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Impact of Different Packaging Materials on the Quality and Shelf Life of Kinnow Mandarin (*Citrus reticulata*)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The experiment carried out on the "Impact of Different Packaging Materials on The Quality and Shelf Life of Kinnow Mandarin (*Citrus reticulata*)".Under the study the packaging treatments include T_1 (Control or no packaging), T_2 (Fruits packed in Newspaper), T_3 (Fruits wrapped in Brown paper bags), T_4 (Fruits packed in Aluminium Foil), T_5 (Fruits wrapped in LDPE (Low Density Polyethylene), T_6 (Fruits packed in Rice stubble), T_7 (fruits packed in Perforated boxes), T_8 (Fruits packed in Gunny bags), T_9 (Fruits packed in Nylon net bags). The main objective of the experiment was to evaluate the effect of various packaging materials on physico-chemical characteristics of Kinnow fruit during storage. The physico-chemical evaluation of the fruits of each treatment was done upto 24 days and all the observations were recorded at every 6 days interval. The Fruit Weight, Polar Diameter, Radial Diameter, Peel weight having the decreasing trend, the highest mean was found in T_5 during storage which were (151.70), (57.58), (59.11), (36.08) respectively.

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The TSS(^{0}Brix) and pH were recorded lowest in the fruits packed in T_5 during storage which were (10.45) and (4.02) respectively. Specific gravity of fruits had decreasing trend during storage period and found highest (0.86) in T_5 at 24 days while ascorbic acid and titrable acidity had decreasing trend and mean values was found highest (17.89) and (0.89) in T_5 respectively during storage. On basis of study results shown by physico-chemical characteristics of kinnow, it was concluded that kinnow fruits packed in T_5 LDPE packing has highest overall acceptability at 24 days of storage. These practices may be passed on for obtaining higher returns with B:C ratio of 2.39.

Keywords: Kinnow; LDPE; shelf life; economics; physico-chemical.

1. INTRODUCTION

Citrus is one of the most important sub-tropical fruits in the world. It primarily refers to *Citrus* × *sinensis*, which is also called sweet orange, to distinguish it from the related *Citrus* × *aurantium*. The sweet orange reproduces asexually (apomixis through nucellar embryony); varieties of sweet orange arise through mutations. The orange is a hybrid between pomelo (*Citrus maxima*) and mandarin (*Citrus reticulata*). The orange originated in a region encompassing Southern China, Northeast India, and Myanmar, and the earliest mention of the sweet orange was in Chinese literature in 314 BC. As of 1987, orange trees were found to be the most cultivated fruit tree in the world. Orange trees are widely grown in tropical and subtropical climates for their sweet fruit. The fruit of the orange tree can be eaten fresh, or processed for its juice or fragrant peel. As of 2012, sweet oranges accounted for approximately 70% of citrus production. In 2019, 79 million tones of oranges were grown worldwide, with Brazil producing 22% of the total, followed by China and India. The total mandarin production in India was 3698.99 thousand tons, 29.97 percent of which is producedin Punjab during 2014-15.

Kinnow is an important citrus fruit grown in subtropical regions of India. Kinnow is a hybrid between King (*Citrus nobilis*) and Willow leaf (*Citrus deliciosa*) mandarins developed in 1915 (Dr. H.B. Frost) at Citrus Research Centre, University of California, River side, USA. After a long evaluation period of 20 years, it was released in 1935 as a new variety for its commercial cultivation in Kinnow. In India, kinnow is cultivated primarily in Punjab, Rajasthan, Haryana, Himachal Pradesh, Jammu & Kashmir and Uttar Pradesh.

The post harvest shelf life of kinnow fruit at room temperature is very limited and shelf life can be extended to a maximum period of up to 45 days under refrigerated storage condition. In view of its limited shelf life the fruit must be processed to extend its availability period and also minimize the glut in the market in its peak season of production. Like all fresh products the quality of kinnow mandarin juice changes with time. Several key parameters influence the rate of microbial spoilage, enzymatic degradation, chemical changes and deterioration in flavor or turn bitter extraction (Dinesh et al. [1]). For improving the taste, aroma, palatability, nutritive value and reducing bitterness kinnow juice was blended with some other highly nutritive fruit juice namely pomegranate and aonla juice with spice extract like ginger.

Packaging is the science, art and technology of enclosing or securing products for distribution, storage, sale and consumption. Packaging also refers to the design process, evaluation and production of cans. Packaging can be described as an integrated system of preparing products for transportation, storage, logistics, sale and consumption. Packaging, holds, protects, preserves, transports, informs and sells. In many countries it is fully integrated into government, business, and institutional, industrial and personal use. The first packages used natural materials available at that time: baskets of reeds, wineskin (bota bags), wooden boxes, clay vases, ceramic amphora, wooden canisters, woven bags, etc. After their development, refined materials were used to make packages: for example, the glass and bronze vessels of the East. The study of old packages is an important aspect of archaeology. The epoch from the stipulated time to age in the manufacture of the cane began in the mid- 19th century.

The role of packaging is very important in post harvest operations of horticultural crops but its role is still underestimated in the country. Use of polymeric films is very pronounced in packaging of fruits with a purpose to extend their storage life. Packing of fruits in polymeric films creates modified atmospheric conditions around the produce inside the package allowing lower degree of control of gases and can interplay with physiological processes of commodity resulting in reduced rate of respiration, transpiration and other metabolic processes of fruits [2] thereby allowing lower physiological weight loss, reducing decay incidence and maintaining retention of colour and texture of fruits during extended shelf life (Sharma et al. 2010).

2. MATERIALS AND METHODS

The present investigation entitled **"**Impact of Different Packaging Materials On The Quality And Shelf Life Of Kinnow Mandarin (*Citrus reticulata)***"** was carried out at post-harvest lab, Department of Horticulture, SHUATS, Naini Agricultural Institute, PRAYAGRAJ in the year 2022.

The treatments were T_1 (Control or no packaging), T_2 (Fruits packed in Newspaper), T_3 (Fruits wrapped in Brown paper bags), T_4 (Fruits packed in Aluminium Foil), T_5 (Fruits wrapped in LDPE (Low Density Polyethylene), T_6 (Fruits packed in Rice stubble), T_7 (fruits packed in Perforated boxes), T_8 (Fruits packed in Gunny bags), T_9 (Fruits packed in Nylon net bags).

Weight of the fruits was measured on top pan balance individually and their average weight was calculated and expressed in gram. Polar Diameter from apex to the pedicel end was measured by vernier caliper and expressed in millimeter. Radial Diameter of the fruits were measured by vernier caliper as diameter and expressed in millimeter.

Specific gravity was measured by dividing weight the fruit by its volume.

$$\text{Specific gravity} = \frac{\text{Weight of the fruits}}{\text{Volume of the fruits}}$$

To calculate the peel weight of the fruit, Firstly the weight of fruit was calculated by electronic balance in gram. After weight the fruit was placed out and then peel weight was calculated by electronic balance in gram. TSS was determined with the help of hand refractrometer of range 0-45 ^{0}Brix (QA Supplies, LLC). The TSS was recorded by placing 1-2 drops of sample on the prism of a hand refractrometer. The result was expressed as (^{0}Brix). Titrable acidity (Ranganna 1986) was calculated by titrating a known volume of the diluted sample against 0.1N NaOH using phenolphthalein as an indicator up to faint pinkend point. The titrable acidity was calculated by using formula and expressed in terms of percent citric acid.

$$\text{Titrable Acidity} = \frac{\text{Eq.wt. of acid} \times \text{Normality of NaoH} \times \text{Titer}}{\text{Sample weight}} \times 100$$

pH was taken with ELTOP-3030 pH meter prior to pH measurement; the instrument was standardized with the buffer solutions of pH 4, 7 and 9. The pH of the samples was estimated directly. Ascorbic acid was determined by using 2,6-Dichlorophenol-indophenols visual titration method (Johnson and Dana 1948).

Standardization of Dye: 5ml of the standard ascorbic acid (0.1mg/ml) and 5 ml of 3% meta-phosphoric acid were taken. This was titrated with the dye solution to the pink color, which persisted for 15 sec. Dye factor is determined by the formula:

Dye Factor = 0.5 / Titre

Samples were individually prepared in 3% meta-phosphoric acid solution. Out of this prepared sample, a known aliquot was taken and titrated against the 2, 6 dichlorophenol - indophenols dye solution till the pink end point obtained which persisted for at least 15 sec. The ascorbic acid was calculated as the formula given below and expressed in mg/100g.

$$\text{Ascorbic acid} = \frac{\text{Titre} \times \text{Dye Factor} \times \text{Volume made up}}{\text{Vol. of Aliquot for estimation volume of sample} \times \text{wt. of sample}} \times 100$$

Total Sugars A known volume of aliquot (0.1 and .01 mL) was taken in separate test tubes and volume was made up to 1 mL with distilled water. One mL of phenol solution (5%) was added to each test tube. After 10 min 5 mL H_2SO_4 (95%) was added in each test tube slowly and carefully then shake the tubes by vortex mixture. The optical density of the sample was recorded at 490 nm with the help of UV-Vis spectrophotometer (UV-1800, Shimadzu, Japan). The standard curve was prepared using different concentrations of glucose and results were expressed as percent and calculated as given below:

$$\text{Total sugars \%} = \frac{\text{Sugar value from standard curve } \mu\text{g} \times \text{Total value of extract}}{\text{Aliquot of sample used} \times \text{Weight sample taken}} \times 100$$

2.1 Packaging of Kinnow Fruits

The fresh kinnow fruits of uniform size and well matured ones were selected. Apart, other traits of healthiness for fruits free from that of disease and bruising on skin were also taken in consideration for selection of fruits for harvest. Before packing the fruit, they were properly washed with chlorinated water (100 ppm) and dried under shade to remove the surface water. Thereafter, the packed fruits were stored under ambient conditions in Post Harvest Laboratory, Department of Horticulture, SHUATS, Prayagraj, Uttar Pradesh. The lab was properly ventilated and thoroughly cleaned.

Fig. 1. Treatment wise packaged fruits

3. RESULTS

The maximum fruit weight of kinnow fruit after 24 days was observed in T_5 packed by using LDPE where Initial Reading was (162.56g), (159.78g) 6days, (157.00g) 12days, (152.47g) 18days, (151.70g) 24Days, followed by T_4 (Aluminium Foil) where Initial reading was (155.22g), (150.56g) 6 Days, (140.84g) 12 Days, (135.04g) 18 Days, (130.21g) 24 Days. Whereas the maximum weight loss of fruit was found in fruits of Treatment T_1 (Control) (142g) Initial Reading, (132g) 6 Days, (116g) 12Days, (95.01g) 18Days, (83.00g) 24 Days.

Maximum Radial Diameter of Kinnow fruit after 24 days was observed in Treatment T_5 where Kinnow fruits were packed using LDPE the Initial Reading was (68.30mm), (66.35mm) 6days, (64.73mm) 12days, (64.26mm) 18days, (59.11mm) 24days, followed by T_4 (Aluminium Foil) where Initial reading was (62.34mm), (62.15mm) 6 Days, (58.51mm) 12 Days, (57.71mm) 18 Days, (54.67mm) 24 Days. Whereas the minimum Radial Diameter of kinnow fruit after 24 Days was found in fruits of Treatment T_1 (Control) where Initial Reading was (62.65mm), (59.35mm) 6 Days, (54.70mm) 12Days, (53.83mm) 18Days, (46.50mm) 24 Days.

Maximum Polar Diameter of the Kinnow fruit after 24 Days was observed in Treatment T_5 where fruits packed by using LDPE there (63.57mm) Initial Reading, (60.80mm) 6days, (59.11mm) 12days, (58.45mm) 18days, (57.58mm) 24days, followed by T_4 (Aluminium Foil) where Initial reading was (62.53mm), (60.80mm) 6 Days, (59.11mm) 12 Days, (58.45mm) 18 Days, (57.58mm) 24 Days. Whereas the minimum Polar Diameter of Kinnow fruit was recorded in fruits of Treatment T_1 (Control) (54.50mm) Initial Reading, (51.02mm) 6 Days, (46.67mm) 12Days, (44.77mm) 18Days, (43.85mm) 24 Days.

Maximum Specific gravity of Kinnow fruits after 24 Days was recorded in the Treatment T_5 where the fruits were packed using LDPE the Initial Day Reading was (1.32 g/m^3), (1.28 g/m^3) 6 days, (1.19 g/m^3) 12 days, (0.93 g/m^3) 18 days, (0.86 g/m^3) 24 days, followed by T_4 (Aluminium Foil) where Initial reading was (1.31 g/m^3), (1.23 g/m^3) 6 days, (1.04 g/m^3) 12 Days, (0.92 g/m^3) 18 Days, (0.84 g/m^3) 24 Days. Whereas the minimum specific gravity was observed in fruits of Treatment T_1 (1.22 g/m^3) Initial Reading, (0.98 g/m^3) 6 days, (0.86 g/m^3) 12days, (0.79 g/m^3) 18 days, (074 g/m^3) 24 days.

Minimum Peel weight loss of the Kinnow fruit was observed in Treatment T_5 in which fruits were packed using LDPE the Initial Day Reading was (46.75g), (46g) 6days, (43.34g) 12days, (38.05g) 18days, (36.08g) 24days, followed by T_4 (Aluminium Foil) where Initial reading was (42.04g), (38.33g) 6 Days, (34.57g) 12 Days, (30.58g) 18 Days, (28.87g) 24 Days. Whereas the maximum Peel Weight loss of fruit was found in fruits of Treatment T_1 (Control) (32.43g) Initial Reading, (27.56g) 6 Days, (20.92g) 12Days, (15.88g) 18Days, (9.37g) 24 Days.

Table 1. Effect of different packaging materials on fruit weight, radial diameter and polar diameter

Treatment	Fruit Weight (g)					Radial Diameter (mm)					Polar Diameter (mm)				
	0 DAP	**6DAP**	**12DAP**	**18DAP**	**24DAP**	**0DAP**	**6DAP**	**12DAP**	**18DAP**	**24DAP**	**0DAP**	**6DAP**	**12DAP**	**18DAP**	**24DAP**
T_1	142.00	132.00	116.00	95.01	83.00	62.65	59.35	54.70	53.83	46.50	54.50	51.02	46.67	44.77	43.85
T_2	112.22	107.56	100.93	94.36	88.40	64.11	62.05	58.11	57.29	50.30	51.00	49.39	48.08	46.83	44.22
T_3	131.00	122.14	107.75	95.58	92.20	60.44	58.69	53.63	52.72	47.11	54.07	52.74	51.64	50.87	50.01
T_4	155.22	150.56	140.84	135.04	130.21	62.34	62.15	58.51	57.71	54.67	62.53	59.82	58.33	57.82	56.74
T_5	162.56	159.78	157.00	152.47	151.70	68.30	66.35	64.73	64.26	59.11	63.57	60.80	59.11	58.45	57.58
T_6	146.00	139.67	132.86	129.92	126.60	63.23	61.22	57.98	55.22	52.75	57.87	56.32	55.44	53.21	52.66
T_7	154.00	146.22	139.41	130.87	125.62	61.28	59.95	56.18	54.56	52.84	58.00	57.18	54.67	54.12	53.48
T_8	142.44	131.33	120.69	110.20	104.70	58.61	54.87	51.24	50.56	47.25	57.13	55.88	52.44	49.97	48.12
T_9	151.00	144.11	137.66	128.96	126.60	66.60	63.80	58.79	57.39	48.67	54.67	52.50	49.11	46.20	45.02
F Test	S	S	S	S	S	S	S	S	S	S	S	NS	S	S	S
SE (m)	2.57	2.51	5.95	1.32	3.48	1.6	1.77	1.8	1.37	1.84	1.66	2.38	1.76	1.8	1.57
CD at 5%	87.81	99.04	50.88	334.08	144.33	5.6	6.06	8.2	12.24	10.79	8.46	5.95	12.09	13.56	16.55

Table 2. Effect of different packaging materials on specific gravity, peel weight and TSS

Treatment	Specific Gravity					Peel Weight (g)					TSS ^{0}Brix				
	0DAP	**6DAP**	**12DAP**	**18DAP**	**24DAP**	**0DAP**	**6DAP**	**12DAP**	**18DAP**	**24DAP**	**0DAP**	**6DAP**	**12DAP**	**18DAP**	**24DAP**
T_1	1.22	0.98	0.86	0.79	0.74	32.43	27.56	20.92	15.88	9.37	9.93	10.37	10.51	10.87	11.80
T_2	1.17	1.07	0.88	0.82	0.77	28.56	26.11	17.27	13.40	10.79	9.67	9.76	10.25	10.48	10.68
T_3	1.15	1.07	0.94	0.84	0.81	30.12	27.11	20.04	12.50	10.67	9.14	9.68	9.80	9.95	10.70
T_4	1.31	1.23	1.04	0.92	0.84	42.04	38.33	34.57	30.58	28.87	9.55	9.98	10.03	10.33	10.65
T_5	1.32	1.28	1.19	0.93	0.86	46.75	46.00	43.34	38.05	36.08	9.40	9.80	9.86	10.22	10.45
T_6	1.20	1.11	0.99	0.88	0.81	41.40	38.11	34.08	26.16	23.57	9.33	9.99	10.10	10.64	10.85
T_7	1.27	1.19	0.98	0.88	0.83	48.67	45.67	35.92	29.08	25.81	9.53	9.96	10.35	10.50	10.73
T_8	1.35	1.18	1.03	0.89	0.78	35.04	33.33	25.81	20.56	18.61	9.67	9.91	9.99	10.60	10.90
T_9	1.13	1.07	0.93	0.82	0.77	38.69	36.44	31.42	26.91	25.39	9.86	10.32	10.58	10.66	11.03
F Test	NS	S	S	S	S	S	S	S	S	S	S	NS	S	S	S
SE (m)	0.02	0.02	0.02	0.07	0.04	1.58	2.09	1.48	1.21	0.85	0.18	0.19	0.16	0.14	0.20
CD at 5%	0.05	0.11	0.59	0.29	0.18	32.37	27.25	51.32	61.95	105.14	1.26	0.22	1.18	0.73	0.76

Table 3. Effect of different packaging materials on titrable acidity, pH and Ascorbic acid

Treatment	Titrable Acidity (%)					pH					Ascorbic Acid (mg/100g)				
	0DAP	6DAP	12DAP	18DAP	24DAP	0DAP	6DAP	12DAP	18DAP	24DAP	0DAP	6DAP	12DAP	18DAP	24DAP
T_1	1.02	0.93	0.89	0.84	0.74	4.14	4.16	4.32	4.39	4.48	24.56	22.69	19.38	16.60	14.43
T_2	1.02	0.93	0.90	0.85	0.81	3.63	3.75	3.86	4.2	4.25	23.77	22.28	20.39	17.62	17.09
T_3	1.02	0.92	0.86	0.83	0.78	3.69	3.85	3.88	4.07	4.19	23.64	22.81	18.71	18.36	15.56
T_4	1.03	0.93	0.92	0.88	0.85	3.64	3.78	3.91	3.94	4.09	23.71	22.37	21.40	19.61	17.30
T_5	1.03	0.98	0.94	0.92	0.89	3.52	3.57	3.64	3.97	4.02	24.42	23.13	21.47	19.81	17.89
T_6	1.02	0.93	0.87	0.84	0.79	3.77	3.79	4.07	4.22	4.44	23.80	22.59	19.33	17.71	16.12
T_7	1.03	0.91	0.86	0.83	0.80	3.78	3.88	3.95	4.13	4.19	24.28	23.63	19.67	15.87	14.51
T_8	1.03	0.92	0.90	0.83	0.81	3.31	3.63	3.77	4.05	4.15	23.63	22.19	21.54	18.59	16.73
T_9	1.02	0.89	0.85	0.82	0.79	3.43	3.76	3.83	3.94	4.18	23.8	23.00	20.11	18.78	16.91
F Test	NS	NS	S	S	S	NS	NS	S	S	S	NS	NS	S	S	S
SE (m)	0.01	0.04	0.03	0.01	0.01	0.15	0.11	0.17	0.1	0.05	0.29	0.36	0.34	0.53	0.06
CD at 5%	0.01	0.02	0.11	0.05	0.09	0.26	0.25	0.65	0.39	0.43	0.45	0.59	3.26	3.42	29.04

Table 4. Effect of different packaging materials on total sugar, B:C ratio

Treatment	Total Sugar					B:C Ratio
	0 DAP	6 DAP	12 DAP	18 DAP	24 DAP	
T_1	4.85	5.04	5.45	5.73	5.75	0.06
T_2	4.81	5.16	5.36	5.68	6.14	0.36
T_3	4.84	4.99	5.40	5.92	6.41	0.61
T_4	5.25	5.48	5.75	6.23	6.47	1.81
T_5	4.72	4.97	5.50	6.12	6.49	2.39
T_6	4.80	5.09	5.46	5.90	6.37	1.04
T_7	4.89	5.09	5.55	5.85	6.24	1.66
T_8	4.71	4.85	5.35	5.78	5.90	1.09
T_9	4.84	5.06	5.51	5.89	6.17	1.01
F Test	S	NS	S	S	S	
SE (m)	0.01	0.17	0.04	0.05	0.15	
CD at 5%	2.3	0.24	0.41	0.55	0.52	

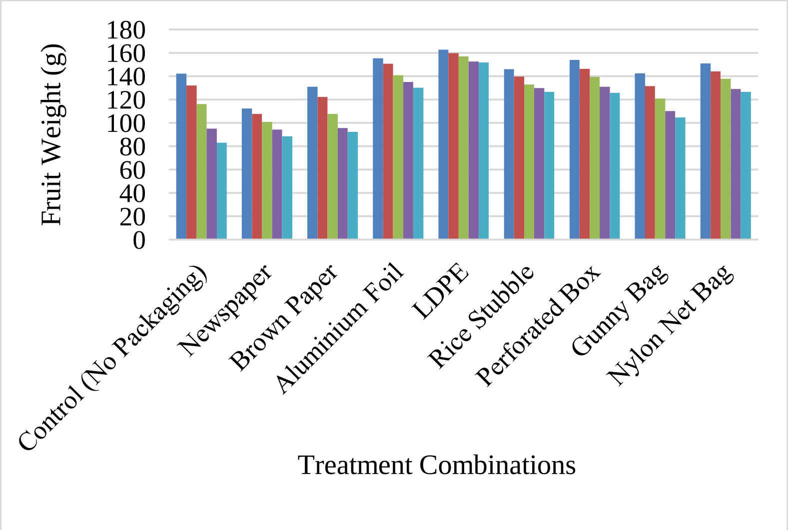

Fig. 2. Fruit Weight

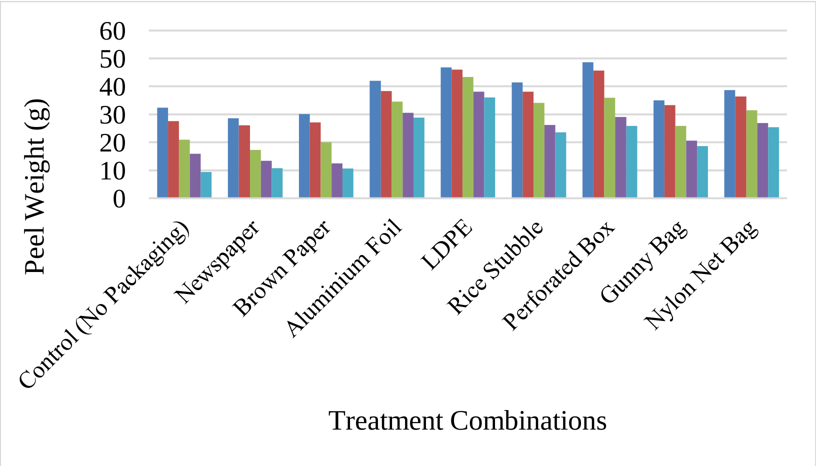

Fig. 3. Peel Weight

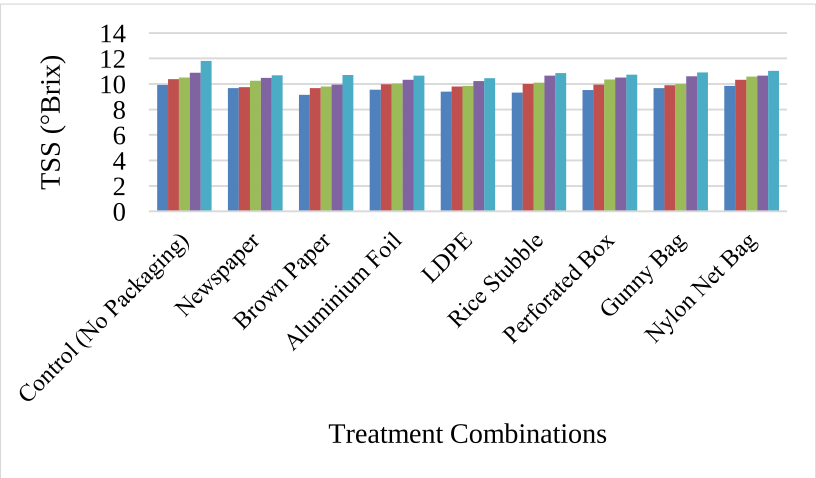

Fig. 4. TSS

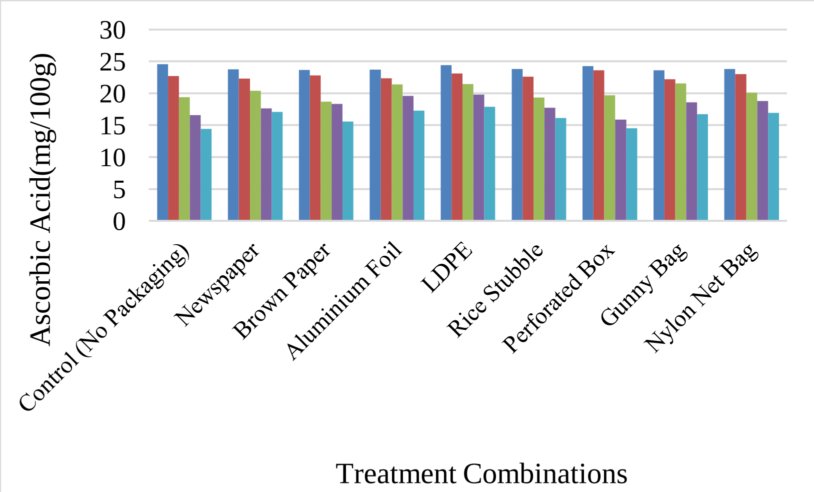

Fig. 5. Ascorbic Acid

Minimum TSS of the Kinnow fruit was observed in Treatment T_5 in which fruits were packed using LDPE where Initial Reading was (9.40 ° Brix), (9.80 ° Brix) 6 days, (9.86 ° Brix) 12 days, (10.22 ° Brix) 18 days, (10.45 ° Brix) 24 days, followed by T_4 (Aluminium Foil) where Initial reading was (9.55 ° Brix), (9.98 ° Brix) 6 Days, (10.03 ° Brix) 12 Days, (10.33 ° Brix) 18 Days, (10.65 ° Brix) 24 Days. Whereas the highest TSS found in Treatment T_1 Control in which the fruits are not packed with any packing material (9.93 ° Brix) Initial Reading, (10.37 ° Brix) 6days, (10.51 ° Brix) 12 days, (10.87 ° Brix) 18 days, (11.80 ° Brix) 24 days.

Maximum titrable acidity of Kinnow fruit was observed in Treatment T_5 in which fruits were packed by using LDPE (1.03 %) Initial day, (0.98 %) 6 days, (0.94 %) 12 days, (0.92 %) 18 days, (0.89 %) 24 days, followed by T_4 (Aluminium Foil) where Initial reading was (1.03 %) Initial day, (0.93 %) 6 days, (0.92 %) 12 days, (0.88 %) 18 days, (0.85 %) 24 days. Whereas the average low titrable acidity was found in Treatment T_1 fruits (1.02 %) 0 day, (0.93 %) 6 days, (0.89 %) 12 days, (0.84 %) 18 days, (0.74 %) 24 days.

pH of Kinnow fruit juice showed significant increase in pH. Minimum pH was found in Treatment T_5 fruits packed by using LDPE (3.52) Initial day, (3.57) 6days, (3.64) 12days, (3.97) 18days, (4.02) 24days, followed by T_4 (Aluminium Foil) where Initial reading was (3.64), (3.78) 6days, (3.91) 12days, (3.94) 18days, (4.09) 24days. Whereas the highest pH of kinnow fruit juice was found in fruits of Treatment T_1 (4.14) Initial Reading, (4.16) 6 days, (4.32) 12days, (4.39) 18days, (4.48) 24 days.

Ascorbic acid in Kinnow fruit showed the ideal decrease in ascorbic acid. Maximum Ascorbic Acid was found in Treatment T_5 where fruits were packed using LDPE (24.42 mg/100g) Initial Reading, (23.13 mg/100g) 6 days, (21.47 mg/100g) 12 days, (19.81 mg/100g) 18 days, (17.89 mg/100g) 24 days, followed by T_4 (Aluminium Foil) where Initial reading was (23.71 mg/100g), (22.37 mg/100g) 6 days, (21.40 mg/100g) 12 days, (19.61 mg/100g) 18 days, (17.30 mg/100g) 24 days. Whereas the minimum Ascorbic Acid was recorded in Treatment T_1 (Control) (24.56 mg/100g) Initial reading, (22.69 mg/100g) 6 days, (19.38 mg/100g) 12 days, (16.60 mg/100g) 18 days, (14.43 mg/100g) 24 days.

Total Sugars showed the significant increase of total sugars. Maximum total sugars were recorded in Treatment T_5 where fruits were packed using LDPE (4.72%) Initial reading, (4.97%) 6 days, (5.50%) 12 days, (6.12%) 18days, (6.49%) 24 days, followed by T_4 (Aluminium Foil) where Initial reading was (5.25 %), (5.48 %) 6 days, (5.75 %) 12 days, (6.23 %) 18 days, (6.47 %) 24 days. Whereas the minimum total sugar was found in Treatment T_1 where fruits were not packed using any packaging material (4.85%) Initial reading, (5.04%) 6day, (5.45%) 12 days, (5.73%) 18 days, (5.75%) 24 days.

Highest B:C ratio of 2.39 was found under treatment T_5 followed by T_4 with 1.81.

4. DISCUSSION

4.1 Fruit Weight (g))

There is a continuous decrease in the fruit weight during storage. Different packaging materials have significant effect on fruit weight. This might be due to the fact that in ambient condition during storage, the moisture loss through respiration and transpiration affect the fruit weight eventually and fruits becomes unsalable as a result of shrinking. Similar results were obtained by Abdelrahman, A. O., El-Bassiouny, H. M., Mahmoud, A. A., & El-Samahy, S.K. [3]. The study found that the fruit weight reduce over time and use of low-density polyethylene bags can effectively reduce the loss of fruit weight in Kinnow.

4.2 Radial Diameter (mm)

Packaging materials and storage period significantly affected the kinnow fruits, this may be due to increase in fruit size with the increase in fruit radial diameter and fruit size decrease with radial diameter decrease. Same result was were obtained by Singh et al. [4] Patel et al. [5] and Jagtap et al. [6] and the study found that the use of low-density polyethylene bags is effective in reducing radial diameter.

4.3 Polar Diameter (mm)

The Polar Diameter of the fruits had a decline trend during storage. It is clear by data of polar diameter that the highest value of polar diameter was found in T_5 and lowest in T_1. This might be due to the fact that in ambient condition during storage, the moisture loss through respiration and transpiration affected Polar diameter and cause shrinkage. The similar result was also reported by Bangulzai et al. [7] the study was carried out on sweet orange and grapefruit it found that the polar diameter of fruit reduce over time.

4.4 Specific Gravity

Specific gravity was significantly affected by packaging material and storage period. The changes are due to shrinkage of fruits over a period of time under extended storage period. The specific gravity value of citrus, carrot and orange juice, pineapple and coconut juice and mango juice was 1.021, 1.033, 1.029 and 1.037 respectively, recorded by Gbarakoro et al. [8]. Egwim et al. [9] revealed that the density of fruits decreases with storability. Decrease in specific gravity with increase in storage period was due to degradation of structural polysaccharides which resulted in decrease of pulp concentration.

4.5 Peel Weight (g)

With the advancement of storage period, peel weight of kinnow fruit decrease continuously. It may be due to the reason that most of the water is lost from peel tissue moisture loss primarily affects the appearance of the fruit. The consequences of peel moisture loss are shrinkage, softening, shriveling and deformation of the fruit. Desiccation of peel is one of the most important causes of loss of commercial value of kinnow fruits. Similar results were obtained by Ahmad et al. [10] and Kaushik et al. (2016). The study found that the LDPE bags reduced the weight loss and maintained the quality of the fruit peel during storage.

4.6 TSS (°Brix)

The TSS of fruits increased in various packaging materials (T_1 to T_9) with the advancement of storage period. The increase in total soluble solids with prolongation of storage period may probably be due to increased hydrolysis of polysaccharides and concentration of juice due to dehydration. At the end of storage maximum TSS was recorded in control fruits. It may be due to maximum water loss in these fruits. Similar results were obtained by Artes et al. [11] and Padilla et al. [12]. The study was conducted on Valencia oranges and Navel oranges respectively. The authors found that packaging with perforated LDPE bags maintained good TSS values compared to other packaging materials during storage.

4.7 Titrable Acidity (%)

The acidity of Kinnow fruit showed a linear declining trend with advancement of storage period. The progressive reduction in the acidity with advancement of storage period might be due to the increased catabolism of organic acids present in fruit through the process of respiration. The decrease in titratable acids during storage may be attributed to utilization of organic acid in pyruvate decarboxylation reaction occurring during the ripening process of fruits. The result of study was in accordance with Narayana et al. [13] and Thakur et al. [14] they observed that fruits had decreasing trend in titrable acidity with an increase in storage duration Bhat et al. [15] also observed a declining trend of acidity in kinnow fruits during ambient storage as Similar results were reported Attri et al. [16] where titrable acidity decreased with increase in the period of storage.

4.8 Ph

It is revealed that the pH of Kinnow juice was significantly increased during all storage periods under ambient condition. The maximum pH was reported at 24 days. The increase in pH during storage was accompanied with decrease in acidity of juice and is in conformity with the findings of Rehman et al. (2014) on study the storage stability of fruit juice concentrates. Similar results were also obtained by Cheema et al. [17] Ben-Amor et al. [18] and Liu et al. [19], the research was carried out on Citrus sinensis and Citrus reticulata Blanco respectively. The authors found that packaging with LDPE bags maintained a lower pH compared to other packaging materials during storage.

4.9 Ascorbic Acid

The ascorbic acid content showed a general declining trend in all treatments during storage period. However, the decrease was more pronounced under ambient condition. Guava cv. L-49 packed in polyethylene bags has 50% loss of vitamin C within 5 days except 300 gauge polybags which retained higher ascorbic acid even after 10 days (Khedkar et al. [20]). The slow degradation rate 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 Sozzi et al. [21] and Kudachikar et al. [22] the research was carried out on lemon and banana fruit respectively. They found that the ascorbic acid content was better maintained when fruits were packaged in a low-density polyethylene (LDPE) bag.

4.10 Total Sugars

Among the different packaging material and storage period treatments, the fruit under the T_5 (Fruits packed in LDPE) had highest positive value for total sugars at 24 days of storage period. Increase in temperature decrease in acid level and increase in sugar content (Benjamin et al. [23]). The maximum value for total sugars might be due to conversion of polysaccharides into soluble sugars, dehydration and transformation of certain cell wall materials like hemicelluloses and pectins and also due to decrease in ascorbic acid content. The results are in line with the findings of Santos et al. [24], Kumar et al. [25] and Navarro et al. [26], the research was carried out on citrus fruits and authors found out that LDPE packaging was generally more effective in preserving the total sugars content compared to PP and PET packaging.

5. CONCLUSION

From the present investigation it is concluded that effect of Treatment T_5 i.e. LDPE was found to be best, in terms of physico-chemical attributes weight (g), radial diameter (mm), polar diameter (mm), specific gravity (g/m^3), peel weight (g), total soluble solids (°Brix), titrable acidity (%), ascorbic acid (mg/100g), pH, total sugars (%). From the economics point of view, Highest B:C ratio of 2.39 was found in treatment T_5.

6. FUTURE SCOPE

Importance of Post-harvest technology lies in the fact that it has the capability to meet food requirement of growing population by eliminating losses making more nutritive food items from raw commodities by proper processing and fortification. Post-harvest technology has potential to create rural industries. India, where 80 percent people live in the villages and 70 percent of them depend on agriculture has experienced that the process of industrialization has shifted the food, feed and fibre industries to urban areas. The farmer whose role has been reduced to producer can be transformed into producer cum processor and thus getting more dividends for hard labour, input, kind of risk taken and generating resource for socio-economic advancement keeping pace with the modern times.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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