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INFLUENCE OF DIFFERENT PACKAGING MATERIALS ON THE SHELF LIFE OF SAPOTA (*ACHARUS ZAPOTA* L.)

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ABSTRACT

Sapota (*Acharus zapota* L.) is a tropical crop, contains 15-20% digestible sugar and an adequate amount of protein, fat, fiber, and minerals Ca, P, and Fe. It is tasty and often served as a dessert fruit, its pulp is sweeter and melting. Sapota fruits are extremely perishable and are typically packaged in gunny bags for storage. In this context, an experiment was conducted in Department of Horticulture, School of Agriculture, ITM University, Gwalior, where different types of packaging materials like Aluminum foil, Nylon bag, Cling film, Brown paper, Tissue paper, HDPE, Banana Leaf, CFB, Rice husk and Paddy Straw were used for packaging of sapota fruit to access the effect of packaging material on quality, shelf life and storability of sapota fruit including control. Results showed that packaging of fruits with the Aluminum foil was found overall best for sapota fruit quality and extension of shelf life during storage. However, HDPE and cling film were also found to be beneficial next to aluminum foil for better physical, physiological and quality related traits of sapota fruits when stored up-to 6 days of storage.
***Keywords*:** Chikoo, packaging material, perishable, shelf life, storability.

Introduction

Sapota (*Acharus zapota* L.) or *Manilkara achras* (Mill). Fosberg is a synonym for chiku, a long-lived, evergreen tree of the sapotaceae or 'naseberry family' that evolved in Southern Mexico, Central America, and the West Indies. India is the world's greatest producer of sapota; however, it is considered a minor crop in India. It is farmed commercially in Maharashtra, Gujarat, Tamil Nadu, Andhra Pradesh, West Bengal, Uttar Pradesh, Punjab, and Haryana (Pratap *et al.*, 2017). The fundamental chromosomal number is 13 (2n=26). According to NHB statistics, the fruit contains 15-20% digestible sugar and an adequate amount of protein, fat, fiber, and minerals Ca, P, and Fe. Sapota, a tropical crop, may be cultivated from sea level to 1200 meters above M.S.L. The coastal climate is ideal for its cultivation. It is a tropical fruit that prefers warm and humid conditions (>70%RH). It grows well at elevations of up to 1,000 meters, although a coastal environment is best for sapota growth. Sapota cultivation is best suited to temperatures ranging from 10-38°C with annual rainfall of 1250-2500 mm, as it blossoms and fruits all year. Temperatures over 43°C cause floral decline (according to NHB). The acreage and yield of sapota in India in 2022-23 were 73 thousand hectares and 875 thousand metric tons, respectively. In MP, the area and output for 2022-23 are 0.39 thousand hectares and 6.76 thousand metric tons. (Anonymous, 2024).

When completely mature, sapota is tasty and often served as a dessert fruit. Its pulp is sweeter and melting; while the pulp is often consumed, the fruit skin may also be consumed since it has more nourishment than the pulp. It is a table fruit that may be consumed fresh or processed into goods such as sapota leather, wine, and dried sapota. The seeds are reported to have diuretic qualities. Sapota is a climacteric fruit that shows a dramatic increase in respiration after harvesting. The sapota fruit is very perishable and cannot be stored for more than five days due to fast metabolic activity. Sapota suffers severe post-harvest losses to the range of 25-40% in India (NHB).

Sapodilla is a high-calorie fruit (100g has 83 calories), with similar calories to sweet potatoes and bananas. Furthermore, it contains a high concentration of dietary fiber (5.6 g/100 g), which helps with constipation. People in India utilized it for its antibacterial and antiviral effects. It promotes general health since it contains a variety of nutrients.

Packaging is critical in the handling and marketing of perishable fruits because it reduces losses during storage, transit, and marketing. Packaging is one strategy used to improve the shelf life of fruits. Furthermore, fruit packaging is an important technology in meeting the growing need for practicality, freshness, shelf life, safety, and security in fruits and other goods. Fresh fruit packaging plays a significant role in decreasing waste. Packaging protects against mechanical damage, undesired physiological alterations, and pathological degeneration during storage. Fruits are transported and stored in a variety of containers, including corrugated fiber board (CFB) boxes, hardwood boxes, and bamboo baskets. The CFB box has various advantages, such being lightweight, causing fewer injuries, being easier to handle and print, improving product image, lowering freight costs, and being made from inexpensive wood as well as plant cellulose waste while maintaining their appeal. Sapota fruits are extremely perishable and are typically packaged in gunny bags for storage. In this context, a study was conducted to study the Influence of different Packaging materials on the quality, shelf Life and storability of Sapota.

Material and Methods

Location of Experiment

Experiment was conducted in the Laboratory of Department of Horticulture, School of Agriculture, ITM University, Gwalior, MP, India during 2023-24.

Experimental Details

The mature, uniform size and disease & pest free high quality graded sapota were used for the study. Different types of packaging / Cushioning materials like, Aluminum foil, Nylon bag, Cling film, Brown paper, Tissue paper, HDPE, Banana Leaf, CFB, Rice husk and Paddy Straw were used for packaging of sapota fruits along with the control and replicated three times. For the experiments fruits were procured from the local market, however similar and uniform sapota fruits were taken for the study and treatment applications on them. Initial physical and biochemical observations of the fruits were taken before application of treatments. The subsequent observations were recorded for the fruits at two days interval from application of treatments *i.e.,* on 2nd day, 4th day and 6rd day.

Physico-Biochemical analysis

Physical parameters of fruit

The fruits subjected to different treatments were weighed and their weights were expressed in grams (g). The lengths of different fruits *i.e.,* polar and equatorial diameter were measured using a Vernier calliper and expressed in millimeter (mm). The volume of fruit was recorded by water displacement method with the help of measuring cylinder and was expressed in cubic centimeters. The fruit's specific gravity was measured by dividing its weight by volume. The fruit firmness was taken by using penetrometer. Physiological loss in weight was expressed in percentage. To measure physiological loss in weight, fruits were weighted on initial, 2nd, 4th and 6th days of storage with the help of an electronic weighing balance. It was calculated by using the following formula.

$$\text{PLW}(\%) = \frac{\text{Fruit weight}(g)\text{on ith day}}{\text{Initial fruit weight}(g)} \times 100$$

Biochemical Parameters

The pH of the fruit pulp was determined by using a digital pH meter (Cyber pH 14 L). Fruits were crushed well to form a homogenized sample and then the juice was extracted through muslin cloth. The extract was used for determination of T.S.S. in ^{0}Brix by digital refractometer (Erma, Japan). An estimation of acidity was followed by the method of Rangana (2000) by titrating the sample with NaOH using phenolphthalein indicator and calculated as below:

$$\text{Acidity\%} = \frac{\text{Titre value X Normality of NaoH X Volume made up X Eq.Wt.of acid}}{\text{Volume of sample taken for estimation X Wt.of Sampletaken X 1000}}$$

TSS: acid ratio was calculated by the following formula:

$$\text{TSS: acid ratio} = \frac{\text{TSS}}{\text{Acidity}}$$

Sugars were determined by the method of Lane and Eynon as described by Ranganna (1986).

Statistical Analysis

Following the guidance of Panse and Sukhatme (1985), the "Analysis of Variance" for Completely Randomized Design was employed to analyze the data collected from the set of observations for each character. F-test was adopted to test the level of significance at 5 %. Standard error of difference (SE_d) and critical difference (CD) were calculated.

Results

Physical parameters

Fruit initial observations

The physical parameters of fruits were observed initially before treatment application. The initial fruit weight was ranged from 72g to 75g, fruit volume 41 cm^3 to 46 cm^3, polar diameter 62mm to 65mm, equatorial diameter 53mm to 58mm, specific gravity 1.09 to 1.17 and fruit firmness 4.7 kg/cm^2 to 5.1 kg/cm^2 were observed.

Fruit weight (g)

The observations recorded for fruit weight whose data analysis is depicted in table 1, the data analysis revealed that data was significantly differed from each other. The maximum fruit weight was observed in T_1 at 2nd day (74.19 g), at 4th day (73.86 g), at 6th day (71.24g). The minimum fruit weight was recorded in control that is T_0 for all days. T_1 was also found significantly different from all other treatments, however T_3 and T_6 were found at par with each other during storage.

Fruit volume (cm^3)

The data analysis is depicted in table 1, the data was found significant. The maximum fruit volume was observed in T_1 at 2nd day (45.57 cm^3), at 4th day (45.37 cm^3), at 6th day (43.76 cm^3). The minimum fruit volume was recorded in control that is T0 for all days. T_1 was also found significantly different from all other treatments for 4th and 6th day, while T_3 and T_6 were equivalent with each other during all days of storage.

Polar diameter (mm)

The data is shown in table 2 which was found remarkably differed. The largest polar diameter was observed in T_1 at 2nd day (63.46 mm), at 4th day (63.13 mm), at 6th day (60.51 mm). The lowest fruit diameter was recorded in control that is T_0 for all days. Same trend was there for polar diameter as T_1 was remarkably differed from all other treatments, while T_3 and T_6 were equivalent with each other during all days of storage.

Equatorial diameter (mm)

The observations recorded for equatorial diameter whose data analysis is shown in table 2. the data analysis revealed that observations are remarkably differed from each other. The largest equatorial diameter was observed in T_1 at 2nd day (56.79 mm), at 4th day (56.46 mm), at 6th day (53.84 mm). The lowest equatorial diameter was recorded in control that is T0 for all days. Similar trend was there for equatorial diameter as T_1 was remarkably differed from all other treatments, while T_3 and T_6 were equivalent with each other during all days of storage.

Specific gravity

The data analysis for specific gravity is depicted in table 1, and the data recoded was found dissimilar from each other. The highest specific gravity was observed in T_1 and T_6 at 2nd day (1.18 g/cm^3), T_1 at 4th day (1.13 g/cm^3), 6th day (1.09 g/cm^3). The lowest specific gravity was recorded in control that is T_0 and T_{10} for all days. T_1 was also found at par with T_6 for all days of storage for the specific gravity.

Fruit firmness (kg/cm^2)

The data analysis on fruit firmness is depicted in table 2, revealing that it was remarkably differed from each other. The maximum fruit firmness was observed in T_1 at 2nd day (5.04 Kg/cm^2), at 4th day (4.86 Kg/cm^2), at 6th day (4.66 Kg/cm^2), while T_{10} at 12th day (3.98 Kg/cm^2). The minimum fruit firmness was recorded in control that is T_0 for all days. For fruit firmness T_1 was significantly dissimilar from all other treatment and T_6 was not at par with T_3 for 2nd and 6th day of storage.

Physiological Loss of Weight (%)

The data recorded on physiological weight loss whose analysis is shown in table 3, the data was significant. The minimum loss of physiological weight was observed in T_1 at 2nd day (0.65%) at 4th day (1.52%)' 6th day (5.01%). The maximum physiological loss of weight was recorded in control that is T_0 for all days. T_1 was significantly dissimilar with all other treatments for PLW and also T_6 & T_3 were found equivalent to each other.

Table 1 : Effect of different packaging materials on fruit weight (g), volume (cm^3) and specific gravity

Treatments	Fruit Weight (g)			Fruit Volume (cm^3)			Specific gravity		
	2nd Day	4th Day	6th Day	2nd Day	4th Day	6th Day	2nd Day	4th Day	6th Day
T0 (Control)	70.78	67.42	60.83	43.48	41.41	37.36	1.10	1.08	1.00
T1 (Aluminium foil)	74.19	73.86	71.24	45.57	45.37	43.76	1.18	1.13	1.09

T2 (Nylon bag)	68.84	67.10	59.90	42.28	41.21	36.80	1.16	1.11	1.05
T3 (Cling film)	71.44	70.27	68.06	44.48	43.51	40.89	1.16	1.08	1.02
T4 (Brown paper)	65.53	62.43	56.83	40.25	38.35	34.91	1.11	1.04	0.98
T5 (Tissue paper)	67.76	64.55	58.30	41.62	39.65	35.81	1.10	1.01	0.95
T6 (HDPE)	72.24	70.76	68.27	44.61	43.68	41.22	1.18	1.10	1.05
T7 (Banana leafs)	70.27	67.75	61.40	43.16	41.61	37.71	1.10	1.04	0.99
T8 (CFB boxes)	72.45	69.59	67.07	44.50	42.74	41.61	1.06	1.05	1.01
T9 (Rice husk)	66.14	63.89	58.56	40.63	39.24	35.97	1.09	1.01	0.95
T10 (Paper straw)	73.92	70.15	66.52	45.41	43.09	40.86	1.11	1.08	1.00
SE(m)±	0.41	0.44	0.38	0.42	0.42	0.44	0.02	0.02	0.02
C.D. (5%)	1.21	1.30	1.12	1.23	1.22	1.28	0.05	0.06	0.06

Table 2 : Effect of different packaging materials on polar and equatorial diameter (mm) and fruit firmness (kg/cm^2)

Treatments	Polar diameter (mm)			Equatorial diameter (mm)			Fruit firmness (Kg/cm^2)		
	2nd Day	4th Day	6th Day	2nd Day	4th Day	6th Day	2nd Day	4th Day	6th Day
T0 (Control)	60.05	56.69	50.10	53.38	50.02	43.43	4.60	4.15	3.75
T1 (Aluminium foil)	63.46	63.13	60.51	56.79	56.46	53.84	5.04	4.86	4.66
T2 (Nylon bag)	58.11	56.37	49.17	51.44	49.70	42.50	4.58	4.09	3.75
T3 (Cling film)	61.05	60.19	56.19	54.76	53.02	50.44	4.73	4.56	4.19
T4 (Brown paper)	54.80	51.70	46.10	48.13	45.03	39.43	4.26	3.88	3.60
T5 (Tissue paper)	57.03	53.82	47.57	50.36	47.15	40.90	4.40	3.98	3.65
T6 (HDPE)	61.51	60.03	56.38	54.84	53.36	50.61	4.83	4.58	4.33
T7 (Banana leafs)	59.54	57.02	50.67	52.87	50.35	44.00	4.62	4.19	3.85
T8 (CFB boxes)	61.72	58.86	57.00	55.05	52.19	50.33	4.75	4.62	4.11
T9 (Rice husk)	55.41	53.16	47.83	48.74	46.49	41.16	4.36	4.00	3.73
T10 (Paper straw)	63.19	59.42	55.79	56.52	52.75	49.12	4.79	4.54	4.03
SE(m)±	0.40	0.40	0.40	0.41	0.41	0.41	0.02	0.02	0.02
C.D. (5%)	1.17	1.18	1.19	1.19	1.19	1.21	0.06	0.07	0.06

Biochemical parameters:

Fruit initial observations

The biochemical parameters of fruits were observed initially before treatment application. The initial fruit TSS were ranged from 19.1 °B to 19.8 °B, pH 5.3 to 5.5, titratable acidity 0.14% to 0.15%, total sugar 9.7 % to 10.2 %, reducing sugar 5.7 % to 6.0 %, non-reducing sugar 4.2 % to 4.0 % and TSS acid ratio 132.3 to 135.7 were observed.

Total Soluble Solids (TSS) (°B)

The data for TSS is presented in table 3 and it confirmed that the data was significant. The TSS recorded in sapota fruit from 2nd day to 6th day of storage, and data clearly showed that least changes in TSS were observed in T_1 (20.25°B, 21.87°B, 20.31°B) followed by T_6 (20.12°B, 21.81°B, 19.83°B) and T_3 (20.28°B, 22.71°B, 20.20°B) at 2nd, 4th and 6th day respectively. However, treatment T_1, T_6 and T_3 were found statistically equivalent to each other for TSS during storage.

pH

The data recorded on pH whose analysis is shown in table 3, the data was significant. The maximum pH was observed in T_9 at 2nd day (5.95), T_8 at 4th day (5.91), T_9 at 6th day (6.28). The minimum pH was recorded in control that is T_0 for 2nd day (5.67), T_7 at 4th day (5.74) and T_6 at 6th day (5.77). The pH was least changed in T_1 followed by T_6 and T_3 respectively from 2nd day to 6th day of storage. Similar trend was seen in pH as T_1, T_6 and T_3 were found statistically at par with each other during storage.

Titratable acidity

The data analysis on titratable acidity is depicted in table 4, revealing that it was remarkably differed from each other. The maximum titratable acidity was observed in T_1 at 2nd day (0.15), subsequently T_1 and T_6 at 4th day (0.14), T_1 at 6th day (0.13) . The minimum titratable acidity was recorded in T_8 and T_9 at 2nd day (0.12), T_0, T_9 and T_{10} at 4th day (0.10) and T_0 ,T_8, T_9 and T_{10} at 6th day (0.08). However, the titratable acidity was minimally changed in T_1 followed by T_6 and T_3

respectively from 2^{nd} day to 6^{th} day of storage as compared to other treatments. Similar to TSS and pH T_1, T_6 and T_3 were found statistically at par with each for titratable acidity other during storage.

Table 3: Effect of different packaging materials on physiological loss of weight (%), TSS (°B) and pH

Treatments	Physiological loss of weight (%)			TSS (degree Brix)			pH		
	2nd Day	4th Day	6th Day	2nd Day	4th Day	6th Day	2nd Day	4th Day	6th Day
T0 (Control)	3.42	8.01	17.00	19.42	23.09	20.63	5.67	5.88	5.95
T1 (Aluminium foil)	0.65	1.52	5.01	20.25	21.87	20.31	5.80	5.81	5.84
T2 (Nylon bag)	2.33	4.80	15.00	20.13	22.71	20.07	5.73	5.76	5.83
T3 (Cling film)	0.88	2.89	8.02	20.28	22.08	20.20	5.81	5.84	5.87
T4 (Brown paper)	1.99	6.62	15.00	20.10	22.35	20.15	5.70	5.74	5.83
T5 (Tissue paper)	2.39	7.02	16.02	19.83	22.54	20.34	5.77	5.81	5.87
T6 (HDPE)	0.73	2.68	7.01	20.12	21.81	19.83	5.72	5.74	5.77
T7 (Banana leafs)	1.99	4.01	13.01	19.50	22.71	20.07	5.73	5.76	5.83
T8 (CFB boxes)	2.67	6.51	9.00	20.78	22.90	20.80	5.78	5.91	5.96
T9 (Rice husk)	1.56	4.00	12.00	19.83	22.90	20.42	5.95	6.22	6.28
T10 (Paper straw)	2.21	7.21	12.01	20.18	22.54	20.34	5.85	5.89	5.95
SE(m)±	0.05	0.38	0.42	0.37	0.40	0.36	0.42	0.40	0.39
C.D. (5%)	0.15	1.11	1.24	1.09	1.16	1.05	1.24	1.17	1.14

Table 4: Effect of different packaging materials on titratable acidity (%) and TSS: Acid ratio

Treatments	Titratable acidity (%)			TSS: Acid ratio		
	2nd Day	4th Day	6th Day	2nd Day	4th Day	6th Day
T0 (Control)	0.13	0.10	0.08	176.01	266.91	389.51
T1 (Aluminum foil)	0.15	0.14	0.13	143.64	167.08	168.89
T2 (Nylon bag)	0.13	0.11	0.09	161.71	223.44	249.44
T3 (Cling film)	0.13	0.11	0.09	160.86	209.53	241.07
T4 (Brown paper)	0.14	0.11	0.09	146.35	203.20	225.80
T5 (Tissue paper)	0.13	0.12	0.10	151.68	196.42	208.31
T6 (HDPE)	0.15	0.14	0.12	139.38	162.75	174.60
T7 (Banana leafs)	0.13	0.11	0.10	148.41	204.72	212.85
T8 (CFB boxes)	0.12	0.10	0.08	174.75	233.67	293.68
T9 (Rice husk)	0.12	0.10	0.08	179.78	257.42	303.77
T10 (Paper straw)	0.13	0.11	0.08	152.35	215.76	248.67
SE(m)±	0.02	0.02	0.02	20.55	33.39	62.02
C.D. (5%)	0.06	0.05	0.06	60.26	97.94	181.92

Total Sugar

The data analysis for specific gravity is depicted in table 5, and the data recoded was found dissimilar from each other. The highest total sugar was observed in T_8 at 2^{nd} day (11.25), T_0 at 4^{th} day (13.56) and (11.63) at 6^{th} day. The lowest total sugar was recorded in control that is T_0 (9.89) at 2^{nd} day, T_1 (11.74) at 4^{th} day, T_3 at 6^{th} day. The same trend was seen in total sugar content and it was minimally changed in T_1 followed by T_6 and T_3 respectively from 2^{nd} day to 6^{th} day of storage as compared to other treatments. Same trend was also observed with total sugar that T_1, T_6 and T_3 were found statistically equivalent to each other during storage.

Reducing Sugar

The data analysis for specific gravity is depicted in table 5, and the data recoded was found dissimilar from each other. The highest reducing sugar was observed in T_8 at 2^{nd} day (7.03), T_0 at 4^{th} day (9.34), T_0 (7.41) 6^{th} day. The lowest total sugar was recorded in control that is T_6 and T_7 (5.75) at 2^{nd} day, T_1 (7.29) at 4^{th} day, T_1 (5.96) at 6^{th} day. Reducing sugar content was also least changed in T_1 followed by T_6 and T_3 respectively from 2^{nd} day to 6^{th} day of storage as compared to other treatments which confirms the stability for fruit shelf life under such treatments. T_1, T_6 and T_3 were found statistically equivalent to each other during storage.

Non-Reducing Sugar

The data analysis for specific gravity is depicted in table 5, and the data recoded was found dissimilar from each other. The highest non-reducing sugar was observed in T_8 at 2nd day (7.19), T_0 at 4th day (9.50) and at 6th day (7.57). The lowest total sugar was recorded in control that is T_0 at 2nd day (5.83), T_1 at 4th day (7.51) and at 6th day (6.12). Treatment T_1, T_6 and T_3 were performed best as the minimum changes in non-reducing sugars was observed in those treatments during storage period.

TSS Acid Ratio

The data for TSS acid ratio is depicted in table 4 and it confirmed that the data was significant. The TSS acid recorded during storage, which indicated that least changes were observed in T_1 (143.64, 167.08, 168.89) from 2nd day to 6th day of storage followed by T_6 (139.38, 162.75) at 2nd and 4th day and T_3 (160.86, 209.53) at 2nd and 4th respectively. Least changes in TSS acid ratio during storage were observed in T_1, T_6, T_7 and T_3. Treatment T_1, T_6 and T_3 were found at par with each other during storage.

Table 5 : Effect of different packaging materials on sugars (%)

Treatments	Reducing sugar (%)			Non-Reducing sugar (%)			Total Sugar (%)		
	2nd Day	4th Day	6th Day	2nd Day	4th Day	6th Day	2nd Day	4th Day	6th Day
T0 (Control)	5.67	9.34	7.41	5.83	9.50	7.57	9.89	13.56	11.63
T1 (Aluminium foil)	5.81	7.29	5.96	5.97	7.51	6.12	10.36	11.74	10.77
T2 (Nylon bag)	6.38	8.96	6.32	6.54	9.12	6.48	10.60	13.18	10.54
T3 (Cling film)	6.78	8.30	6.35	6.94	8.86	7.27	10.67	12.09	10.00
T4 (Brown paper)	6.35	8.60	6.40	6.51	8.76	6.56	10.57	12.82	10.62
T5 (Tissue paper)	6.08	8.79	6.59	6.24	8.95	6.75	10.30	13.01	10.81
T6 (HDPE)	5.75	7.70	5.97	5.91	7.61	6.13	10.07	12.01	10.86
T7 (Banana leafs)	5.75	8.96	6.32	5.91	9.12	6.48	9.97	13.18	10.54
T8 (CFB boxes)	7.03	9.15	7.05	7.19	9.31	7.21	11.25	13.37	11.27
T9 (Rice husk)	6.08	9.15	6.67	6.24	9.31	6.83	10.30	13.37	10.56
T10 (Paper straw)	6.43	8.79	6.59	6.59	8.95	6.75	10.65	13.01	10.48
SE(m)±	0.42	0.41	0.41	0.42	0.42	0.41	0.38	0.40	0.35
C.D. (5%)	1.24	1.21	1.21	1.24	1.23	1.19	1.13	1.18	1.02

Discussion

Fruit Physical parameters

The fruit weight, volume and size of sapota fruit were found significantly highest under treatment Aluminum foil followed by HDPE and Cling film respectively as compared to the other treatments. Also, the physiological loss of weight of sapota fruit was also observed remarkably lowest under such treatment Aluminum foil followed by HDPE and Cling film which were also statistically equivalent. The possible reason for the best results for such packaging materials could be the lowest rate of respiration & evapotranspiration from the fruit surface in the aluminum foil and HDPE which reduced the loss in weight, volume and size of the fruit significantly as compared to the other treatments. Also, fruit weight loss was increased with increasing the storage period in all treatment, due to the evaporation loss, ripening and other metabolic processes which was comparatively low in aluminum foil, HDPE and cling film as compared to other treatments and control where maximum loss occurred due to unavailability of the packaging materials. Similar type of findings was also observed and reviewed by Awasarmal *et al.* (2011); Ankalagi *et al.* (2017); Seema *et al.,* (2021); Lamberti and Escher (2007); Pratap *et al.* (2017); Waskar *et al.* (1999).

The fruit firmness was recorded minimum under packaging material aluminum foil, HDPE, cling film respectively, the possible reason for this could be due to the minimal endo-polygalacturonase activity in such treatments which cause the lesser degradation of pectin component in the fruit. Also, the firmness decreased as advancement of storage period irrespective of treatments as due to the ripening process and change in cell wall polysaccharides. Results are in accordance with the findings of Seema *et al.,* (2021); Singh and

Narayana (1999); Lamberti and Escher (2007); Ankalagi *et al.* (2017a).

Fruit Biochemical parameters

The total soluble solids of sapota fruit initially increased at 4th day and then decreased on 6th day, also high TSS increment was observed under control while the TSS of sapota fruit was stable and least changes were seen under packaging material like aluminum foil, HDPE and cling film etc. The increase in TSS could be due to the respiration and ripening process underlying catabolic reactions, including conversion of starch and other polysaccharides into soluble forms of sugars. And during later stages it was seen decreased because of high rate of respiration and its further utilization in oxidation process through Krebs cycle (Wasker *et al.,* 1999; Ochel *et al.,* 1993; Salunkhe and Desai, 1995). The fruit under control recorded with higher TSS as compared to other treatment because of higher ripening and respiration under the absence of packaging material while TSS was stable under aluminum foil, HDPE etc. because of low respiration and catabolic process. Also, the TSS acid ratio of sapota fruits increased significantly with the storage time. But total soluble solids were initially increased and then decreased, also there was decrease in titratable acidity which was more compared to decrease in total soluble solids in the advance stages of storage period, resulted the TSS acid ratio increased. Similar observations were observed by the Awasarmal *et al.* (2011); Harshitha *et al,* (2020); Seema *et al.,* (2021); Lamberti and Escher (2007); Pratap *et al.* (2017).

The pH was found increased and titratable acidity was decreased with increasing storage period. Least changes in pH and titratable acidity were observed under packaging material aluminum foil, HDPE and cling film. Conversion of organic acids into sugars and its utilization during respiration could be the possible reason for decrease in titratable acidity and increase in pH with the storage time (Mudhe, 2006; Wasker *et al.,* 2005). The lower catabolic reaction could be the possible reason for best results under packaging material like aluminum foil, HDPE and cling film (Awasarmal *et al.*, 2011; Harshitha *et al.,* 2020; Seema *et al.,* 2021; Lamberti and Escher, 2007; Pratap *et al.* 2017; Zhi *et al.,* 2021).

The total sugars, reducing sugars and non-reducing sugars were initially increased from 2nd to 4th day and then decreased from 4th day to 6th day with the increase in storage period. While least changes in sugars were seen under packaging material aluminum foil, HDPE and cling film. The hydrolysis of starch into sugars and breakdown of complex organic metabolites into simple molecules was the reason for increase in the sugar content with storage time but the declination of sugars at advance storage period could be due to the completion of hydrolysis of starch, no more sugars were formed and also along with the organic acids they were utilized as substrate during respiration (Wills *et al.,* 1989; Banik *et al.,* 1988). The inherent property of the packaging material like aluminum foil, HDPE, cling film etc. acted as a medium to delay the ethylene production, ripening, respiration and catabolic processes, in result of that they found to be the best packaging material in current study. The results of current findings are confirmed by the findings of Awasarmal *et al.* (2011); Ankalagi *et al.* (2017b); Harshitha *et al.* (2020); Seema *et al.* (2021); Lamberti and Escher (2007); Pratap *et al.* (2017); Zhi *et al.* (2021).

Packaging material like aluminum foil, HDPE, cling film etc. acted as medium to prevent gaseous exchange, evapo-transpirational losses and suppressed respiration by accumulation of carbon-dioxide and partial depletion of oxygen. This delayed the ethylene liberation, ripening, respirational loss, and senescence of the fruit under such packaging materials by oxidizing ethylene to ethylene-glycol and poly-galacturonase activity. Higher level of CO_2 and lower oxygen minimized the rate of respiration as well in such kind of packaging materials (Harshitha *et al.,* 2020; Seema *et al.,* 2021; Lamberti and Escher, 2007; Pratap *et al.,* 2017; Zhi *et al.,* 2021).

Conclusion

From the above research findings, it was concluded that packaging of sapota fruit with the Aluminum foil was found effective for sapota fruit quality and shelf-life extension during storage. Although high density poly ethylene (HDPE) and cling film were also found better following aluminum foil for retaining better physical, physiological and quality related traits of sapota fruits when stored up-to 6 days of storage. Therefore, packaging of sapota fruits with Aluminum foil, HDPE and cling film can be beneficial for extending shelf life.

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Competing Interest

The authors declare no competing interests exists.

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