically at par with Paraffin wax (100%) and tragacanth gum (4%). Wax treated fruits recorded the maximum juice recovery percentage (31.43%) whereas the minimum juice recovery percentage (27.81%) was observed in control fruits. The control fruits (untreated) showed the maximum TSS (15.03º brix) which was statistically at par with Aloe Vera and Corn starch. Higher acidity was found in the fruits treated with Aloe Vera (100%) (0.917) which was statistically par with corn starch (4%) and tragacanth gum (4%). The marketability value of tragacanth gum treated fruits was reported to be maximum (4.445). Minimum disease index (2.25) was observed in the fruits treated with tragacanth gum which was statistically at par with Aloe vera gel and corn starch treated fruits whereas postharvest life was found maximum (69 Days) in fruits treated with Aloe vera (100%) while it was only 46 in control fruits.

KEYWORDS

Aloe vera, Tragacanth gum, Junar, Coatings

1. INTRODUCTION

Citrus is the important cash crop for farmers of the hill region of Nepal. The total area under citrus, production and productivity of citrus includes 22423 hectares, 130928 metric tons and 10.4 ton/hectare (Budathoki et al., 2004). Among all citrus fruits, Sweet orange is the second both in terms of production and area coverage. Sweet orange is grown in 49 districts of Nepal, but the districts having significant amounts of its production are Sindhuli, and Ramechhap. These two districts are well known for commercial Sweet orange production. The total productive area and production of Sweet Orange in Sindhuli is 623 ha and 7127mt. They are produced in remote and isolated hilly areas where road, market, processing and storage facilities are not available. Therefore, all the storage and transportation activities are done in ambient conditions, without any cold storage facilities. Consequently, the post-harvest losses of citrus including sweet orange are reported to be as high as 29 percent (Kaini, 2013). The post-harvest losses in fruits vary widely from 10 percent to 80 percent in both developed and developing countries (James et al., 2018).

The harvesting period of sweet orange in Nepal lasts for about one and half months (from November to December) (Kaini, 2013). Citrus are perishable fruits. Without cold storage facilities, sweet oranges cannot be stored for long duration; as a result, farmers have to sell their produce in bulk causing glut conditions in the market. As a consequence, farmers cannot get expected prices due to low market value (Shahid and Abbasi, 2011). On the other hand, the consumers are confronted with the problem of non-availability of fruits in the market in the rest of the month such as Magh, Falgun and Chaitra (Jan 15-March 15) where prices go as four times higher (Kaini, 2013). During these months' oranges are imported from India for which consumers are compelled to pay high prices. Due to unavailability of storage facilities at local level, they are forced to sell their fruits within ripening. The loss in citrus during storage is mainly due to pathological breakdown, respiration loss and transpiration loss (Shahid and Abbasi, 2011).

The principal factor affecting fruit quality during transportation, storage, and marketing is often excessive moisture loss. Besides weight loss resulting in a lower price when sold on a weight basis, postharvest moisture loss also reduces fruit quality through loss of glossiness, shriveling, and increased susceptibility to postharvest pathogens (Li et al., 2018). Therefore, to overcome the above mentioned problems, low cost storage techniques should be developed as an alternative method of

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storage in the mid hills areas in which the fruit can be kept in good condition and consumers can get fresh produce without chemical residuals. Coating of fruits with different materials creates modified atmospheric conditions around the coated fruits, thus, allowing lower degree of exchange of gases. It can interplay with physiological processes of commodity resulting in reduced rate of respiration, transpiration and other metabolic processes of fruits thereby allowing lower physiological weight loss, reducing decay incidence and maintaining retention of color and texture of fruits during extended shelf life (Olivas et al., 2008).

This study analyses the effect of different treatments on maintaining quality and prolonging the shelf life of Sweet Orange which is very helpful for developing effective storage technology and increasing the availability of sweet orange till late season and ultimately uplifting the economic status of Sweet orange farmers. The present study was carried out with an objective of evaluating the effect of different postharvest treatments to increase the shelf life and maintaining the quality like TSS, TA, weight loss, shrinkage, disease infestation, marketability of sweet orange under room condition. The barrier properties of *Aloe Vera* gel coatings towards respiratory gases and its antimicrobial functions, were reported in coated fruits and fresh-cut fruits. While in other study Tragacanth gum also showed anti-microbial properties (Radi et al., 2017; Jahanshahi et al., 2018). The first coating that was used in fruits, especially, in citrus fruits was wax. They were applied to oranges and lemons at the beginning of the 12th or 13th centuries in china. In the 1930s, hot melt paraffin waxes were commercially available for coating fresh fruits (Vargas et al., 2008). Similarly, amylose is responsible for the film forming capacity of starch, forming a barrier and inhibiting the oxygen from entering the fruit (Kore et al., 2016).

2. METHODS AND METHODOLOGY

Sindhuli district was purposely selected to conduct the experiment as it is one of the leading districts for sweet orange cultivation in Nepal, located in the Bagmati zone of the Central Development Region. The district (Latitude:26º55" – 27º22" north Longitude: 85º25"-86º15" east) with an altitude range from 168 to 2797 (Adhikari et al., 2012). The experiment was carried out from February 9 to April 18 and the average mean temperature was noted to be 15.15±0.33 and RH 58.16±1.69.

2.1 Selection and Harvesting of Sweet Oranges

The fruit of uniform maturity stage with peel colour as a criterion to judge maturity were harvested by using fruit clipper keeping half cm pedicel intact directly from farmers field. The fruits were graded, sorted and transported using manual labor to the experimental site using plastic crates. After transportation to the experimental site, the fruits were again sorted and mechanically injured fruits were discarded. The fruits were stored under ambient condition at prasodhan Kendra located at 1200masl at Sindhuli.

2.2 Experimental Detail

The experiment was laid out in Completely Randomized Design (CRD) with 5 treatments and each treatment was replicated 4 times. All together 15 fruits were placed in each replication. Seven fruits were used as a non-destructive sample whereas eight fruits were used as destructive samples. Data of one fruit was used from each replication taken at every 5 days interval for 40 days.

Table 1: Treatment details

Treatment	Concentration	Preparation Method
T1: Aloe vera gel	100%	The inner transparent tissue was blended and then filtered through a sterilized cotton cloth and pasteurized at 80ºC for 10minutes. After cooling, fruits were dipped in the gel (Arowora et al., 2013; Misir et al., 2014) .
T2: Paraffin Wax	100%	The wax was melted in a vessel uniformly. The fruit was dipped in the 100% wax and the dipped fruits were air dried (Bahnasawy and Khater, 2014).
T3: Corn Starch	4%	orn starch coating solution was prepared by dissolving 4% (w/v) corn starch in distilled water (40 grams of cornstarch in 1000 ml of distilled water) with agitation for 10 minutes at 90º (Ghosh et al, 2015). Fruits were dipped in the mixture after cooling.
T4: Tragacanth gum	4%	Forty grams of tragacanth powder in 1000 ml of distilled, stirred till dissolved to prepare 4% (w/v) of solution and fruits were dipped in it after cooling (Jahanshahi et al., 2018).
T5: Control	-	The fruits will not be treated with anything and left in room condition.

2.3 Preparation and pre-treatment of the fruits

The fruits were washed with tap water to remove external blemishes and kept in shade for drying (a few minutes) then, were dipped in the solution for 2 minutes to allow complete coating of the fruits. Following treatments, all fruits were allowed to drain and dried at room temperature to allow a thin film layer to be formed on the fruits. The coated and uncoated (control) fruits were then packaged in low density polyethene (LDPE) bags with 4 equal sized perforations at 4 corners. Fruits were then stored at room condition. Three fruits were kept in each bag under the ambient condition.

2.4 Observation

The different parameters recorded were:

2.4.1 Physiological Loss in weight (%)

Weight loss was determined at every 5 days interval from non-destructive samples. Digital sensitive balance was used to determine fruit weight. The weight loss was calculated according to the formula:

$$\text{Weight loss percentage} = \frac{(\text{Initial fresh weight} - \text{successive weight})}{\text{Initial fresh weight}} \times 100\ \%.$$

2.4.2 Shrinkage

Shrinkage was calculated with the help of vernier calliper. Diameter was measured across four different points(2 around the pole and two around the side) for non destructive fruits. Volume was calculated for all four diameter using formula:

$$\text{Volume} = 4/3\pi(\text{radius})^3$$

The average volume is calculated, this volume is subtracted with initial volume to calculate shrinkage according to the formula:

$$\text{Percentage shrinkage} = \frac{(\text{Initial fruit volume} - \text{successive volume})}{\text{Initial fruit volume}} \times 100\%$$

2.4.3 Juice content

Juice was extracted by squeezing manually. The volume of juice was measured (ml/fruit) by the beaker. Averaged juice percentage per fruit was calculated using the formula:

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

2.4.4 Total Soluble Solid (º Brix)

Total soluble solid (^{0} Brix) was determined with the help of a hand held refractometer.

2.4.5 Titratable acidity (TA)

Five grams of juice was weighed out into a 100 ml beaker. To each sample, 25 milliliters(mls) of water was added. Each sample was titrated with 0.1 N NaOH to an end point of 8.1 (with phenolphthalein indicator) and the milliliters of NaOH used was recorded (Saad et al., 2014) . The titratable acidity was calculated using the following formula:

$$\text{\% acid} = \frac{[\text{mls NaOH used}] \times [0.1\ \text{N NaOH}] \times [\text{milliequivalent factor}] \times [100]}{\text{grams of sample}}$$

The process was repeated 2 times and data was averaged to calculate titrable acidity.

2.4.6 TSS/TA ratio

TSS /TA ratio is calculated by using by the formula,

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

2.4.7 Marketability

Marketability was judged by appearance and freshness of the fruit using visual judgement.Various physical characteristics of the fruit checked and rated from 1 to 5 as; Marketability/Acceptability value: 1 = very poor, 2=poor, 3=fair, 4=good and 5=very good (Adekalu and Agboola, 2015).

2.4.8 Disease incidence

Fruits were critically examined every day for the appearance of rot. Disease scoring was done by using a disease rating scale, where 1 represent no disease affected fruit surface, 2 represents <1%; 3 represents 1-5%; 4 represent 6-10%; 5 represent 11-25%; 6 represent 26-50%, and 7 represent over 50% disease affected fruit surface (Hayat et al., 2017).

2.4.9 Shelf life

The shelf life was calculated by counting the days under different treatments depending on the visual observation, physicochemical parameters with edible and marketable quality (Moneruzzaman et al., 2009; Mandal et al., 2018).

2.4.10 Temperature and Relative Humidity

Temperature was recorded each day with the help of a thermo-hygrometer.

2.4.11 Climatic parameters of experimental site

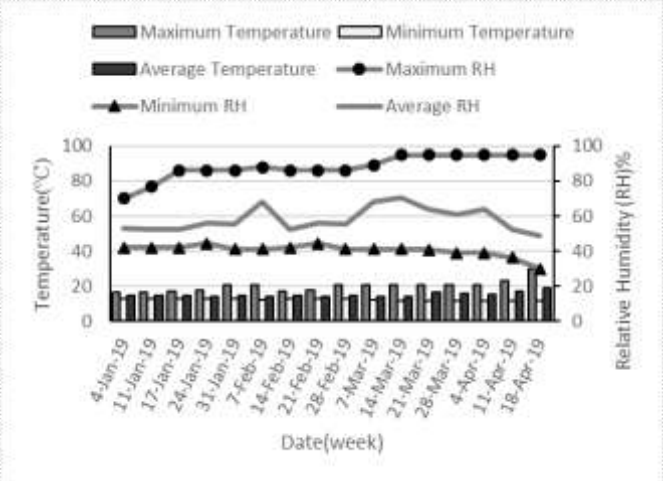

Figure 1: Meteorological data during research period in experimental site The average mean temperature was noted to be 15.15±0.33 and RH 58.16±1.69.

2.5 Data collection and statistical analysis

The collected data were compiled using MS-Excel. The analysis of data was done by using Genstat, 15th edition for the analysis of variance (ANOVA) and mean comparison. For comparing the mean values of treatment, Duncan's Multiple Range Test at 5% level of significance was done. The data was thus analysed and findings were discussed and interpreted.

3. RESULTS

3.1 Physiological loss in weight

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 upto 40 days of storage. Minimum percentage of PLW was observed in the fruits treated with paraffin wax during the whole storage period and the losses ranged from 0.904% in 5th day to 5.83% in 40th day which was statistically par with the findings of all other coated fruits during the storage whereas the maximum weight loss was recorded in the fruits untreated as control (1.141% to 7.41%). There was a significant difference observed between the treatments from 5th day of storage to 15th day of storage. From 20th day of storage to 35th day of storage no significant difference was observed among the treatments (Table 2).

Table 2: Effect of postharvest treatments on the physiological loss in weight (%)

Treatment	The physiological loss in weight (%) on days indicated						
	Day 5	Day 10	Day 15	Day 20	Day 25	Day 30	Day 35
Aloevera	0.962^{b}	1.157^{b}	2.756^{ab}	3.822^{ab}	4.65^{ab}	5.51^{ab}	6.25^{b}
Paraffin Wax	0.904^{b}	1.135^{b}	2.457^{b}	3.619^{b}	4.31^{b}	5.36^{b}	5.83^{b}
Corn Starch	0.940^{b}	1.149^{b}	2.616^{ab}	3.520^{b}	4.36^{b}	5.22^{b}	6.08^{b}
Tragacanth Gum	0.946^{b}	1.121^{b}	2.473^{b}	3.565^{b}	4.66^{ab}	5.56^{ab}	6.15^{b}
Control	1.141^{a}	1.724^{a}	2.967^{a}	4.201^{a}	5.36^{a}	6.22^{a}	7.41^{a}
SEm(±)	0.0235	0.0486	0.1195	0.1632	0.239	0.252	0.276
LSD(0.05)	0.0709	0.1464	0.3601	NS	NS	NS	0.832
CV%	4.8	7.7	9.0	8.7	10.3	9.1	8.7
F-test	***	***	*	NS	NS	NS	**
Grand mean	0.979	1.257	2.654	3.745	4.67	5.57	6.35

Note: LSD= Least Significant difference, SEM= Standard Error of Means, CV= Coefficient of Variation. Same letter(s) indicates the non significant difference between treatments based on DMRT at 5% level of significance.

3.2 Shrinkage

Shrinkage percentage increased with the increasing period of storage in all the treatments and the increasing trend is higher in untreated fruits, Aloe vera and Tragacanth gum coated fruits that fruits which were treated with other coatings. Maximum shrinkage was recorded in untreated fruits which was 1.511% at 5th day of storage to 6.58% at 30th day of storage which was statistically at par with Aloe Vera 100% and Tragacanth gum 4%. Fruits treated with Corn starch showed minimum shrinkage during the storage period and ranged from 1.001% at 5th day of storage to 4.27% at 30th day of storage which was statistically at par with Paraffin wax 100% and Tragacanth gum 4%.

Table 3: Effect of postharvest treatments on Shrinkage percentage

Treatment	Shrinkage(%) on days indicated					
	Day 5	Day 10	Day 15	Day 20	Day 25	Day 30
Aloevera	1.089^{bc}	1.789	2.438^{b}	3.88	4.80	6.04^{bc}
Paraffin Wax	1.159^{b}	1.667	2.406^{b}	3.96	4.70	5.06^{ab}
Corn Starch	1.001^{bc}	1.808	2.600^{b}	3.76	4.09	4.27^{a}
Tragacanth Gum	0.973^{c}	1.849	2.335^{b}	4.54	5.20	5.43^{abc}
Control	1.511^{a}	2.100	2.924^{a}	5.00	5.56	6.58^{c}
SEm(±)	0.0535	0.1245	0.0950	0.339	0.373	0.385
LSD(0.05)	0.1613	NS	0.2865	NS	NS	1.159
CV%	9.3	13.5	7.5	16.1	15.3	14.0
F-test	***	NS	**	NS	NS	**
Grand mean	1.147	1.843	2.541	4.23	4.87	5.48

Note: LSD= Least Significant difference, SEM= Standard Error of Means, CV= Coefficient of Variation. Same letter(s) indicates the non significant difference between treatments based on DMRT at 5% level of significance.

3.3 Juice Content

Table 4. shows that the juice recovery percentage decreased with time during storage in all the treatments. Wax treated fruits recorded the maximum juice recovery percentage (31.43%) whereas the minimum juice recovery percentage (27.81%) was observed in control fruits. Juice recovery percentage was significantly different at 35 days of storage where maximum recovery percentage was shown by paraffin wax (33.13%) whereas untreated fruits showed minimum value (28.77%).

Table 4: Effect of postharvest treatments on Juice recovery %

Treatment	Juice recovery % of fruits on days indicated							
	Day 5	Day 10	Day 15	Day 20	Day 25	Day 30	Day 35	Day 40
Aloevera	37.10	35.42	34.91^{ab}	33.52	33.28	30.59^{b}	33.64^{a}	29.98
Paraffin Wax	36.73	36.68	36.35^{a}	35.98	36.63	34.24^{a}	33.13^{a}	31.43
Corn Starch	38.53	34.39	34.06^{b}	30.59	33.13	30.02^{b}	32.64^{a}	30.52
Tragacanth Gum	37.09	35.62	34.36^{ab}	31.83	33.77	31.73^{ab}	31.70^{ab}	29.87
Control	35.34	32.85	31.83^{c}	33.23	29.68	29.03^{b}	28.77^{b}	27.81
SEm(±)	1.582	0.987	0.635	1.475	1.054	1.037	1.048	0.782
LSD(0.05)	NS	NS	1.913	NS	NS	3.125	NS	NS
CV%	8.6	5.6	3.7	8.9	6.4	6.7	6.6	5.2
F-test	NS	NS	**	NS	NS	*	*	NS
Grand mean	36.96	34.99	34.3	33.03	32.75	31.12	31.98	29.92

Note: LSD= Least Significant difference, SEM= Standard Error of Means, CV= Coefficient of Variation. Same letter(s) indicates the non significant difference between treatments based on DMRT at 5% level of significance.

3.4 Total Soluble Solutes (TSS)

As shown in Table 5., TSS content increased significantly with the increasing period of storage in all the treatments and the increasing trend is higher in untreated fruits (control), Aloe Vera and Corn starch than the fruits treated with other coatings. The control fruits (untreated) showed the maximum TSS content during the storage period and ranged from 11.95 º brix at 5th day to 15.03º brix at 40th day of storage which was statistically at par with Aloe Vera and Corn starch. Minimum TSS content was recorded in the fruits treated with paraffin wax (100%) which was 10.03 º brix at 5th day to 12.18 º brix at 40th day of storage which was statistically par with Tragacanth gum treated fruits (4%).

Table 5: Effect of postharvest treatments on total soluble solid

Treatment	TSS of fruits on days indicated							
	Day 5	Day 10	Day 15	Day 20	Day 25	Day 30	Day 35	Day 40
Aloevera	10.95	11.00^{abc}	11.40^{ab}	11.88^{ab}	12.32^{ab}	12.80^{abc}	13.25^{abc}	13.88^{ab}
Paraffin Wax	10.03	10.32^{c}	10.62^{b}	11.05^{b}	11.32^{b}	11.55^{c}	11.78^{c}	12.18^{c}
Corn Starch	11.00	11.45^{ab}	11.75^{ab}	12.07^{ab}	12.55^{ab}	13.12^{ab}	13.50^{ab}	13.80^{ab}
Tragacanth Gum	10.53	10.73^{bc}	11.00^{b}	11.48^{b}	11.88^{b}	12.30^{bc}	12.47^{bc}	12.88^{bc}
Control	11.30	11.95^{a}	12.53^{a}	12.82^{a}	13.53^{a}	13.93^{a}	14.45^{a}	15.03^{a}
SEm(±)	0.350	0.335	0.359	0.381	0.435	0.484	0.485	0.511
LSD(0.05)	NS	1.008	1.082	1.149	1.310	1.459	1.463	1.540
CV%	6.5	6.0	6.3	6.4	7.1	7.6	7.4	7.5
F-test	NS	*	*	*	*	*	*	*
Grand mean	10.76	11.09	11.46	11.86	12.32	12.74	13.09	13.55

Note: LSD= Least Significant difference, SEM= Standard Error of Means, CV= Coefficient of Variation. Same letter(s) indicates the non significant difference between treatments based on DMRT at 5% level of significance.

3.5 Titratable acidity

The Titratable acidity significantly decreased with the advancement of the storage period. The results were conformable with the study of Nasirifar et al,. 2018 in *Citrus sinensis* . Higher acidity was found in the fruits treated with Aloe Vera 100% which was 1.440at 5th day of storage to 0.917 at 40th day of storage which was statistically par with corn starch 4% and Tragacanth gum 4% whereas there was a significant decrease in the TA content of the fruits left untreated which was 1.443 at 5th day of storage to 0.783 on the 40th day of storage period. Minimum acidity was observed in the fruits treated with paraffin wax which was 1.315 at the 5th day of the storage and decreased to 0.750 at the 40th day of the storage which was statistically at par with control.

Table 6: Effect of postharvest treatments on titratable acidity

Treatment	Titratable Acidity on days indicated (%)							
	Day 5	Day 10	Day 15	Day 20	Day 25	Day 30	Day 35	Day 40
Aloevera	1.440	1.318	1.232	1.149	1.162	1.002	0.953^{a}	0.917^{a}
Paraffin Wax	1.315	1.139	1.078	1.034	1.101	0.921	0.839^{b}	0.750^{b}
Corn Starch	1.241	1.267	1.181	1.114	1.039	1.014	0.949^{a}	0.909^{a}
Tragacanth Gum	1.382	1.229	1.165	1.110	1.053	0.982	0.915^{a}	0.877^{a}
Control	1.443	1.251	1.099	1.069	1.024	0.960	0.860^{b}	0.783^{b}
SEm(±)	0.0733	0.0524	0.0514	0.037	0.074	0.0329	0.0172	0.0250
LSD(0.05)	NS	NS	NS	NS	NS	NS	0.0512	0.0754
CV%	10.7	8.4	8.9	6.8	13.8	6.7	3.8	5.9
F-test	NS	NS	NS	NS	NS	NS	***	***
Grand mean	1.364	1.241	1.151	1.095	1.076	0.976	0.9034	0.847

Note: LSD= Least Significant difference, SEM= Standard Error of Means, CV= Coefficient of Variation. Same letter(s) indicates the non significant difference between treatments based on DMRT at 5% level of significance.

3.6 TSS/TA Ratio

At the beginning of the storage period from 5th day to 20thday no significant differences were observed among the treatments. From 25th day to 40th day of storage significant differences among the treatments were observed. On the 40th day of storage, the significantly maximum ratio was observed with control (19.31) while the minimum ratio was observed with tragacanth gum (14.67).

Table 7: Effect of postharvest treatments on TSS/TA								
Treatment	TSS/TA on days indicated							
	Day 5	Day 10	Day 15	Day 20	Day 25	Day 30	Day 35	Day 40
Aloe vera	7.81	8.47	9.80	11.15	11.50^{b}	12.80	13.91^{b}	15.19^{b}
Paraffin Wax	8.56	9.11	10.39	11.19	10.91^{b}	12.55	14.09^{b}	16.33^{b}
Corn Starch	8.00	9.07	10.23	11.81	13.10^{ab}	13.01	14.24^{b}	15.22^{b}
Tragacanth Gum	7.93	8.75	9.85	11.14	11.90^{b}	12.53	13.63^{b}	14.67^{b}
Control	7.59	9.58	11.76	13.11	14.21^{a}	14.62	16.83^{a}	19.31^{a}
SEm(±)	0.521	0.511	0.681	0.607	0.728	0.684	0.660	0.899
LSD(0.05)	NS	NS	NS	NS	2.194	2.063	1.990	2.709
CV%	13.0	11.4	13.1	10.4	11.8	10.4	9.1	11.1
F-test	NS	NS	NS	NS	*	NS	*	*
Grand mean	7.98	9.00	10.41	11.68	12.33	13.10	14.24	16.14

Note: LSD= Least Significant difference, SEM= Standard Error of Means, CV= Coefficient of Variation. Same letter(s) indicates the non significant difference between treatments based on DMRT at 5% level of significance.

3.7 Marketability

The marketability value of Tragacanth gum treated fruits was reported to be maximum which was 4.938 at 15th days of storage to 4.445 at 35th day of storage while that of paraffin wax coated fruits showed minimum marketability (4.150 to 2.308).

Table 8: Effect of postharvest treatments on Marketability					
Treatment	Marketability on indicated days				
	15 Day	20 Day	25 Day	30 Day	35 Day
Aloevera	4.930^{a}	4.690^{a}	4.530^{a}	4.402^{a}	4.090^{a}
Paraffin Wax	4.150^{b}	3.515^{c}	2.395^{d}	2.567^{c}	2.308^{d}
Corn Starch	4.150^{b}	4.062^{b}	3.647^{c}	3.645^{b}	3.500^{c}
Tragacanth Gum	4.938^{a}	4.890^{a}	4.362^{a}	4.420^{a}	4.445^{a}
Control	4.950^{a}	4.020^{b}	4.000^{b}	3.587^{b}	3.228^{c}
SEm(±)	0.0898	0.1619	0.0812	0.0937	0.1150
LSD(0.05)	0.2206	0.4881	0.2447	0.2826	0.3468
CV%	3.9	7.6	4.3	5.0	6.5
F-test	***	***	***	***	***
Grand mean	4.624	4.236	3.787	3.724	3.514

Note: LSD= Least Significant difference, SEM= Standard Error of Means, CV= Coefficient of Variation. Same letter(s) indicates the non significant difference between treatments based on DMRT at 5% level of significance.

3.8 Disease Infestation

Disease plays a major role in loss of fruits after harvesting, resulting in less profit to farmers. Stomata have been reported as the first door for entry of pathogens into the fruits (Hayat, et al., 2017). After 35 days' highest disease score (5.25) was observed in untreated fruits (control) which was statistically at par with paraffin wax while minimum disease index (2.25) was observed in the fruits treated with tragacanth gum which was statistically at par with Aloe vera gel and corn starch treated fruits.

Table 9: Effect of postharvest treatments on disease infestation						
Treatment	Disease infestation					
	Day 10	Day 15	Day 20	Day 25	Day 30	Day 35
Aloevera	1.000	1.00	1.25^{b}	2.00	2.25^{bc}	2.25^{c}
Paraffin Wax	1.000	1.00	1.00^{b}	2.00	3.25^{ab}	4.50^{ab}
Corn Starch	1.000	1.00	1.50^{b}	2.00	2.00^{c}	3.50^{bc}
Tragacanth Gum	1.000	1.25	1.50^{b}	1.75	2.00^{c}	3.00^{bc}
Control	1.250	1.50	2.50^{a}	3.00	4.25^{a}	5.25^{a}
SEm(±)	0.118	0.250	0.250	0.413	0.359	0.508
LSD(0.05)	NS	NS	0.754	NS	1.083	1.532
CV%	21.3	43.5	32.3	38.4	26.1	27.5
F-test	NS	NS	**	NS	**	**
Grand mean	1.050	1.15	1.55	2.15	2.75	3.70

Note: LSD= Least Significant difference, SEM= Standard Error of Means, CV= Coefficient of Variation. Same letter(s) indicates the non significant difference between treatments based on DMRT at 5% level of significance.

3.9 Postharvest life

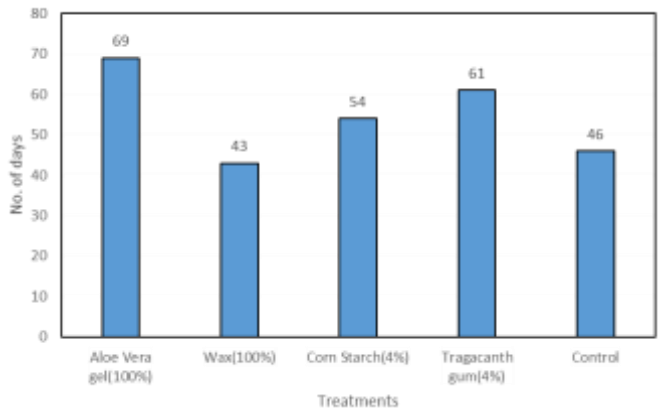

Figure 2: The Postharvest life of different treatments under ambient room condition

4. DISCUSSION

Weight loss is a crucial parameter since every loss in weight can be translated into an economic loss. It has a strong effect on the appearance (Mohebbi et al., 2012). The minimum weight loss in the wax treated fruits might be due to retardation in the process of transpiration and respiration by the closing of lenticels and stomata of the wall of the fruits (Rokaya et al., 2016). Similarly, the increasing trend in shrinkage percentage during the storage might be due to loss of moisture from the surface of the fruits in untreated fruits. The coated fruits might act as a barrier which had checked the losses of the moisture from the fruit surface. A researcher obtained results that indicated that the diameter change decreases with increasing wax solution in cucumber (Bahmasawy, 2014). TSS decreases and shelf life increases with increasing wax solution.

Juice percentage showed a decrease during the storage might be due to loss of moisture from the surface of the fruits. The wax treated fruits showed a low reduction in juice content during storage as compared to other treated fruits and untreated fruits. This might be due to the fact that wax acts as a barrier which checked the loss of moisture from the surface of fruit. Wax treated fruits were significantly superior because of the gradual increment in the TSS change whereas in control it was increased

at a faster pace. The faster rate in the TSS increment in the untreated fruits might be due to faster metabolic activities through respiration and transpiration (Rokaya et al., 2016). A researcher reported that the increase in total soluble solids, reducing sugar content, weight loss and loss of firmness was significantly controlled in oranges coated with A. vera gel (Adetunji, 2012). The increase in TSS during the storage may be due to sugar synthesis from organic acid and degradation of cell wall leading to increase in total dissolved solids increase, hydrolytic enzymes or waste water under storage conditions as stated (Nasirifar et al., 2018). Increase in concentration of Aloe vera gel prevented the increase in the content of soluble solids during storage (Ergun and Satici, 2012). This results were in agreement with the results reported by many studies which stated that the titratable acidity of fruits treated with coating including tragacanth gum in apples, Aloe vera gel in kiwifruit, Aloe vera gel and gum arabic in Bell Pepper (Jahanshahi et al., 2018; Benitez et al., 2013; Ullah et al., 2017).

The higher acidity in Aloe vera treated fruits might be due to less utilization of acids in the tricarboxylic acid cycle in the respiration process whereas wax treated fruits showed minimum acids due to faster utilization of the acids in the respiration process in the storage (Rokaya et al., 2016). Some researcher observed conformable results that the decrease in titratable acidity was repressed in higher concentration of Aloe vera gel coating that may be due to decreased respiration and catabolism of soluble solids including sugar and organic acid (Ergun and Satici, 2012). The organic acids are converted into sugar and their further utilization in the metabolic process (Jahanshahi et al., 2018). Thus, decreasing TA and increasing p^H and TSS (Benítez et al., 2013). The consumption of malic acid and citric acid during ripening or used for alcoholic fermentation. The coating acts as a barrier to gas permeation causing CO_2 accumulation and motivating anaerobic respiration. A study reported that totally making an anaerobic condition would stimulate anaerobic metabolism within the tissue and initiate the development of off-flavours due to ethanol production (Olivas et al., 2008). If O_2 concentration falls below the Pasteur point anaerobic metabolism is induced and the accumulation of ethanol and acetaldehyde can lead to development of off-flavors (Paul and Pandey, 2011).

A study reported that TA was highest in the fruits coated with 15% Aloevera gel when four different concentration (i.e. 0, 1, 5, 15%(v/v)) coatings of aloe vera gel was used in fresh cut kiwifruits (Benitez et al., 2013). TSS/TA ratio is an important parameter when it comes to the taste of the fruits. The ration was maintained moslty by tragacanth gum. It might be due to mainatainance of TSS and TA by reducing respiration and utilization of acids in Tricarboxylic acid cycle as mentioned above. Tragacanth gum showed highest marketability due to the glossiness of the coating and its ability to reduce shrinkage, while wax coated fruits showed lowest marketability as the changes in the color and firmness of the fruits due to off-flavor development (Olivas et al., 2008). A group researcher mentioned that the tragacanth gum desirably preserved the external quality of the coated apples (Jahanshahi et al., 2018).

Paraffin wax might have shown increased disease because of sealing stomata and other minor injuries with the coating material (Hayat et al., 2017). In a study reported that Aloe vera gel applied as an edible coating has been found to be effective in reduction of microbial spoilage of several whole fruits such as sweet cherry, table grapes and nectarines (Martinez-Romero et al., 2013). The antifungal activity of Aloe gel from several species has been correlated with the presence of a phenolic compound, Aloin (Martínez-Romero et al., 2013). Jahanshahi et al., 2018 reported that the tragacanth extract has antimicrobial properties. Tragacanth gum extract had significantly higher antimicrobial activity that other gum extracts (Singh et al., 2015). Shelf-life of the fruits was recorded to be maximum in Aloe vera gel coated fruits (69 days), followed by tragacanth gum (61 days), which might be due to the antibiotic and antifungal properties (Raghav et al., 2016). Wax fruits showed lower storage life than the control fruits due to the off-flavor development and softening.

5. CONCLUSION

From this experiment, it can be concluded that prolongation of shelf life, as well as the quality of Sweet Orange, could be retained with the use of different surface coatings than without using them. However, creation of anoxic condition or decreasing the level of oxygen below Pasteur point can lead to the development of off-flavor (anaerobic respiration). Aloe vera gel coated fruits had maximum shelf-life but tragacanth gum coated fruits were found to be superior in terms of TA, shrinkage, marketability and disease incidence. Fruits can be available in market for a longer duration as well as can be exported to other countries.

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