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**Srinu Banothu**  
Department of Fruit Science,  
College of Horticulture,  
SKLTGHU, Rajendranagar,  
Hyderabad. Telangana. India

**A Bhagwan**  
Department of Fruit Science,  
College of Horticulture,  
SKLTGHU, Rajendranagar,  
Hyderabad. Telangana. India

**Vena Joshi**  
Department of Fruit Science,  
College of Horticulture,  
SKLTGHU, Rajendranagar,  
Hyderabad. Telangana. India.

**Corresponding Author:**  
**Srinu Banothu**  
Department of Fruit Science,  
College of Horticulture,  
SKLTGHU, Rajendranagar,  
Hyderabad. Telangana. India

## Evaluates the influence of polypropylene (PP) packaging on the shelf life, physiological characteristics, and quality of sapota (cv. KALIPATTI) during storage

**Srinu Banothu, A Bhagwan and Vena Joshi**

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### Abstract

The present study evaluates the influence of polypropylene (PP) packaging on the shelf life, physiological characteristics, and quality of Sapota (cv. Kalipatti) during storage period. Sapota is a highly perishable tropical fruit, requiring effective post-harvest management techniques to minimize quality deterioration and extend marketable shelf life. This study explores the potential of polypropylene packaging as a modified atmospheric packaging (MAP) material to create an optimal microenvironment for storage. Key physiological parameters such as Weight loss, Firmness and Spoilage were analyzed, along with quality attributes including total soluble solids (TSS), titratable acidity, ascorbic acid content, and shelf life over the storage period.

Results demonstrated that polypropylene packaging effectively reduced moisture loss, maintained firmness, and delayed ripening by lowering the respiration rate and ethylene production. Fruits packed in 100 gauge polypropylene bags exhibited slower physiological changes, retaining higher levels of TSS and ascorbic acid, along with better texture and visual appeal compared to control fruits stored under ambient conditions. The polypropylene packaging extended the shelf life of Sapota (cv. Kalipatti) up to 14-16 days, whereas control fruits deteriorated within 7 to 9 days.

This study highlights polypropylene packaging as a cost-effective and practical solution for enhancing the post-harvest storage stability of Sapota (cv. Kalipatti). Further optimization of packaging design and perforation levels can improve gas exchange properties, making it an ideal choice for commercial storage and transportation of perishable fruits.

**Keywords:** Sapota, shelf life, firmness, polypropylene package and spoilage

### Introduction

Sapota (*Manilkara achras*), a major fruit crop in India, is valued for its high yield per unit area, year-round fruiting, and tolerance to salinity and drought. The fruit's sweet, nutritious pulp is consumed fresh or processed into products such as juice, sharbat, and halwa. In India, sapota occupies about 1,50,400 ha with a productivity of 8.23 t/ha, with Andhra Pradesh ranking third in production. Native to Tropical America, the evergreen tree can grow up to 20 m in height and bears fruits of varied shapes, rich in carbohydrates and tannins. Despite its economic importance, sapota suffers from rapid ripening and poor shelf life, leading to postharvest losses of 25-30%, contributing to the country's overall 35 - 40% wastage of fruits and vegetables due to improper handling.

Postharvest losses can be minimized through proper handling practices and a better understanding of the biochemical processes controlling fruit ripening and senescence. In most fruits, ripening is induced by ethylene biosynthesis via the pathway: L-methionine → S-adenosyl methionine (SAM) → 1-amino cyclopropane-1-carboxylic acid (ACC) → ethylene, with free radicals involved in the final step. As a climacteric fruit, sapota exhibits ethylene-dependent ripening and deteriorates quickly once the climacteric peak is reached. To extend shelf life, techniques such as cold storage, antioxidant treatments, and modified atmosphere packaging (MAP) have been studied. Storage at 15-20 °C and 85-90% relative humidity can maintain quality for 2 to 3 weeks, whereas excessively low temperatures can cause irreversible damage to the ripening process. Chemical dips, though effective, may leave residues that affect

consumer acceptance and export potential, making polypropylene-based MAP a safer alternative. During peak harvest seasons, when market glut is common, shelf life extension becomes vital to regulate supply, reduce microbial spoilage, and ensure better returns for growers.

## Materials and Methods

The experiment was carried out at Fruit Research Station Sangareddy, Medak, SKLTGHU, and Telalngana. The materials used and methods adopted during the course of investigation are presented under the following heads.

### Sapota cv. Kalipatti

The variety selected for carrying out the present investigation is sapota cv. Kalipatti. Fruits of sapota cv. Kalipatti were obtained from sapota orchard located at Agricultural Research Institute, Rajendranagar, Hyderabad were used for investigation. Kalipatti is one of the leading varieties with predominantly oval fruits of outstanding quality. The fruits are less seeded with sweet mellow, flesh of excellent quality with mild fragrance.

### Stage of harvest

Sapota fruits cv. Kalipatti were harvested at full maturity as judged by absence of green tissue or latex when scratched and smooth external surface with yellowish tinge intermixed with corky brown colour. Matured fruits of uniform size, firm, free from disease and injuries were selected and were brought to the laboratory. The fruits were cleaned with tap water and then allowed to dry in shade prior to imposition of the treatments.

### Polypropylene bags

Polypropylene bags of 100 and 150 gauge polypropylene bags of size 35 x 25 cm with or without 0.1% ventilation were used for packing of sapota fruits. Circular holes with 0.5 mm diameter were made to cover the 0.1 percent of the surface area of the polypropylene bags.

### Treatments details

#### Factor 1

**T<sub>1</sub>:** Fruits packed in polypropylene bags of 100 gauge without perforation

**T<sub>2</sub>:** Fruits packed in polypropylene bags of 100 gauge with 0.1% perforation

**T<sub>3</sub>:** Fruits packed in polypropylene bags of 150 gauge without perforation

**T<sub>4</sub>:** Fruits packed in polypropylene bags of 150 gauge with 0.1% perforation

**T<sub>5</sub>:** Control (Fruit without any packaging)

#### Factor 2

**D<sub>1</sub>:** Fruits stored at 15 °C for 15 days and then transferred to room temperature

**D<sub>2</sub>:** Fruits stored at 15 °C for 30 days and then transferred to room temperature

### Treatmental combinations

T<sub>1</sub>D<sub>1</sub>, T<sub>1</sub>D<sub>2</sub>, T<sub>2</sub>D<sub>1</sub>, T<sub>2</sub>D<sub>2</sub>, T<sub>3</sub>D<sub>1</sub>, T<sub>3</sub>D<sub>2</sub>, T<sub>4</sub>D<sub>1</sub>, T<sub>4</sub>D<sub>2</sub>, T<sub>5</sub>D<sub>1</sub>, T<sub>5</sub>D<sub>2</sub>

No. of treatment: 10

Replications: 3

No of units per replication: 5

No. of fruits per unit: 5

Design: Factorial Completely Randomized Design

## Physical parameters

### 1. Physiological loss in weight (%)

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

$$PLW (\%) = \frac{(\text{Initial weight} - \text{weight after storage})}{\text{Initial weight}} \times 100$$

### 2. Firmness (kg/cm<sup>2</sup>)

A table top penetrometer was used to record the firmness of the fruits and obtained direct readings in kg/cm<sup>2</sup>.

### 3. Spoilage (%)

The number of fruits spoiled in a replication was counted and expressed in percentage. The spoilage was determined based on the following visual observations.

1. Shrivelling of the fruit and hardening of the rind.
2. Fungal infection and subsequent rotting.

$$\text{Spoilage (\%)} = \frac{\text{Number of spoiled fruits}}{\text{Total number of fruits}} \times 100$$

### 4. Shelf life (Days)

The shelf life of fruits was determined by recording the number of days the fruits remained in good condition in storage. The stage where in more than 50 percent of the stored fruits became unfit for consumption was considered as end of shelf life in that particular treatment and expressed as mean number of days (Padmalatha, 1995).

## Physio-chemical parameters

### 5. Titrable acidity (%)

Ten grams of fruit pulp was taken and ground well and then transferred to volumetric flask. The volume was made up to 100 ml in volumetric flask. The contents were filtered through whatman No.1 filter paper. An aliquot of 10 ml was taken into conical flask to which 2-3 drops of phenolphthalein indicator was added and titrated against 0.1 N NaOH to a pink colour obtained which persists atleast for 15 seconds, as end point. (Ranganna, 1986).

Factor for acidity = one ml of N/NaOH = 0.0064g of the citric acid

### 6. TSS: acid ratio

TSS: acid ratio was calculated by dividing the TSS value by the acid value

### 7. Reducing sugars (%)

Reducing sugars were determined by the method of Lane and Eyon (AOAC, 1965). Ten grams of fruit pulp was taken and ground well and transferred to 250 ml volumetric flask, and the volume was made up. Two ml of lead acetate solution (45%) was added to the flask to precipitate colloidal matter and kept for 24 hour. Potassium oxalate (22%) of 2 ml was added in this solution to precipitate the lead acetate and the volume was made up to 250 ml using distilled water. The contents were then filtered through whatman No. 1 filter paper after testing a little of filtrate for its freedom from lead by adding a drop of potassium oxalate. Reducing sugars in the lead free solution was taken in burette and titrated against 10 ml of standard Fehling's

solution mixture of A and B (1: 1) using methylene blue as an indicator till the end point was indicated by the formation of brick red precipitate. The titration was carried out by keeping the Fehling's solution boiling on the heating mantle. The results were expressed as per cent reducing sugar.

### 8. Total sugars (%)

Total sugars were determined following the method described by Lane and Eyon (AOAC, 1965). A quantity of 50 ml lead free filtrate was taken in a 100 ml volumetric flask and to it 5 ml of concentrated HCl was added, mixed well and then kept for 24 hours at ambient temperature. Acid was then neutralized with NaOH using a drop of phenolphthalein as an indicator till the pink colour persisted for at least few seconds. The volume was then made up to 100 ml with distilled water. Total sugars were then estimated by taking this solution in a burette and titrating it against standard Fehling's solution mixture of A and B (1:1) using methylene blue as an indicator and taking brick red colour as an end point.

### Statistical analysis

The data were subjected to statistical analysis as per the procedure outlined by Panse and Sukhatme (1985)

## Results and Discussion

### Physiological Loss in Weight (%)

#### Initial Day

Sapota cv. Kalipatti stored at 15 °C for 30 days showed the highest PLW (5.54%), while 15-day storage resulted in the lowest (1.63%). Among packaging treatments, the untreated control had the highest PLW (5.35%), while 100-gauge polypropylene bags without perforation had the lowest (2.51%). The interaction between storage duration and packaging was significant, with the lowest PLW (1.20%) in 100-gauge bags and the highest (8.20%) in the untreated control.

#### Third Day (Ripe Stage)

On the third day (ripe stage), the treated fruits exhibited significant differences in PLW (Table 1). The highest PLW (6.52%) was recorded in fruits stored at 15 °C for 30 days and transferred to room temperature, irrespective of the packaging material. Conversely, the lowest PLW (2.64%) was observed in fruits packed in polypropylene bags and stored at 15 °C for 15 days before transfer to room temperature.

Among the polypropylene packaging treatments, the untreated control exhibited the highest PLW (6.70%), regardless of the storage duration. The lowest PLW (3.54%) was recorded in fruits packed in 100-gauge polypropylene bags without perforation, which was on par with those packed in 150-gauge polypropylene bags without perforation (3.88%).

The interaction between polypropylene bag treatments and storage duration was significant. Fruits stored at 15 °C for 30 days and transferred to room temperature showed higher PLW compared to those stored for 15 days, regardless of packaging. The highest PLW (9.10%) was recorded in the control, while the lowest PLW (1.98%) was observed in fruits packed in 100-gauge polypropylene bags without perforation.

### Progressive Changes in PLW

The progressive increase in PLW from the initial day to the end of the storage period at room temperature, following storage at 15 °C for 15 or 30 days, is presented in Table 1. The lowest mean PLW (1.50%) was observed in fruits packed in 100 gauge polypropylene bags without perforation, while the highest mean

PLW (8.66%) was recorded in the untreated control.

Fruits stored at 15 °C for 15 days and packed in 100 gauge polypropylene bags without perforation exhibited the lowest PLW (2.50%). In contrast, fruits stored at 15 °C for 30 days exhibited significantly higher PLW compared to those stored for 15 days, particularly on the third day (ripe stage).

The fruit packed in 100 or 150 gauge polypropylene bags without perforation has recorded significantly lower PLW on initial and 3<sup>rd</sup> day (ripe stage) after transfer to normal room temperature, irrespective of days of storage at 15 °C. The minimum PLW recorded in polypropylene bags could be due to low rate of respiration and transpiration. Kumbhar and Desai (1986) also reported similar reduction in PLW of sapota packed in polyethylene bags. The reduced rate of moisture loss in fruits packed in polythene bags (Philipose and Sathiyamorthy 1993) [6] has resulted in minimal PLW in polypropylene bags without perforation when compared to control in the present investigation.

### Firmness (kg/cm<sup>2</sup>)

Table.2 shows the effect of polypropylene packaging on sapota firmness at 15 °C. Fruits stored for 30 days had the lowest firmness (0.33), while those stored for 15 days showed significantly higher firmness (3.16), regardless of packaging type.

Fruits packed in 100-gauge polypropylene bags with 0.1% perforation showed significantly higher firmness (2.16), while control fruits had the lowest (0.65), regardless of storage duration. Interaction effects were also significant, with the highest firmness (4.30) in fruits stored at 15 °C for 15 days in 100-gauge bags, and the lowest (0.01) in control stored for 30 days.

#### Third Day (Ripe Stage)

Fruits stored for 15 days at 15 °C had higher firmness (1.38) than those stored for 30 days. Packaging in 100-gauge with 0.1% perforation maintained the highest firmness (1.25), while control had the lowest (0.06). The best result (2.50) was from fruits stored 15 days in 100-gauge bags, then transferred to room temperature.

### Overall Trend

Firmness decreased over time regardless of packaging. The highest firmness (3.40) was in fruits packed in 100-gauge bags after 15 days at 15 °C, while the lowest (0.01) was in control. On the sixth day, 100-gauge bags still maintained higher firmness (1.00).

The maintenance of higher firmness in polypropylene bags could be due to low rate of respiration and transpiration. Polythene bags helps in arresting the moisture loss and maintain turgidity tolerance. Kumbhar and Desai (1986) also reported similar increased in firmness of sapota packed in polyethylene bags. In control, lower firmness was recorded resulting from the exposure of fruit to atmosphere and concomitant increased and ripening process (Littiman, 1972) [5]. Fruit softening during ripening and concomitant decrease in firmness is attributed to increase solubilization of cell wall pectin by the action of pectin methyl esterase and polygalactouranase hydrolysis of starch to glucose in sapota (Selvaraj and Pal, 1984) [10].

### Spoilage (%)

Table.3. Lowest spoilage (21.80%) was recorded in fruits stored at 15 °C for 15 days, regardless of packaging. Highest spoilage (41.00%) occurred in control fruits. Among packaging

treatments, 100-gauge with 0.1% perforation showed the lowest spoilage (23.50%), followed by 150-gauge with 0.1% perforation (28.50%).

### Interaction Effects

Spoilage was higher in fruits stored for 30 days at 15 °C. The lowest spoilage (12.00%) was in 100-gauge with 0.1% perforation, and highest in control (42.00%).

### Third Day (Ripe Stage)

Spoilage increased in fruits stored for 30 days (47.60%) compared to 15 days (34.80%). Control fruits had the highest spoilage (50.50%), while 100-gauge with 0.1% perforation showed the lowest (35.50%).

**Table 1:** Effect of polypropylene packaging on physiological loss in weight (%) of sapota cv. Kalipatti during storage at room temperature after transferred from 15°C for 15 and 30 days.

| Treatments                    | Initial day                                 | 3 <sup>rd</sup> day(Ripe stage)             | Mean | 6 <sup>th</sup> day |
|-------------------------------|---------------------------------------------|---------------------------------------------|------|---------------------|
| T <sub>1</sub> D <sub>1</sub> | 1.20                                        | 1.98                                        | 1.59 | 3.40                |
| T <sub>2</sub> D <sub>1</sub> | 1.60                                        | 2.30                                        | 1.95 | 2.50                |
| T <sub>3</sub> D <sub>1</sub> | 1.35                                        | 2.06                                        | 1.70 | 3.71                |
| T <sub>4</sub> D <sub>1</sub> | 1.50                                        | 2.60                                        | 2.05 | 2.85                |
| T <sub>5</sub> D <sub>1</sub> | 2.50                                        | 4.30                                        | 3.40 | -                   |
| T <sub>1</sub> D <sub>2</sub> | 3.83                                        | 5.10                                        | 4.46 | -                   |
| T <sub>2</sub> D <sub>2</sub> | 5.25                                        | 6.20                                        | 5.72 | -                   |
| T <sub>3</sub> D <sub>2</sub> | 4.10                                        | 5.70                                        | 4.90 | -                   |
| T <sub>4</sub> D <sub>2</sub> | 6.33                                        | 6.50                                        | 6.41 | -                   |
| T <sub>5</sub> D <sub>2</sub> | 8.20                                        | 9.10                                        | 8.66 | -                   |
| Mean                          | 3.58                                        | 4.58                                        |      | -                   |
| For Days(D)                   | F-test S.Em±<br>CD at (0.05)<br>* 0.37 0.77 | F-test S.Em±<br>CD at (0.05)<br>* 0.20 0.43 |      |                     |
| Treatments                    | * 0.58 1.22                                 | * 0.33 0.68                                 |      |                     |
| For D× T                      | * 0.83 1.77                                 | * 0.46 0.97                                 |      |                     |

\*Significant at P=0.05% level; \*\* Significant at P = 0.01% level; NS- Non significant “—“Fruits not available for analysis, D<sub>1</sub>= 15 days, D<sub>2</sub> = 30 days T<sub>1</sub>= 100 gauge without perforation, T<sub>2</sub>=100 gauge with 0.1% perforation, T<sub>3</sub>= 100 gauge without perforation T<sub>4</sub>= 100 gauge with 0.1% perforation, T<sub>5</sub>= control (without packaging)

**Table 2:** Effect of polypropylene packaging on firmness (kg/cm<sup>2</sup>) of sapota cv. Kalipatti stored at 15°C for 15 and 30 days and then transferred to room temperature

| Treatments                    | Initial day                                 | 3 <sup>rd</sup> day (Ripe stage)            | Mean | 6 <sup>th</sup> day |
|-------------------------------|---------------------------------------------|---------------------------------------------|------|---------------------|
| T <sub>1</sub> D <sub>1</sub> | 3.20                                        | 1.40                                        | 2.30 | 0.95                |
| T <sub>2</sub> D <sub>1</sub> | 4.30                                        | 2.50                                        | 3.40 | 1.00                |
| T <sub>3</sub> D <sub>1</sub> | 3.40                                        | 1.04                                        | 2.22 | 0.80                |
| T <sub>4</sub> D <sub>1</sub> | 3.60                                        | 1.90                                        | 2.75 | 0.75                |
| T <sub>5</sub> D <sub>1</sub> | 1.30                                        | 0.10                                        | 0.70 | -                   |
| T <sub>1</sub> D <sub>2</sub> | 0.10                                        | 0.04                                        | 0.07 | -                   |
| T <sub>2</sub> D <sub>2</sub> | 0.02                                        | 0.01                                        | 0.01 | -                   |
| T <sub>3</sub> D <sub>2</sub> | 0.03                                        | 0.02                                        | 0.02 | -                   |
| T <sub>4</sub> D <sub>2</sub> | 0.01                                        | 0.01                                        | 0.01 | -                   |
| T <sub>5</sub> D <sub>2</sub> | 0.01                                        | 0.01                                        | 0.01 | -                   |
| Mean                          | 1.59                                        | 0.70                                        |      | -                   |
| For Days                      | F-test S.Em±<br>CD at (0.05)<br>* 0.05 0.10 | F-test S.Em±<br>CD at (0.05)<br>* 0.03 0.06 |      |                     |
| Treatments                    | * 0.08 0.16                                 | * 0.04 0.10                                 |      |                     |
| For D× T                      | * 0.11 0.23                                 | * 0.06 0.14                                 |      |                     |

\*Significant at P=0.05% level; \*\* Significant at P = 0.01% level; NS- Non significant “—“Fruits not available for analysis D<sub>1</sub>= 15 days, D<sub>2</sub> = 30 days T<sub>1</sub>= 100 gauge without perforation, T<sub>2</sub>=100 gauge with 0.1% perforation, T<sub>3</sub>= 100 gauge without perforation T<sub>4</sub>= 100 gauge with 0.1% perforation, T<sub>5</sub>= control (without packaging)

### Overall Trend

Spoilage increased from initial to sixth day. The highest mean spoilage (46.50%) was in control, and the lowest (19.50%) in 100-gauge with 0.1% perforation at 15 °C for 15 days. On the sixth day, spoilage reached 45% in the same treatment.

The spoilage of climacteric fruits increase with progressive of ripening (Kumbhar and Desai (1986), Willis *et al.* (1983). The fruit packed in 100 gauge polypropylene bags with 0.1% perforation has recorded significantly lower spoilage on all days of storage after transfer to normal temperature, irrespective of days of storage at low temperature. The minimum spoilage in packed fruits may be due to limited exposure of fruits to micro flora and atmospheric oxygen (Singh 1985) <sup>[12]</sup>. High spoilage of fruit in perforated polypropylene bags then in unperforated polypropylene bags can be attributed accumulation of moisture which leads to fungal growth (Sadasivam *et al.*, 1972, Philipose and Satiamoorthy, 1993) <sup>[8, 6]</sup>.

### Shelf Life (days)

Table 4. shows that fruits stored at 15 °C for 15 days had the highest shelf life (4.26 days), while the lowest (2.59 days) was from 30- day storage. Among packaging treatments, 100-gauge polypropylene with 0.1% perforation recorded the highest shelf life (4.98 days), regardless of storage duration.

The maximum shelf life in fruits packed with polypropylene bags of 100 gauge with 0.1% perforation stored at 15 °C for 15 days and then transferred to room could be attributed to low levels of O<sub>2</sub> and increased CO<sub>2</sub> concentration which might have caused reduction in respiration rate and metabolic activity leading to prolonged shelf life (Sharma *et al.*,1993) <sup>[11]</sup>. The results were in close conformity with the finding of Kumbhar and Desai (1986) and Sudha *et al.*, (2007) <sup>[14]</sup> in sapota. A total storability of 21 days (15 days at 15 °C and 6 days at room temperature) was observed in fruits packed in polypropylene bags 100 gauge with 0.1% perforation.

**Table 3:** Effect of polypropylene packaging on spoilage (%) of sapota cv. Kalipatti stored at 15°C for 15and30 days and then transferred to room temperature

| Treatments                    | Initial day                                 | 3 <sup>rd</sup> day (Ripe stage)            | Mean  | 6 <sup>th</sup> day |
|-------------------------------|---------------------------------------------|---------------------------------------------|-------|---------------------|
| T <sub>1</sub> D <sub>1</sub> | 20.00                                       | 35.00                                       | 27.50 | 53.00               |
| T <sub>2</sub> D <sub>1</sub> | 12.00                                       | 27.00                                       | 19.50 | 49.00               |
| T <sub>3</sub> D <sub>1</sub> | 19.00                                       | 30.00                                       | 24.50 | 56.00               |
| T <sub>4</sub> D <sub>1</sub> | 18.00                                       | 32.00                                       | 25.00 | 54.00               |
| T <sub>5</sub> D <sub>1</sub> | 40.00                                       | 50.00                                       | 45.00 | -                   |
| T <sub>1</sub> D <sub>2</sub> | 40.00                                       | 45.00                                       | 42.50 | -                   |
| T <sub>2</sub> D <sub>2</sub> | 35.00                                       | 44.00                                       | 39.50 | -                   |
| T <sub>3</sub> D <sub>2</sub> | 38.00                                       | 50.00                                       | 42.50 | -                   |
| T <sub>4</sub> D <sub>2</sub> | 39.00                                       | 48.00                                       | 43.50 | -                   |
| T <sub>5</sub> D <sub>2</sub> | 42.00                                       | 51.00                                       | 46.50 | -                   |
| Mean                          | 30.30                                       | 41.20                                       |       | -                   |
| For Days                      | F-test S.Em±<br>CD at (0.05)<br>* 0.53 1.11 | F-test S.Em±<br>CD at (0.05)<br>* 0.67 1.40 |       |                     |
| Treatments                    | * 0.84 1.75                                 | * 1.06 2.22                                 |       |                     |
| For D× T                      | * 1.19 2.48                                 | * 1.50 3.14                                 |       |                     |

\*Significant at P=0.05% level; \*\* Significant at P = 0.01% level; NS- Non significant “—“Fruits not available for analysis D<sub>1</sub>= 15 days, D<sub>2</sub> = 30 days T<sub>1</sub>= 100 gauge without perforation, T<sub>2</sub>=100 gauge with 0.1% perforation, T<sub>3</sub>= 100 gauge without perforation T<sub>4</sub>= 100 gauge with 0.1% perforation, T<sub>5</sub>= control (without packaging)

**Table 4:** Effect of polypropylene packaging on shelf life (days) of sapota cv. Kalipatti stored at 15°C for 15 and 30 days and then transferred to room temperature

| Treatments               | T <sub>1</sub>    | T <sub>2</sub>    | T <sub>3</sub>    | T <sub>4</sub>    | T <sub>5</sub>    | Mean              |
|--------------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| D <sub>1</sub> (15 days) | 4.81              | 5.80              | 4.50              | 5.00              | 1.20              | 4.26 <sup>b</sup> |
| D <sub>2</sub> (30 days) | 2.45              | 4.16              | 1.80              | 3.37              | 1.20              | 2.59 <sup>a</sup> |
| Mean                     | 3.63 <sup>c</sup> | 4.98 <sup>e</sup> | 3.15 <sup>b</sup> | 4.18 <sup>d</sup> | 1.20 <sup>a</sup> | 3.42              |
|                          | F-test            |                   | S.Em±             |                   | CD at (0.05)      |                   |
| For Days                 | 1. *              |                   | 2. 0.08           |                   | 3. 0.15           |                   |
| For treatments           | *                 |                   | 0.12              |                   | 0.25              |                   |
| For D×T                  | *                 |                   | 0.17              |                   | 0.35              |                   |

\*Significant at P=0.05% level; \*\* Significant at P = 0.01% level; NS- Non significant

Figures with same alphabet did not differ significantly

### Total soluble solids (<sup>0</sup>B)

#### Initial Day

TSS was higher (20.90<sup>0</sup>B) in fruits stored at 15 °C for 30 days and lower (18.52<sup>0</sup>B) in fruits stored for 15 days. No significant differences were observed among packaging treatments or their interaction.

#### Third Day (Ripe Stage)

Fruits stored for 15 days had higher TSS (20.33<sup>0</sup>B) than those

stored for 30 days (18.34<sup>0</sup>B). Although packaging had no significant effect, interaction was significant control fruits stored for 15 days showed the highest TSS (20.84<sup>0</sup>B), while lowest (17.60<sup>0</sup>B) was in control stored for 30 days.

### Overall Trend

TSS increased from initial to third day in fruits stored for 15 days but decreased in fruits stored for 30 days. On the sixth day, highest TSS (19.74<sup>0</sup>B) was recorded in fruits packed in 100-gauge bags with 0.1% perforation after 15-day cold storage. The total soluble solids of climacteric fruits increase with progressive of ripening (Kumbhar and Desai (1986), Willis *et al.* (1983). There is no significant difference noticed among the different packaging material with respect to the TSS on initial day of storage at room temperature. The fruits packed in 100 gauge polypropylene bags with 0.1% perforation and stored at 15 °C for 15 days has recorded significantly higher total soluble solids on 3<sup>rd</sup> day of storage (ripe stage) after transfer to normal temperature. This could be due to slow ripening process in the modified atmospheric packaging which leads to slow build up of the total soluble solids as reported by Johnson and Ertorn, (1983) [3].

**Table 5:** Effect of polypropylene packaging on TSS (<sup>0</sup>Brix) of sapota cv. Kalipatti stored at 15°C for 15 and 30 days and then transferred to room temperature

| Treatments                    | Initial day                  | 3 <sup>rd</sup> day (Ripe stage) | Mean  | 6 <sup>th</sup> day |
|-------------------------------|------------------------------|----------------------------------|-------|---------------------|
| T <sub>1</sub> D <sub>1</sub> | 18.84                        | 20.08                            | 19.46 | 18.58               |
| T <sub>2</sub> D <sub>1</sub> | 18.63                        | 20.33                            | 19.48 | 19.74               |
| T <sub>3</sub> D <sub>1</sub> | 18.45                        | 20.30                            | 19.37 | 18.75               |
| T <sub>4</sub> D <sub>1</sub> | 18.53                        | 20.11                            | 19.32 | 18.30               |
| T <sub>5</sub> D <sub>1</sub> | 18.17                        | 20.84                            | 19.50 | -                   |
| T <sub>1</sub> D <sub>2</sub> | 21.56                        | 18.50                            | 20.03 | -                   |
| T <sub>2</sub> D <sub>2</sub> | 20.39                        | 18.40                            | 19.39 | -                   |
| T <sub>3</sub> D <sub>2</sub> | 20.39                        | 19.20                            | 19.79 | -                   |
| T <sub>4</sub> D <sub>2</sub> | 21.50                        | 18.00                            | 19.75 | -                   |
| T <sub>5</sub> D <sub>2</sub> | 20.67                        | 17.60                            | 19.13 | -                   |
| Mean                          | 19.71                        | 17.57                            |       | -                   |
|                               | F-test S.Em±<br>CD at (0.05) | F-test S.Em±<br>CD at (0.05)     |       |                     |
| For Days                      | * 0.46 0.96                  | * 0.40 0.83                      |       |                     |
| Treatments                    | NS 0.72 -                    | NS 0.63 -                        |       |                     |
| For D× T                      | NS 1.03 -                    | * 0.89 1.86                      |       |                     |

\*Significant at P=0.05% level; \*\* Significant at P = 0.01% level; NS-Non significant “—“Fruits not available for analysis D<sub>1</sub>= 15 days, D<sub>2</sub> = 30 days T<sub>1</sub>= 100 gauge without perforation, T<sub>2</sub>=100 gauge with 0.1% perforation, T<sub>3</sub>= 100 gauge without perforation T<sub>4</sub>= 100 gauge with 0.1% perforation, T<sub>5</sub>= control (without packaging)

### Acidity (%)

#### Initial Day

No significant difference was found between storage durations. However, packaging had a significant effect highest acidity (0.32%) was in fruits packed in 100-gauge with 0.1% perforation, and lowest (0.20%) in control. Interaction was significant, with lowest acidity (0.14%) in 100-gauge without perforation after 30 days, and highest (0.32%) in 100-gauge with perforation.

#### Third Day (Ripe Stage)

Fruits stored for 15 days showed higher acidity (0.17%) than those stored for 30 days (0.06%). Packaging effect was significant highest acidity (0.16%) in 100-gauge without perforation, lowest (0.09%) in 100-gauge with 0.1% perforation. Interaction showed acidity ranging from 0.01% to 0.20%.

### Overall Trend

Acidity declined over time across all treatments. On the sixth day, highest acidity (0.16%) was in 100-gauge with perforation stored for 15 days, and lowest (0.01%) in 100-gauge with perforation stored for 30 days.

The fruit stored at 15 °C for 15 days recorded significant higher acidity when compare to fruit stored at 15 ° C or 30 days on third day (eating ripe stage) of transfer to room temperature irrespective of the packaging material (Table 4.1.7a.b.c). The fruit packed in 100 gauge polypropylene bags with 0.1% perforation has recorded significantly higher acidity on all days of storage after transfer to normal temperature, irrespective of days of storage at low temperature. The acidity of sapota fruits decreased throughout the storage period of sapota. Similar decreased in acidity was reported by Barnell (1941) [1] and Pool *et al.*, (1972) [7]. The continuous decrease in acidity of sapota

fruits can be attributed to the conversion of acids, into sugar (Pool *et al.*, 1972) <sup>[7]</sup> and utilization of organic acid during respiration (Singh *et al.*, 1954, Srivastava *et al* 1971) <sup>[12, 13]</sup>.

**Table 6:** Effect of polypropylene packaging on Acidity (%) of sapota cv. Kalipatti stored at 15°C for 15 and 30 days and then transferred to room temperature

| Treatments                    | Initial day                               | 3 <sup>rd</sup> day (Ripe stage)            | Mean | 6 <sup>th</sup> day |
|-------------------------------|-------------------------------------------|---------------------------------------------|------|---------------------|
| T <sub>1</sub> D <sub>1</sub> | 12.5                                      | 0.16                                        | 0.22 | 0.12                |
| T <sub>2</sub> D <sub>1</sub> | 0.28                                      | 0.14                                        | 0.21 | 0.16                |
| T <sub>3</sub> D <sub>1</sub> | 0.29                                      | 0.20                                        | 0.24 | 0.11                |
| T <sub>4</sub> D <sub>1</sub> | 0.26                                      | 0.19                                        | 0.22 | 0.14                |
| T <sub>5</sub> D <sub>1</sub> | 0.24                                      | 0.16                                        | 0.20 | -                   |
| T <sub>1</sub> D <sub>2</sub> | 0.14                                      | 0.10                                        | 0.12 | -                   |
| T <sub>2</sub> D <sub>2</sub> | 0.37                                      | 0.01                                        | 0.19 | -                   |
| T <sub>3</sub> D <sub>2</sub> | 0.15                                      | 0.12                                        | 0.13 | -                   |
| T <sub>4</sub> D <sub>2</sub> | 0.16                                      | 0.08                                        | 0.12 | -                   |
| T <sub>5</sub> D <sub>2</sub> | 0.16                                      | 0.05                                        | 0.10 | -                   |
| Mean                          | 0.23                                      | 0.12                                        |      | -                   |
| For Days                      | F-test S.Em±<br>CD at (0.05)<br>NS 0.01 - | F-test S.Em±<br>CD at (0.05)<br>* 0.01 0.04 |      |                     |
| Treatments                    | * 0.03 0.06                               | * 0.03 0.06                                 |      |                     |
| For D× T                      | * 0.04 0.08                               | * 0.04 0.09                                 |      |                     |

\*Significant at P=0.05% level; \*\* Significant at P = 0.01% level; NS-Non significant “—“Fruits not available for analysis D<sub>1</sub>= 15 days, D<sub>2</sub> = 30 days T<sub>1</sub>= 100 gauge without perforation, T<sub>2</sub>=100 gauge with 0.1% perforation, T<sub>3</sub>= 100 gauge without perforation T<sub>4</sub>= 100 gauge with 0.1% perforation, T<sub>5</sub>= control (without packaging)

### Reducing sugar (%)

#### Initial Day

Table.7. Fruits stored at 15 °C for 30 days showed higher reducing sugar (8.36%) than those stored for 15 days (5.60%). Among packaging, 100-gauge with 0.1% perforation had the highest sugar (7.51%), while the lowest (6.30%) was in 100-gauge without perforation. Interaction effect was significant highest (9.30%) in 100-gauge with perforation (30 days), and lowest (5.40%) in 100-gauge without perforation (15 days).

**Table 7:** Effect of polypropylene packaging on reducing sugar (%) of sapota cv. Kalipatti stored at 15°C for 15 and 30 days and then transferred to room temperature

| Treatments                    | Initial day                                 | 3 <sup>rd</sup> day (Ripe stage)            | Mean | 6 <sup>th</sup> day |
|-------------------------------|---------------------------------------------|---------------------------------------------|------|---------------------|
| T <sub>1</sub> D <sub>1</sub> | 5.40                                        | 6.20                                        | 5.80 | 5.88                |
| T <sub>2</sub> D <sub>1</sub> | 5.70                                        | 8.50                                        | 7.10 | 6.20                |
| T <sub>3</sub> D <sub>1</sub> | 5.60                                        | 7.00                                        | 6.30 | 6.10                |
| T <sub>4</sub> D <sub>1</sub> | 5.60                                        | 8.13                                        | 6.86 | 6.15                |
| T <sub>5</sub> D <sub>1</sub> | 5.80                                        | 7.00                                        | 6.40 | -                   |
| T <sub>1</sub> D <sub>2</sub> | 7.20                                        | 6.20                                        | 6.70 | -                   |
| T <sub>2</sub> D <sub>2</sub> | 9.30                                        | 7.15                                        | 8.22 | -                   |
| T <sub>3</sub> D <sub>2</sub> | 8.50                                        | 7.20                                        | 7.85 | -                   |
| T <sub>4</sub> D <sub>2</sub> | 8.70                                        | 6.60                                        | 7.65 | -                   |
| T <sub>5</sub> D <sub>2</sub> | 8.08                                        | 6.40                                        | 7.20 | -                   |
| Mean                          | 6.99                                        | 6.39                                        |      | -                   |
| For Days                      | F-test S.Em±<br>CD at (0.05)<br>* 0.11 0.24 | F-test S.Em±<br>CD at (0.05)<br>* 0.26 0.56 |      |                     |
| Treatments                    | * 0.18 0.38                                 | * 0.42 0.88                                 |      |                     |
| For D× T                      | * 0.26 0.54                                 | * 0.60 1.25                                 |      |                     |

\*Significant at P=0.05% level; \*\* Significant at P = 0.01% level; NS-Non significant “—“Fruits not available for analysis D<sub>1</sub>= 15 days, D<sub>2</sub> = 30 days T<sub>1</sub>= 100 gauge without perforation, T<sub>2</sub>=100 gauge with 0.1% perforation, T<sub>3</sub>= 100 gauge without perforation T<sub>4</sub>= 100 gauge with 0.1% perforation, T<sub>5</sub>= control (without packaging)

**Table 8:** Effect of polypropylene packaging on TSS: Acid ratio of sapota cv. Kalipatti stored at 15°C for 15 and 30 days and then transferred to room temperature

| Treatments                    | Initial day                                 | 3 <sup>rd</sup> day (Ripe stage)            | Mean   | 6 <sup>th</sup> day |
|-------------------------------|---------------------------------------------|---------------------------------------------|--------|---------------------|
| T <sub>1</sub> D <sub>1</sub> | 74.28                                       | 120.32                                      | 97.30  | 165.51              |
| T <sub>2</sub> D <sub>1</sub> | 80.59                                       | 145.05                                      | 112.82 | 185.83              |
| T <sub>3</sub> D <sub>1</sub> | 75.30                                       | 108.81                                      | 92.05  | 122.15              |
| T <sub>4</sub> D <sub>1</sub> | 81.40                                       | 118.21                                      | 99.80  | 137.10              |
| T <sub>5</sub> D <sub>1</sub> | 71.90                                       | 145.90                                      | 108.90 | -                   |
| T <sub>1</sub> D <sub>2</sub> | 164.00                                      | 185.00                                      | 174.50 | -                   |
| T <sub>2</sub> D <sub>2</sub> | 192.00                                      | 192.40                                      | 192.20 | -                   |
| T <sub>3</sub> D <sub>2</sub> | 154.00                                      | 160.00                                      | 157.00 | -                   |
| T <sub>4</sub> D <sub>2</sub> | 180.00                                      | 185.00                                      | 182.50 | -                   |
| T <sub>5</sub> D <sub>2</sub> | 217.00                                      | 220.35                                      | 218.67 | -                   |
| Mean                          | 129.04                                      | 136.06                                      |        | -                   |
| For Days                      | F-test S.Em±<br>CD at (0.05)<br>* 0.63 1.31 | F-test S.Em±<br>CD at (0.05)<br>* 0.02 0.04 |        |                     |
| Treatments                    | * 0.99 2.08                                 | * 0.03 0.07                                 |        |                     |
| For D× T                      | * 1.41 2.94                                 | * 0.05 0.11                                 |        |                     |

\*Significant at P=0.05% level; \*\* Significant at P = 0.01% level; NS-Non significant “—“Fruits not available for analysis D<sub>1</sub>= 15 days, D<sub>2</sub> = 30 days T<sub>1</sub>= 100 gauge without perforation, T<sub>2</sub>=100 gauge with 0.1% perforation, T<sub>3</sub>= 100 gauge without perforation T<sub>4</sub>= 100 gauge with 0.1% perforation, T<sub>5</sub>= control (without packaging)

### Third Day (Ripe Stage)

Higher reducing sugar (7.36%) was found in fruits stored for 15 days vs. 30 days (6.71%). Packaging effect was significant 100-gauge with 0.1% perforation had highest (7.82%), and 100-gauge without perforation had lowest (6.20%). Interaction showed max sugar (8.50%) in 100-gauge with perforation (15 days).

Reducing sugar increased by the third day in fruits stored at 15 °C for 15 days but decreased in those stored for 30 days. The highest value (8.50%) was in 100-gauge with 0.1% perforation. By the sixth day, reducing sugar declined, with a maximum of 6.20% in the same packaging.

The sugars (both reducing and total sugars) increased on 3<sup>rd</sup> day (ripe stage) of storage at room temperature in fruits stored at 15 °C for 15 days indicating delayed ripening process. This slow increase has resulted in significantly higher accumulation of sugars on eating ripe stage in fruits stored at 15 °C for 15 days then for 30 days. Total and reducing sugar increase initially and decrease as the day of storage proceeded. Satahal and Camp (1971) stated that the increase in sugar in initial period of storage may be due to conversion of cell wall material to reducing sugar by hydrolysis of polysaccharides.

### TSS: Acid Ratio

#### Initial Day

Table.8.TSS: Acid ratio was higher in fruits stored at 15 °C for 30 days (181.40) than 15 days (76.69). Among treatments, control showed the highest ratio (144.45), and the lowest (114.14) was in 150-gauge without perforation. Interaction effect was significant control at 30 days had the highest ratio (217.00) and lowest (71.90) at 15 days.

### Third Day (Ripe Stage)

Fruits stored for 30 days had a higher TSS: Acid ratio (188.55) than 15 days (127.65). Control again recorded the highest (183.12), and 150-gauge without perforation the lowest (134.40). The highest overall (220.35) was in control stored for 30 days, and the lowest (108.81) in 150-gauge without perforation stored for 15 days.

TSS:Acid ratio increased steadily from the initial day to the end of storage at 15 °C for both 15 and 30 days. The highest ratio (145.05) was in fruits packed in 100-gauge bags with 0.1% perforation (15-day storage), and the lowest (92.05) in 150-gauge without perforation. On the sixth day, the highest ratio (185.83) was again observed in 100-gauge with 0.1% perforation.

The TSS: acid ratio increased throughout the storage period irrespective of the packaging material and storage conditions. The TSS: acid ratio of climacteric fruits increase with progressive of ripening (Sudha *et al.*, 2007) <sup>[14]</sup>. This increase might be due to the magnitude of decreased in acidity is more compared to decrease in TSS in the later stage of storage. The finding was in close conformity with the Goud (1979) <sup>[2]</sup> in sapota. The fruit packed in 100 gauge polypropylene bags without perforation has recorded significantly lower TSS: Acid ratio on all days of storage after transfer to normal temperature, irrespective of days of storage at low temperature. This reduced in TSS: Acid ratio in polypropylene bags could be due to retarded ripening in packed fruit. This could be due to slow ripening process in the modified atmospheric packaging which leads to slow build up of the total soluble solids and acidity as reported by Johnsonn and Ertorn, (1983) <sup>[3]</sup>.

### Conclusion

The present investigation on Sapota (cv. Kalipatti) stored at 15 °C under different packaging conditions revealed significant effects on physiological loss in weight (PLW), firmness, spoilage, shelf life, TSS, acidity, sugars, and TSS:acid ratio.

Storage of fruits at 15 °C for 15 days in 100-gauge polypropylene bags with 0.1% perforation proved to be the most effective treatment, maintaining minimum PLW (1.20-2.50%), highest firmness (4.30 kg/cm<sup>2</sup> initially, 2.50 kg/cm<sup>2</sup> on the 3rd day), and lowest spoilage (12-23.5%) compared to other treatments. In contrast, untreated control fruits showed maximum PLW (8.20%), lowest firmness (0.01 kg/cm<sup>2</sup>), and highest spoilage (up to 50.5%).

The progressive increase in PLW and decline in firmness were more pronounced in control fruits, while polypropylene packaging effectively reduced respiration and transpiration rates, resulting in better retention of moisture, texture, and quality. Similarly, the shelf life was significantly extended in fruits stored for 15 days at low temperature followed by room temperature storage, achieving up to 21 days total storability (15 days at 15 °C+6 days at room temperature) in 100-gauge polypropylene bags with 0.1% perforation.

In terms of biochemical parameters, TSS, reducing sugars, and TSS:Acid ratio increased progressively during ripening, especially in fruits stored for 15 days and packed in 100-gauge perforated bags, indicating controlled ripening. Acidity declined steadily in all treatments due to conversion of organic acids into sugars, with the lowest acidity recorded in fruits stored for 30 days.

Overall, modified atmospheric packaging (MAP) using 100-gauge polypropylene bags with 0.1% perforation at 15 °C for 15 days proved to be the most effective in maintaining fruit quality, reducing spoilage, delaying ripening, and extending the storage and shelf life of sapota cv. Kalipatti.

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