STUDIES ON EXTENSION OF SHELF-LIFE OF SAPOTA [*Manilkara achras* (Mill.) Fosberg] FRUITS Cv. KALIPATTI

By

Tushar Tukaram Mali

(Reg. No.98093)

A Thesis submitted to the
MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI - 413 722, DIST.AHMEDNAGAR,
MAHARASHTRA, INDIA

in partial fulfilment of the requirements for the degree

of

MASTER OF SCIENCE (AGRICULTURE)

in

HORTICULTURE

DEPARTMENT OF HORTICULTURE

POST GRADUATE INSTITUTE
MAHATMA PHULE KRISHI VIDYAPEETH,
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DEPARTMENT OF HORTICULTURE

POST GRADUATE INSTITUTE
MAHATMA PHULE KRISHI VIDYAPEETH, RAHURI - 413 722
2001

CANDIDATE'S DECLARATION

I hereby declare that this thesis or part thereof has not been submitted by me or any other person to any other University or Institute for Degree or Diploma

Place : MPKV,Rahuri

Dated :19/06 /2001

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Maharashtra State (INDIA)

CERTIFICATE

This is to certify that the thesis entitled, **"Studies on extension of shelf-life of sapota [*Manilkara achras* (Mill) Fosberg] fruits Cv. Kalipatti"**, submitted to the Mahatma Phule Krishi Vidyapeeth, Rahuri for the award of the degree of **MASTER OF SCIENCE** (AGRICULTURE) in **HORTICULTURE**, embodies the results of a *bona fide* research carried out by **Mr. TUSHAR TUKARAM MALI** under my guidance and supervision and that no part of the thesis has been submitted for any other Degree or Diploma.

The assistance and help received during the course of this investigation have been acknowledged.

Place : MPKV, Rahuri

Dated : 19 /06/2001.

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Place : MPKV, Rahuri (S.S. Kadam)

Dated : / /2001.

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Place : MPKV, Rahuri (T.T. Mali)

Dated : 19/ 06 /2001

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LIST OF ABBREVIATIONS

°C	Degree Celsius
CC	Cool chamber
CFB	Corrugated fibre board box
cm	Centimetre
Eq.wt.	Equivalent weight
et al.	And others
Fig.	Figure
g	Gram (s)
GA	Gibberellic acid
ha	Hectare
i.e.	That is
I.U.	International units
kg	Kilogram
mg	Milligram
ml	millilitre
mm	Millimetre
N	Normality
N.S.	Non-significant
PE	Polyethylene bags
PLW	Physiological loss in weight
ppm	Parts per million
RH	Relative humidity
RT	Room temperature
S.E.	Standard Error of means
TSS	Total soluble solids
vit.	Vitamin
viz.,	Namely
%	Per cent

ABSTRACT

STUDIES ON EXTENSION OF SHELF-LIFE OF SAPOTA [*Manilkara achras* (Mill.) Fosberg] FRUITS Cv. KALIPATTI

By

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2001

Research Guide	:	Dr. A.R. Karale
Department	:	Horticulture

The present investigation entitled, "Studies on extension of shelf-life of sapota [*Manilkara achras* (Mill.) Fosberg] fruits cv. Kaliptti was carried out with four chemical and three packaging treatments making in all 12 treatment combinations with three replications. The experiment was conducted in two sets in Factorial Completely Randomised Design (FCRD).

The treated sapota fruits Cv. Kalipatti were stored at room temperature (11-35^{0}C, 22-65 % RH) and in low cost, low energy input cool chamber (10-20^{0}C, 85-90 % RH) in March-2000. In present study, it was observed that sapota fruits under all the treatment combinations had increased total weight loss, rotting, fruit softening

Abstract contd…… **T.T. Mali**

and fruit skin shrinkage with subsequent increase in storage period. *Aspergillus niger* and *Fusarium* sp. were found to be associated with rotting under both the storage condition. There was an increase followed by gradual decrease in TSS, reducing, non-reducing and total sugars content with corresponding decrease in acidity upon prolonged storage under both the storage conditions irrespective of storage treatments. Fruits stored in cool chamber followed the same trend of physico-chemical changes but at a slower rate.

The shelf life and organoleptic qualities of untreated and unpacked sapota fruits were found to be good hardly for 5 days at room temperature. However, fruits treated with 6 % waxol and packed in 150 guage polyethylene bags with 1.2 per cent vents could be stored well upto 8 days at room temperature.

The present study made it clear that, the treatment of sapota fruits with 6 % waxol and packed in 150 gauge polyethylene bags with 1.2 % vents was the best and it had a great significance in retaining the better physcio-chemical characteristics. This treatment combination could extend the shelf-life of sapota fruits upto 16 days in cool chamber with only 19.20 per cent cumulative weight loss and better marketable and organoleptic qualities while untreated and unpacked fruits recorded 36.12 per cent cumulative weight loss and had lost almost complete marketable qualities on 10th day of storage in cool chamber.

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INTRODUCTION

1. INTRODUCTION

Sapota (*Manilkara achras* (Mill.) Fosberg.) is one of the important tropical fruit valued for it's mellow, sweet and delicious pulp. The native place of sapota is considered to be Mexico. This fruit crop is cultivated extensively and claims commercial importance in coastal belt throughout India. Due to wide adaptability and high economic returns it's cultivation is extending to the dry zones of Deccan plateau, humid tracts of South India and the sub-mountane tracts of North India. In India, area under this crop is estimated to be 48,125 ha (Singhal, 1999) mainly in the states of Gujrat, Maharashtra, Andhra Pradesh, Karnataka, Tamil Nadu, Kerala, Uttar Pradesh, West Bengal, Punjab and Haryana. Well organized orcharding of this crop can be seen in coastal region of Maharashtra mainly in Thane, Ratnagiri, Raigarh and Sindhudurg districts.

In the last decade, the Government of Maharashtra has announced 100 per cent subsidy to the farmers for growing fruit crops. It has definitely motivated the farmers to take up the plantation of fruit crops and helped in increasing the area under sapota fruit crop. It occupies an area of 5,912 ha with a total production of 37,555 tones and productivity of 6.92 tones/ha (Singhal, 1999). It is expected that both area and production of this fruit will increase by many folds in near future.

Sapota is considered as one of the delicious fruit for taste purpose. It is eaten as dessert fruit, although the pulp of the fruit may be utilized in preparation of sherbets, halwas and mixed jam. This also canned into slices. The pulp is a good source of sugars, appreciable amounts of proteins, fats, fiber, calcium, phosphorus and iron. The fruit pulp has got medicinal properties (Kirthikar and Basu, 1975). The fruit pulp is also a good source of raw material for the manufacture of industrial glucose and pectin.

The sapota fruits are very delicate and highly perishable and rated poor for it's processability. Therefore, mainly used for table purpose only. The post harvest losses in fruits like sapota are high in tropical country like India, which ranges between 25-30 per cent. (Salunkhe and Desai, 1984). The bio-chemical changes in the fruit after harvest occur at a faster rate and fruit becomes unfit for consumption within the short period of transportation to distant market. The storage life of sapota fruit is 5 days at ambient temperature conditions (Rao and Chundawat, 1988). This fruit is also sensitive to cold storage (Lakshminarayana, 1980). If the bio-chemical changes and spoilage of fruit during storage could be slowed down to certain extent without any damage to the quality, then their shelf-life can be increased.

The present study, therefore, is undertaken to investigate the possibilities of prolonging the shelf-life of sapota fruits using simple and less expensive methods of storage conditions like zero energy cool chamber, growth regulators, skin coating waxes and packagings like polyethylene and corrugated fiber board boxes with the following objectives.

1. To study the effects of various chemicals, packagings and storage conditions on physico-chemical characteristics of sapota fruits.
2. To study the effects of various chemicals, packagings and storage conditions on shelf-life and quality of sapota fruits.
3. To find out the suitable method to prolong the shelf -life of sapota fruits.

REVIEW OF LITERATURE

2. REVIEW OF LITERATTURE

The harvested fruits are living entities. The respiration and bio-chemical processes of ripening continues leading to bio-degradation and senescence. All the changes that occur do not prevent deterioration. In a real sense, fruit ripening may be regarded as a special cause of organ senescence (Moore, 1980).

To arrest the senescence in fruits and to prolong the shelf-life of climacteric fruits like sapota, it is necessary to prevent peak ethylene production and delay the onset of climacteric phase. This can be achieved by employing various means viz., suitable packagings, controlled atmospheric storage, sub-atmospheric pressure storage, modified atmosphere storage and application of senescence delaying chemicals. The post harvest microbial spoilage of fruits can be reduced or eliminated by pre-harvest spray or post harvest dip in proper fungicides. There are different techniques and methods to increase the storage life of fruits which are reviewed below

2.1 Growth regulators and retardants

The plant harmones have profound influence on various developmental processes of plant. Auxines, Gibberellins and Cytokinins along with other uses have been very widely used in prolonging the shelf-life of flowers, fruits and vegetables. However, they behave differently in different tissues and at different concentrations. As the mode of action of every hormone is very specific, it requires careful understanding of it's use during such studies. The work done on prolonging the shelf-life of different fruits by Gibberellins (GA) and Cycocel (CCC) is reviewed here under.

2.1.1 Gibberellic acid (GA)

Gibberellin is an important class of plant growth regulators. Besides profound effects on various developmental processes, gibberellins were first reported to retard ripening by Coggins and Lewis (1962). It was inferred that gibberellins too can alter the course of fruit ripening. Subsequently, gibberellins have been tried, either alone or in combination with other plant hormones like auxins, cytokinins, abscisic acid, etc. in fruits to prolong the shelf-life and had positive results in respect of gibberellins as a senescence delaying hormone.

Saha (1971) reported that mature green guava fruits when treated with GA_3 at 100 ppm retarded both ripening and weight loss during storage.

Murthy and Rao (1982) reported that 250 ppm GA treatment to Alphonso fruits significantly retarded the ripening during storage at 28^0C and recorded lower values for brix/acid ratio and firmness indicating their unripe stage.

Kumbhar and Desai (1986) observed that when mature sapota fruits Cv. Kalipatti were dipped in 75 ppm GA solution for 3 minute and packed in PE bags of 100 gauge with 1.2 per cent vents could be stored up to 11 days at room temperature and further reported significant reduction in total weight loss of 13.89 per cent with negligible skin shrinkage and excellent organoleptic qualities as against 90.20 per cent cumulative weight loss in untreated fruits.

Rao and Chundawat (1986) observed retardation in shelf-life of banana Cv. Lacatan fruits treated with 150 ppm GA + 6 % Waxol up to 16 days at 30^{0}C.

Banik *et al.* (1988) reported that sapota fruits treated with 50 ppm GA alone or in combination with 6 per cent paraffin wax recorded the lowest weight loss of 8.99 per cent and 6.33 per cent respectively.

Gautam and Chundawat (1990) reported that sapota fruits Cv. Kalipatti when treated with GA_3 300 ppm took maximum number of days (7.7) to ripen and extended the ripening period by 2.9 days over control. They also recorded reduced weight loss (5.5 per cent) without any adverse effect on the quality of fruits.

Storage studies carried out by Sandbhor and Desai (1991) showed that maximum duration of storage (7 days) with minimum weight loss (10.86 per cent) was obtained by treatment with GA_3 at 50 ppm and packed in perforated PE bags at room temperature in ber Cv. Umran fruits.

Storage studies on sapota fruits Cv. Pilipatti carried out at GAU, Junagadh showed that GA_3 significantly reduced PLW during storage followed by skin coating resins, $CaCl_2$ and Cycocel. However, on 8th day of storage GA_3 recorded significantly minimum percentage of shriveling and spoilage of fruits (Avaiya and Singh,1991)

Chattopadhayay *et al.* (1992) observed best results with 50 ppm GA in sweet orange Cv. Jaffa where fruits could be stored up to 21 days with no spoilage as compared to greatest spoilage (45 per cent) in untreated fruits.

Bhanja and Lenka (1994) during the experiment carried out at Bhubaneshwar treated sapota Cv. Oval fruits with GA_3 100 ppm for 10 minutes and recorded extended shelf-life of 36 days with reduced PLW (2.5 to 4 per cent) and rotting (10 per cent).

Bandopadhayay and Sen (1995) observed that when freshly harvested fruits of ber Cv. Gola treated with 100 ppm GA and stored at room temperature increased fruit marketability, TSS, and ascorbic acid content and reduced titratable acidity after 12days.

Kumar and Nagpal (1996) in mango Cv. Dashehari reported that when the fruits were given post-harvest dip of 200 ppm GA shown reduced weight loss (20.10 per cent) and rotting (19.20 per cent) on 11th day with increased TSS and maximum marketability.

Singh and Kumar (1997) reported that treatment of GA (10 and 25 ppm) for 10 min and stored at room temperature in aonla Cv. Chakkaiya were effective in reducing physiological loss in weight. TSS and acidity were increased continuously and ascorbic acid content decreased irrespective of treatments during storage.

Saraswathi and Azhakiamanavalan (1997) observed that when mature fruits of mandarin treated with 50 and 100 ppm GA and stored at room temperature (12 to 30^{0}C) recorded the highest percentage of edible fruits (96.3 %) with good physical and chemical qualities and marketability at the end of 15 days storage period.

Patil and Hulamani (1998) during their studies on effect of growth regulators and wax coating on shelf life of banana fruits observed that treatment with GA_3 150 ppm resulted in significantly lower physiological weight loss, decay loss, per cent fruit ripening and extended the storage life up to 20 days under ambient conditions.

Patel and Katrodia (1998) during the study carried out at Valsad (Gujrat) reported that sapota Cv. Kalipatti fruits treated with 150 ppm GA extended the shelf life upto 8 days without affecting there quality adversely.

Ahmed and Singh (1999) reported that when mature Amrapali mango fruits were dipped in 50 ppm GA and 500 ppm Bavistin and packed in polyethylene bags and stored at room temperature (33-37^{0}C) had storage life of 11 days (compared with 7 days in control fruits).

2.1.2 Cycocel (CCC)

Cycocel is one of the important plant growth retardant and is a synthetic organic compound which when applied to responsive crop in relatively high concentration can induce beneficial post harvest changes in many of the fruit crops. They elicit many bio-chemical changes in fruit tissues and several modes of actions have been suggested by many workers. The hypothesis that is best supported both by physiological and biochemical studies, involves inhibition of bio-synthesis of precursor of diterpenoid harmones (Clifford and Lenton, 1980). Cycocel when applied in higher concentration, reduces post harvest decay, delay senescence, reduce fruit weight loss, reduce physiological deterioration, improves colour and enhance market values of different fruits (Purohit, 1993). Beneficial effects of cycocel in extending the shelf-life of different fruits are reviewed hereunder.

Garg *et al.* (1978) reported that when guava fruits treated with maleic hydrazide (500 ppm) and cycocel (500 ppm) for 30 seconds and air dried and kept at room temperature recorded reduced rate of fruit ripening and fruit spoilage. 500 ppm cycocel recorded extended storage life of 8 days.

Mitra *et al.* (1981) during their studies on prolonging shelf-life of guava fruits reported that mature green guava fruits when treated with 100 ppm cycocel and 6 per cent waxol separately and stored at room temperature. The cycocel treated fruits had minimum spoilage (20 %) followed by 6 per cent waxol treated fruits (22 %).

Bhullar *et al.* (1981) found that Valencial late oranges treated with 1000 ppm cycocel recorded extended shelf-life of 10 days with minimum rotting (16 %), and increased TSS and sugars while juice content and titratable acidity decreased with prolonged storage period.

Murthy and Rao (1982) reported that post-harvest dip of Alphanso mango fruits with CCC (500 ppm), Alar (500 ppm) or Menadine bisulphite (Vit K_3) at 500 ppm significantly retarded the ripening during storage at 28^0C as judged by number of ripe fruits. However, with cycocel treatment retardation of ripening was observed only in the early stage of storage.

Sud and Nayital (1992) reported that post harvest treatment of 4000 ppm cycocel (1 minute dip) in Peach Cv. Alexander was most effective in maintaining fruit firmness and quality upto 7 days. They also recorded the reduced weight loss (13.65 %), highest sugars (4.75 %), highest Vit. C (5.42 mg/100 g) content at the end of storage life.

Siddiqui and Gupta (1995) observed that post harvest dip for 15 min in cycocel (500 and 1000 ppm) was given to ber Cv. Umran at 6^{th} day of storage. Minimum PLW (22 %) was recorded in both the concentrations. The decay loss also significantly affected by cycocel.

Patel and Sachan (1995) during shelf-life studies in aonla fruits observed that fruits treated with CCC (400 ppm) and packed in perforated polyethylene bags and stored at room temperature recorded reduced PLW (16.26 %), rotting (9.90 %) and highest Vit.C (471.40 mg/100 g) content on 15^{th} day of storage.

Kumar and Prasad (1997) in a storage experiment conducted at Faizabad in papaya observed that papaya fruits given 50 ppm cycocel post harvest dip for 3 minutes prolonged the fruit ripening by 12.2 days and maximum TSS (10.50 %), Vit.A (2450 I.U./100 g) and Vit.C (58.5 mg/100 g) were recorded.

2.2 Wax coating

The outer surface of fruits have a natural waxy layer which is partly removed during handling. An extra discontinuous layer of wax applied artificially provides the necessary protection against decay organisms. The practical benefit from wax coating is usually a reduction in evaporation and respiration. It has been reported that where refrigerated storage facilities are not available, protective skin coating with wax is one of the methods developed for increasing the storage life of fresh fruits. Wax coating does not leave any residue or impart undesirable odour or flavour or interfere with the natural appearance of fruits and its quality.

Das and Acharya (1969) observed that guava Cv. Banaras Round fruits with 2 or 3 dips in 6 % waxol and one dip in 9 per cent wax stored well for one month.

Garg *et al.* (1971) mango fruits stored at 29 to 35^{0}C and treated with 6 % wax emulsion and pre-packaging (1 kg lot in 200 gauge PE bags with 0.6 % ventilation) resulted in reduction of weight loss and spoilage with prolonged shelf-life.

Sadasivam *et al.* (1971) reported that double coating of 12 % wax emulsion prolonged the storage life of Dwarf Cavendish banana by 10-12 days at 4-5^{0}C.

Jawanda *et al.* (1978) reported that kinnow mandarin fruits looked glossy due to wax coating. The shriveling of fruits under wax treatment appeared after 20 days of storage against 10 days in control fruits.

Jawanda *et al.* (1980) reported that it is possible to extend storage life of ber upto 10 days in Cv. Umran and 12 days in Cv. Sanaur-2 when fruits were treated with W-0-12 and W-W-12 wax emulsions and stored in ventilated PE bags. Both the treatments were effective in reducing the per cent loss in weight than the untreated and unpacked ones.

Bhullar and Farmahan (1980) reported that wax coating with 6 per cent waxol retarded ripening and prolonged the storage life upto 10 days at room temperature in guava.

Ingale *et al.* (1982) concluded that treatment of sapota fruits Cv. Kalipatti with 2,4-D at 4 ppm and wax emulsion (waxol-O) effectively retard the ripening process and prolong the storage life of fruits upto 12 days.

Storage studies conducted at Udaipur have shown that custard apple fruits can be easily stored upto 7 days after treatment with 8 per cent wax emulsion in combination with 400 ppm 2,4-D or 400 ppm 2,4,5-T (Anonymous, 1983).

Bhullar *et al.* (1984) in mango observed the best fruit appearance at the end of storage when fruits treated with 6 per cent wax emulsion and packed in perforated PE bags.

Singh *et al.* (1984) treated guava fruits Cv. Allahabad safeda with 6 % wax emulsion and observed the extended shelf-life upto 8 days as against only 5 days in control fruits.

Baviskar (1993) reported that 6 per cent wax treatment coupled with polyethylene and CFB box packaging was beneficial in extending the shelf life of ber Cv. Umran under cold storage and room temperature with only 33.2 per cent weight loss in 6 per cent wax treated fruits against 59.9 per cent in untreated fruits.

Patel *et al.* (1993) found that guava fruits treated with waxol (6 % and 12 %) could be stored well upto 12 days with reduced weight loss, retarded ripening and higher marketability.

Naik and Rokhade (1994) reported that ripe fruits of ber Cv. Umran when subjected to 6 % waxol and packed in PE bags and stored at room temperature showed minimum PLW (18.65 %) and rotting (11.22 %) at the end of 9^{th} day.

Sarkar *et al.* (1995) reported that 6 % wax emulsion prolonged the storage life of banana upto 14 days after harvest without affecting quality at room temperature.

Jagadeesh and Rokhade (1998) observed in guava fruits when treated with 6 and 9 per cent waxol for one minute retained highest TSS, ascorbic acid (210 mg/100 g) content with better organoleptic qualities and decreased acidity at ambient conditions (21-25^{0}C) on 10th day of storage.

Bhadra *et al.* (1999) observed that when mature fruits of ber Cv. Narikeli treated with liquid paraffin wax and packed in perforated polyethylene bags could be stored upto 12 days under ambient temperature conditions with reduced weight loss, higher TSS and also observed decreased acidity and ascorbic acid content.

Singh (2000) observed that when guava fruits dipped in 6 per cent wax emulsion and stored at room temperature could be stored well upto 8 days with better physico-chemical characters.

2.3 Packaging materials

Fresh fruits even after harvest are subjected to deterioration as they are composed of living tissues. These living tissues have high moisture content. Sapota has as high as 75 to 80 per cent moisture content (Gopalan *et al.*, 1971). Loss of moisture in such fruits leads to loss of turgidity and shrinkage of cells of fruit rind under ambient conditions. The use of polyethylene packaging seen to prevent the fruits from loss of turgidity and to keep the fruits fresh for a longer time. Further such packaging help to arrest senescence process by creating micro-climate around the fruits (Salunkhe and Desai, 1984).

2.3.1 Polyethylene bags

Polyethylene is not fully permeable either to O_2 or CO_2 or ethylene (Scott *et al.*, 1971). Okuba and Ishii (1973) noticed that as the fresh fruits ripen, metabolic changes occur faster and the level of NADP, ATP and ADP rise during this process. But if polyethylene films are used as wrappers over the fruits, the level of all these three remains lower than in unwrapped fruits and tend to remain constant. Thus, the polyethylene packs of different thickness have been found to alter metabolic events in the fruit ripening which also helps in lowering the transpiration rate of packed fruits and thereby maintains its turgidity.

Ben Yehoushua (1966) studied some effects of plastic coatings on Dwarf Cavendish banana and reported following desirable effects as extension of storage life by 9-14 days, delay in the climacteric rise (ripening process) by 1-2 weeks as measured by respiratory activity, rate of softening and degreening, reduction in weight loss by 25-50 per cent , inhibition of darkening of skin, improvement in the appearance of skin by imparting glossy skin and preventing skin shrinkage.

Ahmed *et al.* (1972) observed that wax paper box liners and polyethylene liners increased the post harvest life of guavas by 6 and 7 days respectively over control. The organoleptic quality of fruits even after 10 days of storage was the best in PE bags.

Sadasivam *et al.* (1973) found minimum weight loss in orange fruits packed in polyethylene bags (100 gauge with 1 % vents). Fungal infection was also less and cost and consumer appeal were the best with PE bags.

Singh *et al.* (1976) stored guava successfully upto 6 days in perforated polybags without rotting and much loss in weight.

The polythene thickness (gauge) and ventilation vary with the commodity. In general less than 0.6 per cent have been observed optimum for various fruits (Yagi, 1980).

Jain *et al.* (1981) reported a lower weight loss and better physical appearance in ber fruit Cv. Umran stored for 3 weeks in perforated polyethylene bags (400 gauge and 0.4 % vents).

Reddy and Thimma (1981) found that mango fruits Cv. Alphanso packed in 150 gauge PE bags with 20 per cent vents retarded their edible qualities upto 20 days of storage. There was significant reduction in weight loss, microbial spoilage during storage. It also retarded ripening as evidanced by slow rate of increase in TSS and better retention of acidity. Organoleptic score was maximum in that treatment.

Khedkar *et al.* (1982) observed that guava fruit Cv. L-49 when packed in 300 gauge PE bags had less weight loss (20.25 %), more percentage of pulp and more retention of vit. C (205 mg/100 g) with no adverse change in fruit quality.

Tandon *et al.* (1984) could store the mature but green to slightly yellow fruits of guava Cv. Allahabad Safeda in low density polyethylene bags upto 14 days at ambient temperature (17-23^{0}C).

Dhoot *et al.* (1984) observed that polyethylene packaging was highly effective in checking weight loss (2.21 to 2.37 %) as against 33.18 per cent with no polyethylene and maintains turgidity and glossiness in Sardar guava fruits.

Kumbhar (1984) during his studies on shelf life of sapota recorded that sapota fruits treated with 75 ppm GA and packed in 100 gauge PE bags with 1.2 per cent vents can be stored upto 11 days at ambient temperature.

Pota *et al.* (1987) reported storage life of pomegranate upto 12 weeks in PE bags (0.02 mm) at 10^0C with slight changes in quality.

Banik *et al.* (1988) reported that sapota fruits kept at 10-12^0C in PE bags with permanganate silica gel could be stored well upto 18 days with least PLW (11.91 %) while the untreated and unpacked had lost their shelf-life on 9^{th} day of storage.

Jadhav (1990) reported that custard apple under all the chemical treatments packed in polyethylene bags (100 gauge with 2 % vents) were fresh, turgid and glossy as compared to open fruits throughout the storage period. Unpacked fruits lost their marketability on 7^{th} day of storage.

Kariyanna *et al.* (1993) reported that packing of sapota Cv. Kalipatti fruits in PE bags (150 gauge with 1 % vents) reduced the physiological loss in weight significantly, but the spoilage due to fungal rot was maximum.

Venkatesha and Reddy (1994) recorded the least weight loss (25.55 %), more firmness and retarded ripening in guava fruits packed in PE bags. Extended shelf-life of 10 days was recorded in fruits packed in PE bags at room temperature as against only 3 days in control fruits.

Singh and Narayana (1995) concluded that packaging of mango Cv. Dashehari in PE bags (200 gauge with 0.5 % vents) extended their storage life, marketability and preserved quality better than control fruits upto 10 days under ambient conditions.

Geetha Lekshmi (1999) observed that custard apple fruits packed in perforated PE bags with ethylene absorbent delayed ripening by 2 days and the fruits were acceptable even on 6th day of storage.

Chamara *et al.* (2000) recorded that banana fruits Cv. Kolikuttu could be stored upto 24 days when packed under modified atmosphere conditions using low density polyethylene packaging (LDPE) at stored at 14^{0}C and 94 per cent RH.

Singh (2000) reported that packaging of guava fruits in 200 gauge PE bags with 0.25 and 0.50 per cent ventilation was found to extend shelf life of fruits upto 8 days at room temperature.

2.3.2 Corrugated fiber board packaging (CFB)

CFB is an important package form used in the transportation and distribution of fruits in most of the developing countries. CFB boxes have mostly substituted for wooden boxes in the advanced countries. CFB boxes are internationally accepted for packaging of horticultural produce. This package is light in weight, cause less damage to fruits, easy to handle, stack, pallatise and print, reduces the freight cost, improves the appearance of product and can be prepared from cheaper wood and other plant cellulose waste material. These CFB boxes have great potentialities for export market. At CFTRI, Mysore, a corrugated box with plastic tray has been designed for packaging of different fruits for export (Nanjundaswamy, 1991).

Gupta *et al.* (1981) studied the effect of various packaging materials on the storage behaviour of Kaithali and Umran ber and reported that hard board corrugated cartons of 1 to 5 kg capacity with 6 holes on two sides of 1 cm diameter with sufficient cushioning material retained good quality fruits for 9 to 12 days.

Anand and Maini (1982) reported that CFB cartons were satisfactory during transshipment and storage in conventional cool structures. The apple fruits suffered less bruising damage as compared to wooden boxes.

Joshi and Roy (1986) reported that CFB boxes were effective for transport and storage of mango Cv. Alphanso. They also recorded lower spoilage and shriveling in case of fruits stored in CFB boxes with 3 partitions.

Kaushal and Anand (1986) in their studies on grading and packaging of apple observed that fruit quality remained good when packed in CFB boxes.

Nikam (1994) in sapota Cv. Kalipatti reported that fruits packed in CFB boxes extended the shelf-life of fruit upto 15 days in cool chamber as against only 8 days at room temperature.

Chundawat and Rao (1996) during the packing trials conducted in Basrai and Lacatan varieties of banana revealed that packing of banana hands in fiber board cartons retarded ripening and extended the shelf-life of the fruits by 3-4 days at ambient temperature.

Waskar *et al.* (1997) reported that sapota fruits when packed in polyethylene bags + CFB boxes could extend shelf-life upto 8 days at room temperature, with minimum loss in weight and marketable qualities.

Damodaran *et al.* (1999) reported that sapota fruits treated with Kinetin 40 ppm and packed in CFB box with coir waste as filling material can be stored for 14 days after harvest with minimum PLW. These fruits also shown higher organoleptic values and better consumers appeal in rural and urban households.

Roy and Pal (2000) reported that ventilated corrugated fiber board (CFB) boxes were very useful for packaging and transportation of mangoes. This box has been successfully modified for export of different fruits on behalf of NAFED.

Sarkale (2000) during his studies on extending shelf-life of pomegranate observed that fruits treated with 12 per cent waxol and packed in CFB boxes shown extended shelf-life upto 15 days at room temperature and 90 days in cold storage conditions.

2.4 Storage environments

Storage is one of the most important aspects of postharvest handling of fruits. The main object of storage of fresh fruits is to extend their period of availability. The primary purpose of storage is to control the rate of transpiration, respiration, ripening and any other undesirable biochemical changes and disease infection. The loss of many perishable fruits can be prevented to a great extent by controlling the post harvest environmental conditions of temperatures, relative humidities, atmospheric concentration of certain gases and also by chemical treatments. The post harvest life of fruits is primarily dependent on storage temperature. The temperature not only regulate all the physiological activities but also affects the physico-chemical changes during storage.

2.4.1 Storage of fruits at room temperature (RT)

Flores and Rivas (1975) reported that under ordinary conditions sapota fruits keep well for 7-8 days from picking. Unripe fruits can be made ripen slowly by maintaing temperature between 12-14^{0}C so that they can keep well for 2 weeks.

Scott (1975) observed that simple polythene bagging with potassium permanganate as ethylene absorbent was adequate for extending the storage life of banana fruits by about a week at warm ambient temperature.

Broughton *et al.* (1977) reported that room temperature (28-32^{0}C) was practically unsuitable for storage of papaya fruits. A temperature of about 20^{0}C was found optimum both for ripening and satisfactory storage. Temperature above this made the fruits susceptible to fungal attack while at very low temperature may cause chilling injuries.

According to Broughton and Wong (1979) the sapota fruits are climacteric and the respiratory peak occurs at the same time or one or two days after peak ethylene production. At the optimum storage temperature of 20^{0}C, the storage life could be increased by removing ethylene and adding 5-10 per cent CO_2 to storage atmosphere.

Bal (1982) found unripe fruit of ber Cv. Sanaur-2 edible upto 7 days when stored at room temperature and fruit colour changes to greyish purple.

Bhullar *et al.* (1984) stored fully mature but unripe mango Cv. Langara and Dashehari at room temperature for 12 days.

Dhoot *et al.* (1984) stored 15 ppm NAA treated fruits of guava Cv. Sardar upto 12 days at room temperature.

Banik *et al.* (1988) reported that sapota fruits treated with 6 per cent waxol and 50 ppm NAA could be stored upto 12 days at room temperature without much deterioration of physico-chemical qualities.

Rao and Chundawat (1988) reported that under ordinary conditions, sapota fruits keep well for 5-7 days from picking.

Gautam and Chundawat (1990) reported in sapota Cv. Kalipatti the shelf-life of 11 days at room temperature when fruits were dipped in 300 ppm GA over non-treated fruits which ripened in 5 days.

Baviskar (1993) reported the properly ripe untreated fruits of ber Cv. Umran could be stored for about a week at room temperature. However, fruits could be stored upto 11 days when treated with 6 per cent waxol and packed in perforated PE bags.

Venkatesha and Reddy (1994) reported the shelf life of guava fruits at room temperature only 3 days as against 10 days, when packed in 300 gauge polyethylene bags.

Bangarusamy (2001) observed retarded ripening and longer shelf life upto 8 days under ambient conditions in sapota fruits when treated with 12 per cent waxol and packed in CFB boxes.

2.4.2 Storage of fruits in cool chamber (CC)

Based on the principle of evaporative cooling, low cost, low energy input cool chamber has been developed in the Division of Horticulture and Fruit Technology, IARI, New Delhi (Roy and Khurdiya, 1986). This can be used for storage of horticultural produce. Inside the cool chamber, temperature can be reduced by 15-20^{0}C than that of ambient temperature during the peak summer months. Further the relative humidity inside the cool chamber is maintained around 90 per cent even when ambient humidity falls below 20 per cent (Roy, 1982). In peak winter months also the average maximum temperature inside the cool chamber remains about 5^0C less than the average maximum ambient temperature. It has also been noticed that the ripening process of the fruits inside the cool chamber is uniform as compared to those riped under ambient temperature conditions.

Shukla (1979) observed that the storage life of jamun fruits is 6 days at room temperature and 3 weeks at low temperature (9 ± 1^0C) and high relative humidity (85-90 %) conditions when fruits were kept in PE bags.

Roy and Khurdiya (1983) reported that in fruits like ripe mangoes in summer, oranges in winter and ber in spring, the storage life was increased to 8, 27 and 12 days respectively in cool chambers as compared to 4,7 and 5 days respectively at ambient conditions.

Gupta (1985) observed that Gola, Kaithali and Umran ber fruits could be stored upto 18, 14 and 15 days respectively under evaporative cool storage conditions.

Singh (1987) reported the use of zero energy cool chamber for increasing the storage life of ber fruits Cv. Gola. Fruits were better in quality as well as physiological and biochemical factors as compared to room temperature.

Experiment of Arora and Narsimhan (1988) revealed that the storage life of coorg mandarine can be extended upto 20 days in evaporative cool storage conditions when fruits were treated with 6 per cent wax emulsion compared to 5 days in untreated fruits at ambient conditions.

In fruits like banana, the storage life is increased to 20.5 days in cool chamber compared to 14 days in ambient conditions (Waskar, 1989).

Gautam and Chudawat (1990) concluded that keeping sapota fruits initially for short duration in cold storage (4^{0}C) and then shifting to cool chamber (20^{0}C) extends its shelf life considerably upto 14 days.

Joshi and Paralkar (1991) reported less PLW at cool chamber in sapota fruits. The TSS and sugars increased gradually during ripening till it reached the peak and declined during post ripening irrespective of storage conditions

Joshi and Sawant (1991) during experiment carried out at KKV, Dapoli have indicated that tissue paper wrapping extended the shelf life of mature sapota fruits by delaying ripening process in cool chamber. These fruits recorded maximum moisture and TSS content with no appriciable difference in other chemical constituents.

Nagaraju (1991) observed that cool chamber storage delayed ripening process, rate of increase in PLW, TSS and sugars in bananas, mangoes and sapotas and also extended shelf-life by 3-5 days in Pairi mangoes.

Singh and Rana (1992) recorded reduced weight loss (5.90 %), increased TSS (10.22 %), decreased ascorbic acid (47.39 mg/100 ml juice) content in sweet orange Cv. Blood Red fruits. The packaging of fruits in PE bags maintains the edible quality up to 80 days in zero energy cool chamber.

Baviskar (1993) reported that ber fruits Cv. Umran, dipped in 6 per cent waxol and packed in PE bags and CFB boxes could be stored upto 15 days in cool chamber.

Reddy and Nagaraju (1993) reported increased shelf-life of 15 days of sapota fruits Cv. Kalipatti when stored in evaporative cool chamber. The rate of ripening, weight loss and spoilage were significantly low at cool chamber storage.

Chattopadhayay *et al.* (1994) extended the post harvest life of sapota fruits in cool chamber upto 29 days without any adverse effect on the palatability by treatment of fruits with 100 ppm GA_3.

Nikam (1994) during his studies on shelf-life of sapota Cv. Kalipatti recorded that when mature fruits are packed in perforated PE bags and kept at cool chamber can extend the shelf life upto 15 days without much deterioration in marketability.

Singh and Kumar (1997) stored fully mature fruits of aonla Cv. Chakaiya at room temperature and zero energy cool chamber and found that cool chamber is effective in reducing loss of ascorbic acid, loss in weight. But with increase in storage period, TSS and acidity increased continuously and ascorbic acid content decreased irrespective of storage conditions.

Khedkar (1997) observed that pomegranate fruits Cv. Ganesh remain in good condition upto 35 days in the cool chamber when treated with 6 % waxol and kept in CFB boxes.

Pal *et al.* (1997) reported that storage life of kinnow mandarins could be extended upto 40 days in evaporative cool chamber when treated with Bavistin and Semfresh as against only 15 days at room temperature.

Waskar and Masalkar (1997) observed in mango Cv. Kesar, Totapuri and Vanraj that when fruits hydro-cooled at 12^{0}C, given post harvest dip of Bavistin (1000 ppm) and stored at room temperature (22-35^{0}C, 47-83 % RH) and in cool chamber (16-22 ^{0}C, 92-95 % RH) recorded extended shelf-life of 25,26 and 31 respectively in cool chambers as against 17, 21 and 19 days at room temperature.

Ladaniya and Singh (1998) observed that film wrapping of Nagpur mandarin and their storage in evaporative cool chamber increased shelf-life upto 12 days with good marketability and less loss in weight.

MATERIALS AND METHODS

3. MATERIAL AND METHODS

The present investigation entitled "Studies on extension of shelf-life of sapota [*Manilkara achras* (Mill) Fosberg] fruits Cv. Kalipatti" was undertaken at the Post Harvest Technology Laboratory, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri during summer season of 1999-2000.

The experimental material, sapota fruit was obtained from uniform and healthy trees of Kalipatti variety grown in Instructional-Cum-Research orchard of Department of Horticulture. For this purpose fruits of uniform size, shape and colour were harvested at proper stage of maturity. Then fruits were brought to the laboratory for conducting experiment.

3.1 Experimental details

The experiment was conducted in Factorial Completely Randomized Design (FCRD) with three replications and 12 treatment (Table 1) comprising of four chemicals and three packaging materials. The treatment details were as follows.

3.1.1 Post harvest treatments

Total treatments = 4 chemicals x 3 packagings = 12

3.1.1.1 Chemicals

1. Control (Untreated)
2. Gibberellic acid (75 ppm)
3. Cycocel (500 ppm)

4. Waxol (6 %)

3.1.1.2 Packagings

1. Control (Unpacked)
2. Polyethylene bags (150 gauge with 1.2 vents)
3. Corrugated fiber Board Boxes (CFB)

The experiment was carried out at two different storage environments i.e. the treated sapota fruits were stored at room temperature (RT) and zero energy cool chamber (CC).

Table 1. Treatment combinations

Sr.No.	Treatment combinations
1.	Control (untreated) + Control (unpacked)
2.	Control (untreated) + PE bags
3.	Control (untreated) + CFB boxes
4.	75 ppm GA + Control (unpacked)
5.	75 ppm GA + PE bags
6.	75 ppm GA + CFB boxes
7.	500 ppm cycocel + control (unpacked)
8.	500 ppm cycocel + PE bags
9.	500 ppm cycocel + CFB boxes
10.	6 % waxol + control (unpacked)
11.	6 % waxol + PE bags
12.	6 % waxol + CFB boxes

3.1.2 Treatment application

3.1.2.1 Chemicals

1. Control (untreated)

The fruits were washed with distilled water and then surface dried in shade at room temperature.

2. 75 ppm Gibberellic acid (GA)

Two grams of GA was dissolved in a little amount of ethyl alcohol (just sufficient to dissolve) and with distilled water volume was made to one liter. From this stock solution, desired concentration as per treatment (75 ppm) was prepared by diluting with distilled water and used for dipping the fruits. The fruits were dipped in this solution for three minutes and surface dried in room temperature.

3. 500 ppm cycocel (CCC)

The stock solution was prepared by dissolving 4 gm of cycocel in little amount of distilled water and diluted it with distilled water to 2 liters. From this stock solution, desired concentration as per treatment (500 ppm) was prepared by diluting with distilled water and used for dipping of fruits. The fruits were dipped for one minute and surface dried in room temperature.

4. 6 % waxol

6 % waxol was brought from M/S. Stayfresh, Post-Harvest Chemicals, Belapur, Navi Mumbai in readymade form. Fruits were immersed in 6 % waxol for 3 minutes and surface dried in room temperature.

3.1.2.2 Packagings

1. Control (Unpacked)

The treated fruits weighing 2 kg were kept in plastic baskets without any packaging i.e. open fruits.

2. Polyethylene bags

Polyethylene bags of 25 x 40 cm size and 150 gauge thickness were brought from the market. With the help of punching machine, they were punched for 1.2 per cent vents. The treated and dried fruits weighing 2 kg each were packed in each polyethylene bag.

3. Corrugated fiber board boxes (CFB)

In each CFB box of 35 x 25 x 10 cm size having 4 holes of 1 cm diameter, 2 kg treated and dried fruits were spread evenly in single layer. Sufficient cushioning material of waste paper was used below the fruits.

3.1.3 Storage conditions

a. At room temperature (RT)

The unpacked fruits, fruits packed in PE bags and CFB boxes were kept at room temperature.

b. In cool chamber (CC)

The unpacked fruits, fruits packed in PE bags and CFB boxes were also kept in cool chamber.

Based on the principle of direct evaporative cooling, the design and construction of low cost, low energy input cool chamber

Plate 1. Storage of sapota fruits in zero energy cool chamber

was made as per the method described by Anonymous (1985). The cool chamber was made saturated with water by sprinkling water once in the morning and once in the evening to maintain the temperature and relative humidity. The treated fruits were kept in plastic crates and these crates were stored in CC. A thin sheet of polyethylene was placed on the top of the crates in order to avoid any dripping of water from the top cover.

The temperature (^{0}C) and relative humidity (%) both inside and outside the cool chamber were recorded with the help of wet bulb and dry bulb thermometer during the entire period of experiment. It ranged between 20-38^{0}C and 55-70 % at RT and 10-22^{0}C and 80-95 % in CC respectively (Appendix I and II).

Under each treatment, two sets of 2 kg fruits were maintained. One set was used for recording weight loss, rotting per cent, fruit softening and fruit skin shrinkage at every alternate day. The other set was used for chemical analysis after every alternate day and organoleptic evaluation was done at edible ripe stage. For analysis of fresh fruit, before treatment application, ten fruits were randomly selected from the whole lot and used for analysis.

3.2 Details of observations

The observations in respect of weight loss, rotting, fruit softening and fruit skin shrinkage were recorded on every alternate day. The observations regarding other bio-chemical parameters were recorded initially as fresh fruits and then at one day interval for fruits stored at room temperature and in cool chamber.

3.2.1 Physical properties

3.2.1.1 Total weight loss

Immediately after treatment application, the weight of fruits under each treatment was taken. After wards, the weight was recorded at an interval of one day. At each observation, the rotten fruit, if any, was removed and the weight was taken. The weight of rotten fruit was also taken. The cumulative weight loss both on account of physiological weight loss and rotting was recorded. Weight loss was expressed in percentage as

$$\% \text{ total weight loss} = \frac{\text{Initial weight of fruits - Final weight}}{\text{Initial weight}} \times 100$$

3.2.1.2 Rotting percentage

The observations in respect of rotting was recorded at every alternate day. At the time of observation of weight loss, the rotten fruit, if any, was removed and weighed. The percentage of weight loss on account of rotting was also worked out.

3.2.1.3 Fruit softening

The progress of fruit ripening as denoted by fruit softening was observed by finger feel at every alternate day. The intensity of softening was worked out on 0 to 4 scale as described by Kumbhar and Desai (1986) and Nikam (1994) is given below.

Degree of softening	Score
Hard	0
Slightly soft	1
Medium soft	2
Considerable soft	3
Complete soft	4

At each observation, the stage of softening of each fruit under each treatment was noted and the score was given. The scores obtained by all the fruits under a treatment were summed up and divided by the number of fruits to obtain the average score of that treatment on that day.

3.2.1.4 Fruit skin shrinkage

The progress of development of fruit skin shrinkage was observed visually at every alternate day. The intensity of skin shrinkage was worked out on 0 to 4 scale as described by (Kumbhar and Desai, 1986) and Nikam (1994) is given below.

Intensity of shrinkage	Score
No shrinkage	0
Slightly shrinkage	1
Medium shrinkage	2
Heavy shrinkage	3
Complete shrinkage	4

The average score for shrinkage was worked out for each treatment as described earlier in fruit softening. The fruits scoring more than 3 out of 4 score were considered as lost commodity.

3.2.2 Chemical properties

3.2.2.1 Total soluble solids (TSS)

The content of total soluble solids (%) in the pulp was estimated by using a Erma Tokyo A^{0}32 hand refractometer and the values were corrected to 20^{0}C with the help of temperature correction chart (A.O.A.C., 1975) and expressed in percentage.

3.2.2.2 Acidity (%)

The titratable acidity percentage of the pulp was determined by titrating ten grams of macerated pulp and diluted with 100 ml of distilled water. This solution was titrated against 0.1 N NaOH solution using phenolphthelin as an indicator as per the procedure given by Ranganna (1979). The per cent acidity was expressed in terms of malic acid. Multiplying factor was 0.02235.

$$\%\ \text{total acid} = \frac{\text{Titre x Normality of alkali x Eq.wt. of acid x 100}}{\text{Weight of pulp taken x 1000}}$$

3.2.2.3 Sugars

The reducing and total sugars (%) of the pulp were estimated by the volumetric method of Lane and Eynon (1960) as reported by Ranganna (1979). The non-reducing sugars (%) were calculated by deducting the reducing sugars from total sugars.

3.2.3 Organoleptic evaluations

The organoleptic evaluation in respect of colour, flavour, texture and palatability of the pulp at edible ripe stage of sapota fruit was worked out by judges using one to nine point Hedonic scale (Amerine et al., 1965) as given below

Organoleptic score	Rating
9	Like extremely
8	Like very much
7	Like moderately
6	Like slightly
5	Neither like nor dislike
4	Dislike slightly
3	Dislike moderately
2	Dislike very much
1	Dislike extremely

The final rating was calculated by averaging the score. A score of 5.5 and above was rated as acceptable and treatment showing score less than 5.5 was terminated.

3.2.4 Statistical analysis

Analysis of variance for all the characters except organoleptic evaluation was done as per the method of analysis of variance as given by Gomez and Gomez (1984).

EXPERIMENTAL RESULTS

4. EXPERIMENTAL RESULTS

The present investigation was undertaken with a view to study the effect of various chemicals and packaging materials under different storage environments on the shelf-life and changes in physico-chemical characteristics of sapota fruits Cv. Kalipatti during storage.

The periodical observations of physico-chemical parameters were recorded. Data pertaining to cumulative total weight loss (%), rotting (%), fruit softening, fruit skin shrinkage, total soluble solids (TSS %), acidity (%), reducing, non-reducing and total sugars (%) and organoleptic evaluation of sapota fruits as influenced by various pre-storage treatments and storage environments are presented hereunder.

4.1 Cumulative total weight loss (%)

The data regarding effect of various chemicals and packaging materials on the cumulative total weight loss (%) during the course of storage at RT and in CC have been given in Table 2 and 3 respectively and graphically represented in Fig. 1 (for RT) and Fig. 3 (For CC) respectively.

The data in Table 2 and 3 indicated that, at all the stages (days) of storage, both at RT and in CC, the total weight loss (%) of the fruits was significantly influenced by various chemicals and

Table 2. Effect of various chemicals and packaging materials on cumulative total weight loss (%) of sapota fruits at RT storage conditions

Treatment combinations	Days to storage			
	2nd	4th	6th	8th
Initial value	0.00	0.00	0.00	0.00
T_1	2.84	8.66	17.42	29.02
T_2	2.15	5.05	12.47	22.20
T_3	2.40	6.87	12.81	26.43
T_4	2.38	6.35	13.00	28.10
T_5	1.67	3.86	7.57	21.00
T_6	2.02	4.48	10.22	20.90
T_7	2.56	7.51	15.62	28.88
T_8	1.90	4.35	9.80	21.90
T_9	2.15	5.42	11.82	25.78
T_{10}	1.89	5.66	10.42	27.27
T_{11}	1.35	3.18	6.92	17.90
T_{12}	1.68	4.05	9.02	21.08
A. Means for chemicals				
1. Untreated	2.46	6.86	14.23	25.89
2. GA (75 ppm)	2.02	4.89	10.27	23.38
3. Cycocel (500 ppm)	2.20	5.76	12.42	25.52
4. Waxol (6 %)	1.64	5.30	8.79	22.06
B. Means for packagings				
1. Unpacked	2.42	7.04	14.12	28.32
2. PE bags	1.77	4.11	9.19	20.75
3. CFB boxes	2.06	5.20	10.97	23.52
Chemicals				
S.E. ±	0.027	0.065	0.142	0.290
CD at 5 %	0.079	0.190	0.414	0.847
Packagings				
S.E. ±	0.023	0.056	0.123	0.251
CD at 5 %	0.069	0.164	0.359	0.733
Interactions				
S.E. ±	0.047	0.112	0.246	0.503
CD at 5 %	N.S.	0.328	0.719	1.46

Table 3. Effect of various chemicals and packaging materials on cumulative total weight loss (%) of sapota fruits at CC storage conditions

Treatment combinations	Days to storage							
	2nd	4th	6th	8th	10th	12th	14th	16th
Initial value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T_1	0.90	1.95	3.58	5.92	9.76	14.01	22.60	36.12
T_2	0.21	1.30	2.51	4.10	6.68	9.61	16.22	29.13
T_3	0.46	1.56	2.87	4.45	7.81	10.91	19.21	33.42
T_4	0.37	1.36	2.81	3.55	7.22	10.43	19.81	32.03
T_5	0.15	0.91	1.84	2.95	5.31	8.63	14.23	24.20
T_6	0.23	1.01	2.35	3.34	6.20	9.43	16.81	27.92
T_7	0.51	1.59	3.02	4.61	8.20	12.02	21.71	35.81
T_8	0.20	1.22	1.97	3.38	6.30	9.52	16.38	26.60
T_9	0.36	1.38	2.55	3.86	7.1	10.92	19.64	31.09
T_{10}	0.25	1.23	2.32	3.45	6.63	9.91	17.41	29.78
T_{11}	0.10	0.85	1.65	2.68	3.74	5.85	9.54	19.20
T_{12}	0.18	0.95	1.94	3.01	5.43	9.39	14.90	25.51
A. Means for chemicals								
1. Untreated	0.52	1.60	2.99	4.83	8.08	11.51	19.34	32.88
2. GA (75 ppm)	0.25	1.09	2.33	3.28	6.24	9.50	16.95	28.05
3. Cycocel (500 ppm)	0.36	1.40	2.51	3.95	7.20	10.82	19.24	31.37
4. Waxol (6 %)	0.18	1.01	1.97	3.22	5.27	8.38	13.95	24.83
B. Means for packagings								
1. Unpacked	0.51	1.53	2.93	4.51	7.95	11.59	20.39	33.43
2. PE bags	0.17	1.07	1.99	3.28	5.51	8.40	14.09	24.78
3. CFB boxes	0.31	1.23	2.43	3.67	6.64	10.16	17.64	29.63
Chemicals								
S.E. ±	0.0058	0.015	0.028	0.121	0.081	0.120	0.211	0.357
CD at 5 %	0.0171	0.044	0.082	0.352	0.236	0.352	0.617	1.04
Packagings								
S.E. ±	0.0051	0.013	0.024	0.105	0.070	0.105	0.183	0.309
CD at 5 %	0.0148	0.038	0.070	0.305	0.205	0.305	0.534	0.901
Interactions								
S.E. ±	0.010	0.026	0.048	0.0210	0.140	0.210	0.367	0.418
CD at 5 %	0.0296	0.076	0.0141	N.S.	0.409	0.610	1.07	1.232

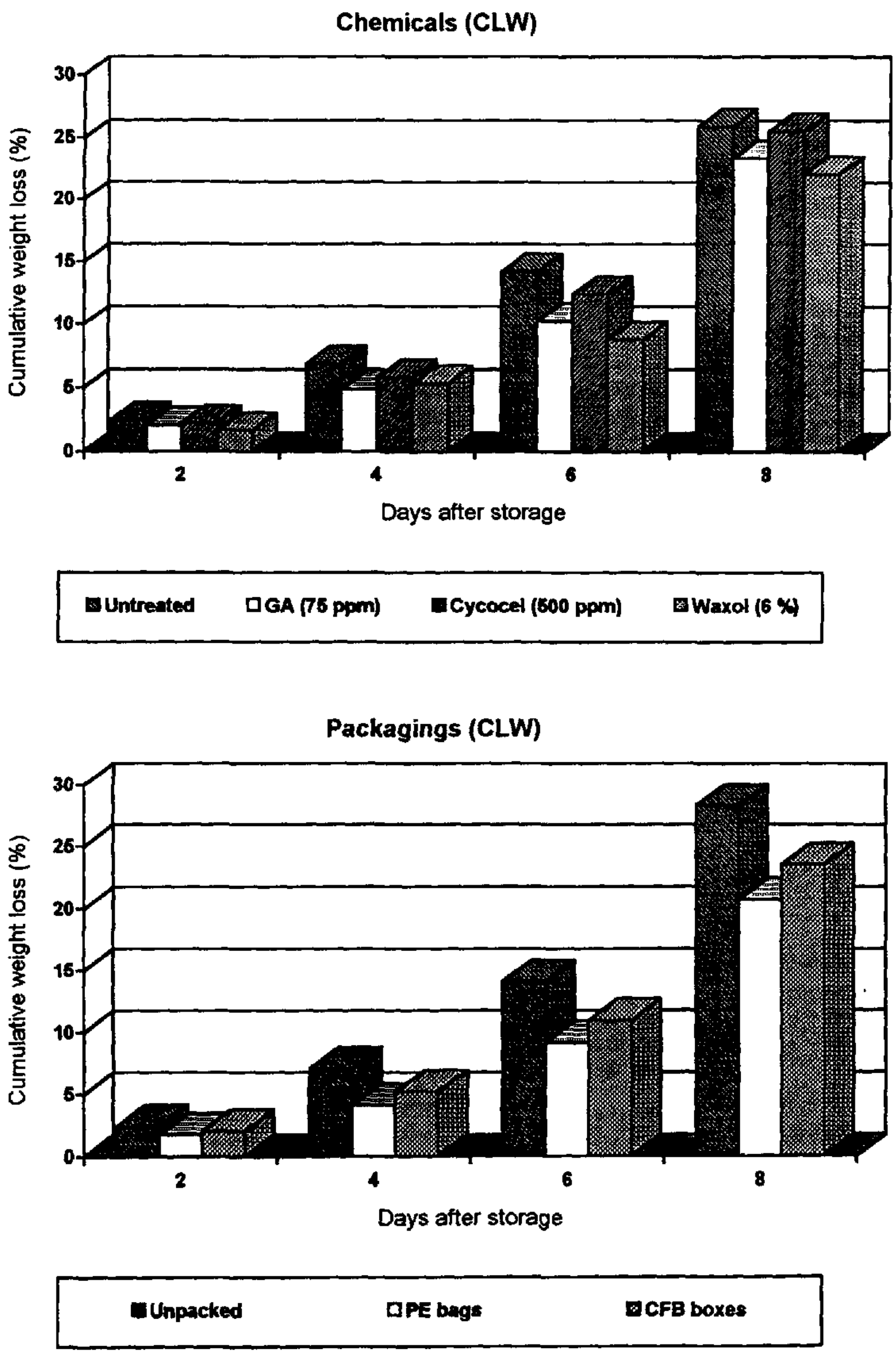

Fig. 1. Effect of various chemicals and packaging materials on cumulative total weight loss (%) of sapota fruits at RT storage conditions

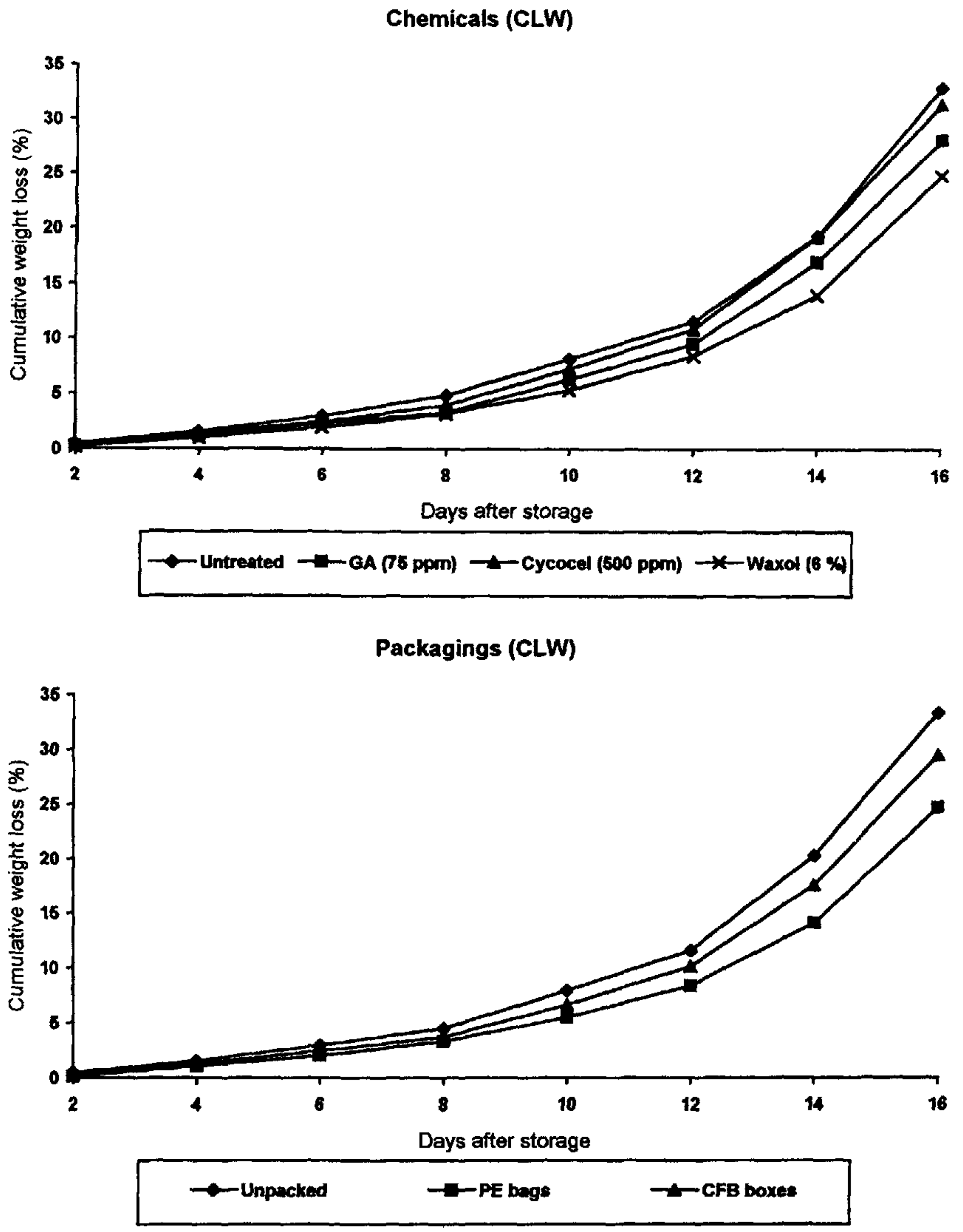

Fig. 2. Effect of various chemicals and packaging materials on cumulative total weight loss (%) of sapota fruits in CC storage conditions

packagings. The interaction between chemicals and packaging was also found to be significant most of times.

It was revealed from Fig. 1 that as the storage period at RT progressed, the total weight loss was increased irrespective of storage treatments. At all the stages (days) of storage, the untreated fruits showed the highest total weight loss and 6 per cent waxol treated fruits showed the lowest total weight loss. On 8^{th} day of storage at RT, 6 per cent waxol treated fruits recorded only 22.06 per cent weight loss (Table 2). As regards the packaging at all the stages (days) of storage, the cumulative weight loss in unpacked fruits was very high as against the fruits packed in CFB boxes and fruits packed in PE bags (Fig. 1). Packing of fruits in PE bags recorded the lowest cumulative weight loss (20.75 %) at the end of 8^{th} day at RT (Table 2). Among the various treatment combinations, on 8^{th} day of storage, the lowest cumulative total weight loss (17.90 %) was recorded in fruits treated with 6 % waxol and packed in PE bags (T_{11}) and the highest cumulative total weight loss (29.02 %) was recorded in untreated fruits kept open (T_1).

It is revealed from Fig. 2 that the same trend of continuous increase in total weight loss during the course of storage irrespective of storage treatments was observed in CC conditions but at a slower rate. At all the stages (days) of storage in CC, all the chemical treated fruits had significantly lower cumulative total weight loss than untreated fruits and the lowest weight loss was observed in 6 % waxol treated fruits (Fig. 2). On 16th day of storage in CC, 6 % waxol treated fruits recorded the lowest (24.83 %) cumulative total weight loss as against 32.88 per cent in untreated fruits (Table 3). As regards packagings, at all the stages of storage (days), packed fruits had lower cumulative total weight loss as against unpacked fruits and the lowest weight loss was recorded in fruits packed in PE bags (Fig. 2). On 16th day of storage in CC, the fruits packed in PE bags recorded significantly lowest cumulative total weight loss (24.78 %) as against 29.63 per cent in fruits packed in CFB boxes and 33.43 per cent in unpacked fruits (Table 3). As regards the various treatment combinations, on 16th day of storage, the lowest cumulative total weight loss (19.20 %) was recorded in fruits treated with 6 per cent waxol and packed in PE bags (T_{11}) and the highest cumulative weight loss (36.12 %) was recorded in untreated fruits kept open (T_1).

In general, it was found that, as the storage period progressed, the cumulative total weight loss (%) was increased both at RT and CC. The rate of increase in weight loss was faster in untreated fruits than in treated fruits and in unpacked fruits than in packed fruits. It was also clear from the data that increase in weight loss was at slower rate in CC storage than at RT storage conditions. Among all the treatment combinations, 6 per cent waxol + PE bags (T_{11}) was the best combination wherein the pace of cumulative total weight loss, at all the stage (days) was the lowest, under both the storage conditions.

4.2 Rotting (%)

The data regarding effect of various chemicals and packaging materials on rotting (%) of sapota fruits at RT and in CC have been graphically represented in Fig. 3 and 4 respectively and given in Table 4 . The data clearly indicates that the chemical and packaging treatments significantly influenced the rotting of sapota fruits. Interaction between chemicals and packaging was also found to be significant.

It was obvious from the Table 4 that upto 5^{th} day, no rotting was observed in sapota fruits in any of the treatment combination at RT storage and hence, the data from 6^{th} day onwards have been graphically presented in Fig. 3. Similarly, the data in respect of rotting (%) of sapota fruit in CC storage from 12^{th} day onwards have been graphically presented in Fig. 4.

It will be revealed from the Fig. 3 (at RT) and Fig. 4 (in CC) that as the storage period progressed, the rotting (%) was increased irrespective of storage treatments. Among the chemical treatments, the untreated fruits showed the highest rotting (%) and fruits treated with 6 per cent waxol recorded the lowest rotting (%) at the end of storage life. Among the packagings, the rotting (%) in the fruits kept open was the highest and fruits packed in PE bags recorded the lowest rotting (%) at the end of storage life (Table 4).

Table 4. Effect of various chemicals and packaging materials on rotting (%) of sapota fruits at RT and in CC storage conditions

Treatment combinations	At RT		In CC		
	Days after storage		Days after storage		
	6th	8th	12th	14th	16th
Initial value	0.00	0.00	0.00	0.00	0.00
T_1	15.80	23.31	8.66	11.46	14.45
T_2	9.96	16.44	4.85	8.70	11.90
T_3	12.22	19.72	6.24	9.98	13.25
T_4	11.91	18.65	4.90	6.96	10.45
T_5	7.05	11.52	2.35	5.43	8.48
T_6	9.12	15.32	3.80	6.00	9.67
T_7	12.52	19.18	6.11	8.55	11.64
T_8	8.65	13.20	3.58	6.18	9.51
T_9	11.20	16.46	4.67	7.23	10.13
T_{10}	10.80	15.28	3.64	6.24	9.25
T_{11}	5.84	10.15	1.72	4.69	7.28
T_{12}	8.04	12.10	2.16	6.16	8.75
A. Means for chemicals					
1. Untreated	12.66	19.82	6.57	10.05	13.20
2. GA (75 ppm)	9.36	15.16	3.68	6.13	9.53
3. Cycocel (500 ppm)	10.79	16.28	4.79	7.32	10.43
4. Waxol (6 %)	8.23	12.51	2.51	5.70	8.43
B. Means for packagings					
1. Unpacked	12.76	19.10	5.83	8.30	11.45
2. PE bags	7.88	12.83	3.13	6.25	9.29
3. CFB boxes	10.14	15.90	4.22	7.35	10.45
Chemicals					
S.E. ±	0.129	0.201	0.058	0.098	0.131
CD at 5 %	0.377	0.586	0.168	0.284	0.382
Packagings					
S.E. ±	0.112	0.174	0.050	0.085	0.113
CD at 5 %	0.326	0.507	0.146	0.246	0.330
Interactions					
S.E. ±	0.326	0.507	0.146	0.246	0.330
CD at 5 %	0.652	0.780	0.292	0.492	0.662

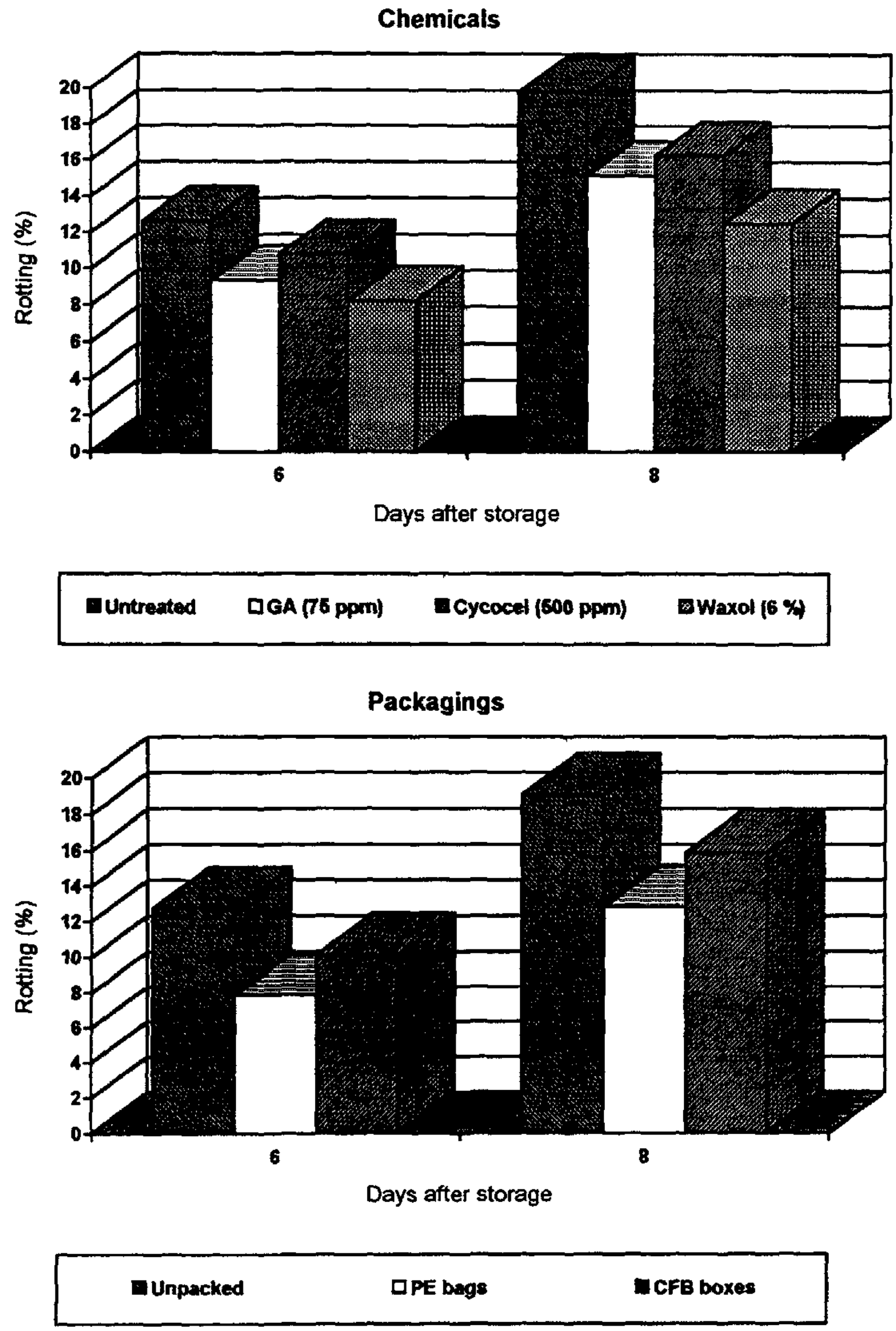

Fig. 3. Effect of various chemicals and packaging materials on rotting (%) of sapota fruits at RT storage conditions

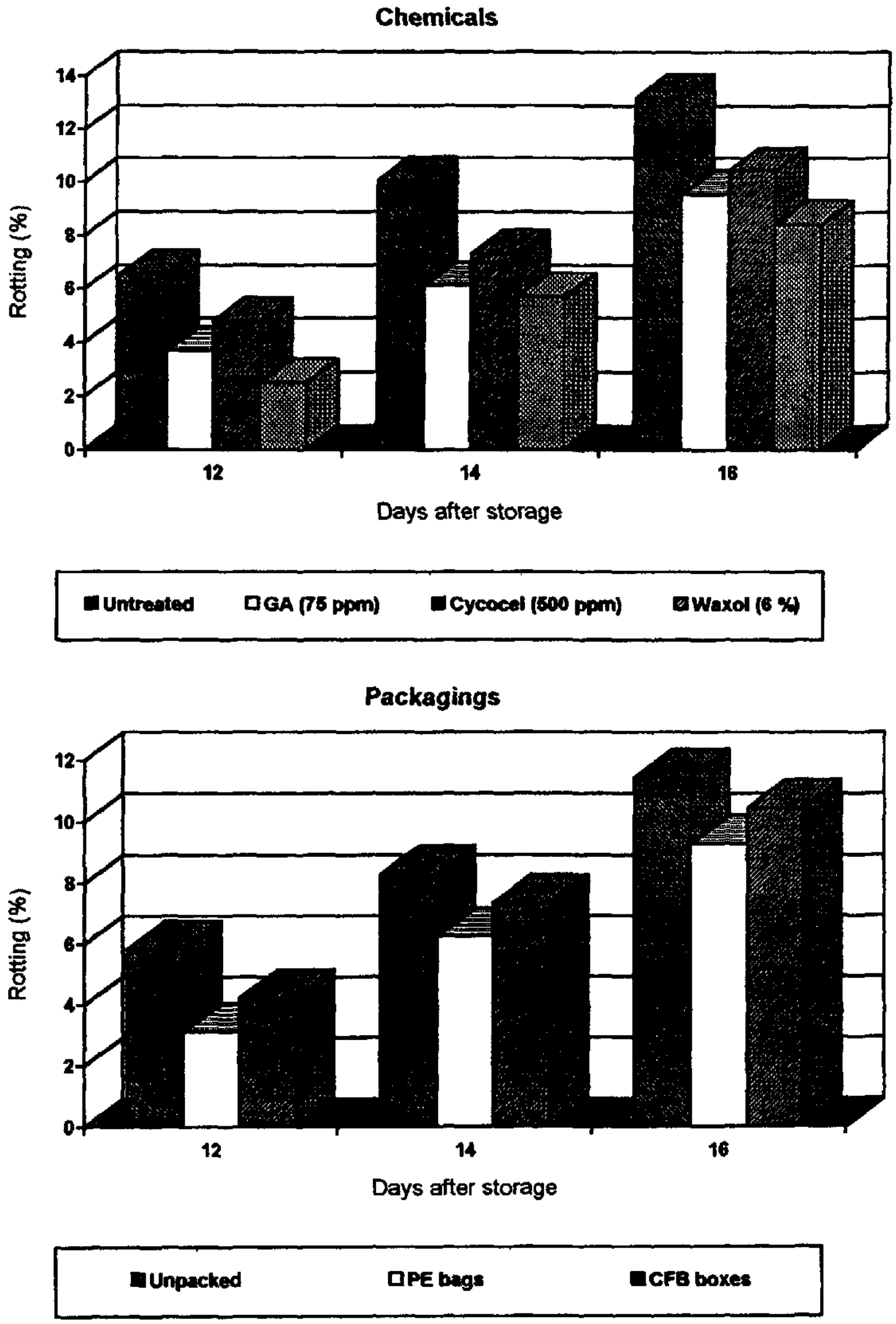

Fig. 4. Effect of various chemicals and packaging materials on rotting (%) of sapota fruits in CC storage conditions

Plate 2. Isolation of micro-organisms associated with spoilage of sapota fruits during storage

A. *Aspergillus niger* B. *Fusarium* sp.

It will be seen from Table 4 that at RT storage, on 8th day the rotting in untreated fruits was the highest (19.82 %), while the fruits treated with 6 % waxol recorded the lowest (12.51 %) rotting. Among the packagings, fruits packed in PE bags registered the lowest (12.83 %) rotting as against the highest (19.10 %) rotting in unpacked fruits. As regards treatment combinations, fruits treated with 6 % waxol and packed in PE bags (T_{11}) recorded only 10.15 per cent rotting as against 23.31 per cent rotting in untreated fruits kept open (T_1).

Similarly, in CC storage, on 16th day the highest rotting (13.20 %) was recorded in untreated fruits while 6 per cent waxol treated fruits recorded the lowest (8.43 %) rotting. Among the packagings fruits that were unpacked recorded the highest (11.45 %) rotting and the lowest (9.29 %) rotting was observed in fruits packed in PE bags. In case of treatment combinations, fruits treated with 6 per cent waxol and packed in PE bags (T_{11}) recorded the lowest (7.28 %) rotting and untreated fruits kept open (T_1) recorded the highest (14.45 %) rotting at the end of storage life.

To sum up as the storage period progressed, both at RT and in CC, the rotting (%) was increased irrespective of storage treatments. The rotting in fruits kept at RT storage condition was higher as against low in the fruits stored in cool chamber. The isolation and culturing of organisms causing rotting was done. It was clear that *Fusarium* sp. and *Aspergillus niger* were associated with rotting of sapota fruits under both the storage conditions.

4.3 Fruit softening

The data in respect of effect of various chemicals and packaging materials on the progress of fruit softening during the course of storage at RT and in CC have been presented in the Tables 5 and 6 respectively.

The data presented in the Table 5 revealed that at all the stages (days) of storage at RT, the fruit softening score was significantly influenced by various chemicals, packagings and their interactions. As regards the chemical treatments, on 2nd day, the highest fruit softening score was observed in untreated fruits (1.02) and the lowest score (0.59) was observed in 6 per cent waxol treated fruits. At all the stages (days) of storage, the untreated fruits had the highest fruit softening score and 6 per cent waxol treated fruits had the lowest fruit softening score. Among the packagings, by the end of 2nd day, unpacked fruits recorded the highest fruit softening score (1.12) while the lowest fruit softening score (0.57) was recorded in fruits packed in PE bags, followed by fruits packed in CFB boxes recorded 0.63 fruit softening score. The progress of fruit softening was the highest in open fruits and lowest in polyethylene packed fruits.

As regards the various treatment combinations at RT storage, fruit softening was first noticed in untreated + unpacked

Table 5. Effect of various chemicals and packaging materials on the changes of fruit softening of sapota fruits at RT storage conditions

Treatment combinations	Days to storage			
	2nd	4th	6th	8th
Initial value	0.00	0.00	0.00	0.00
T_1	1.65	2.89	4.00	4.00
T_2	0.66	1.78	2.19	3.57
T_3	0.74	1.95	2.43	3.75
T_4	0.93	2.12	2.21	3.50
T_5	0.57	1.43	1.77	3.08
T_6	0.69	1.85	1.93	3.24
T_7	1.04	2.26	2.48	3.83
T_8	0.63	1.62	1.90	3.31
T_9	0.72	1.93	2.12	3.56
T_{10}	0.84	2.04	2.18	3.26
T_{11}	0.42	1.25	1.51	2.99
T_{12}	0.50	1.63	1.72	3.13
A. Means for chemicals				
1. Untreated	1.02	2.20	2.87	3.77
2. GA (75 ppm)	0.73	1.80	1.97	3.27
3. Cycocel (500 ppm)	0.80	1.94	2.16	3.58
4. Waxol (6 %)	0.59	1.64	1.82	3.12
B. Means for packagings				
1. Unpacked	1.12	2.33	2.73	3.64
2. PE bags	0.57	1.52	1.84	3.25
3. CFB boxes	0.63	1.84	2.05	3.41
Chemicals				
S.E. ±	0.0043	0.0078	0.0314	0.0132
CD at 5 %	0.0125	0.0228	0.0914	0.039
Packagings				
S.E. ±	0.0037	0.0068	0.0272	0.011
CD at 5 %	0.0109	0.0198	0.0792	0.034
Interactions				
S.E. ±	0.0075	0.0135	0.0544	0.023
CD at 5 %	0.0217	0.0395	0.158	0.067

Table 6. Effect of various chemicals and packaging materials on the changes of fruit softening of sapota fruits in CC storage conditions

Treatment combinations	Days to storage							
	2nd	4th	6th	8th	10th	12th	14th	16th
Initial value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T_1	0.61	1.21	1.98	3.07	3.88	4.00	4.00	4.00
T_2	0.05	0.73	1.33	2.29	2.69	3.42	3.88	3.95
T_3	0.33	0.88	1.50	2.43	3.04	3.70	3.96	4.00
T_4	0.33	0.82	0.94	1.58	2.72	3.58	3.46	4.00
T_5	0.00	0.25	0.67	1.09	1.95	2.75	3.05	3.15
T_6	0.13	0.39	0.80	1.34	2.18	3.06	3.32	3.31
T_7	0.40	0.98	1.17	2.06	2.88	4.00	4.00	4.00
T_8	0.04	0.51	0.85	1.59	2.20	3.11	3.80	3.93
T_9	0.23	0.63	0.93	1.77	2.56	3.52	3.92	4.00
T_{10}	0.26	0.64	0.82	1.32	2.02	3.26	3.26	4.00
T_{11}	0.00	0.11	0.48	0.98	1.61	2.39	2.88	3.10
T_{12}	0.08	0.15	0.54	1.10	1.70	2.70	3.08	3.22
A. Means for chemicals								
1. Untreated	0.33	0.94	1.60	2.60	3.20	3.71	3.95	3.99
2. GA (75 ppm)	0.15	0.49	0.80	1.34	2.28	3.13	3.29	3.49
3. Cycocel (500 ppm)	0.23	0.71	0.98	1.81	2.55	3.54	3.90	3.98
4. Waxol (6 %)	0.11	0.30	0.61	1.13	1.78	2.78	3.07	3.44
B. Means for packagings								
1. Unpacked	0.40	0.91	1.23	2.01	2.88	3.71	3.81	4.00
2. PE bags	0.02	0.40	0.83	1.49	2.12	2.92	3.40	3.53
3. CFB boxes	0.19	0.51	0.94	1.66	2.37	3.24	3.56	3.80
Chemicals								
S.E. ±	0.0043	0.0049	0.012	0.016	0.017	0.016	0.015	0.0068
CD at 5 %	0.0126	0.0143	0.035	0.048	0.050	0.046	0.043	0.0198
Packagings								
S.E. ±	0.0038	0.0043	0.010	0.014	0.015	0.014	0.013	0.0059
CD at 5 %	0.0110	0.0125	0.030	0.041	0.043	0.040	0.037	0.0172
Interactions								
S.E. ±	0.0075	0.0085	0.021	0.028	0.030	0.027	0.026	0.0117
CD at 5 %	0.0219	0.0250	0.061	0.083	0.088	0.079	0.075	0.0343

fruits (T_1). At the end of 2nd day, fruit softening was noticed in all the treatment combinations, however, it was at higher side in unpacked fruits as against packed fruits and in untreated fruits as against treated fruits. Complete fruit softening (score : 4.0) was first observed at the end of 6th day in the fruits which were neither treated nor packed (T_1). At the end of 8th day all the untreated fruits (T_1, T_2 and T_3), 75 ppm GA treated fruits and kept open (T_4) and packed in CFB box (T_6), 500 ppm cycocel treated fruits + unpacked (T_7), 500 ppm cycocel + PE bags (T_8), 500 ppm cycocel + CFB box (T_9) recorded more than 3 out of 4 fruits score, which was considered as unacceptable. Even on 8th day of storage at RT, the 6 % waxol treated fruits packed in PE bags (T_{11}) had scored the lowest fruit softening score (2.99) which was considered acceptable for consumption and marketing.

The data presented in Table 6 shows fruit softening scores of sapota fruits in CC storage. From the data it revealed that at all the stages (days) of storage in CC, the fruit softening score was significantly influenced by various chemicals, packagings and their interactions. In case of chemical treatments, on 2nd day, the highest fruit softening score was recorded in untreated fruit (0.33) and the lowest score (0.11) was recorded in 6 per cent waxol treated fruits. At all the stages (day) of storage, the untreated fruits recorded the highest fruit softening score and 6% waxol treated fruits had the lowest score. Among the packagings, by the end of 2nd day, unpacked fruits recorded the highest fruit softening score (0.40) while the lowest fruit softening score (0.02) was recorded in fruits packed in PE bags. The progress of fruit softening was the highest in unpacked fruits and the lowest in polyethylene packed fruits.

As regards various treatment combinations, in CC storage, at the end of 2nd day, fruit softening was noticed in all the treatment combinations except 6% waxol + PE bags (T_{11}) and 75 ppm GA + PE bag (T_5). However, it was at higher side in unpacked fruits as against packed fruits and in untreated fruits as against treated fruits. Complete fruit softening (Score : 4.0) was first observed at the end of 12th day in untreated + unpacked (T_1) fruits and 500 ppm Cycocel + unpacked (T_7) fruits. On 16th day of storage in CC, all the untreated fruits (T_1, T_2, T_3), 75 ppm GA + unpacked (T_4), 500 ppm Cycocel + unpacked (T_7), 500 ppm Cycocel + CFB boxes (T_9) and 6% waxol + untreated (T_{10}) were fully soften. On the same day, the lowest fruit softening score was recorded (3.10) in 6% waxol treated fruits packed in PE bags (T_{11}), which was considered to be acceptable for consumption and marketing.

An overall assessment in respect of fruit softening during the course of storage, both under RT and CC storage conditions, it was found that with the advancement of storage period, fruit softening was increased irrespective of storage treatment. The progress of fruit softening was faster in untreated fruits than in treated fruits and in unpacked fruits than in packed fruits. It was also clear from the data that the progress of fruit softening was found to be slower in CC storage as against RT storage conditions. Among all the treatment combinations, 6% waxol + PE bags (T_{11}) was the best combination wherein the progress of fruit softening, at all the stages (days) was the lowest, under both the storage conditions.

4.4 Fruit skin shrinkage

The data in respect of various chemicals and packaging materials on the progress of fruit skin shrinkage of sapota fruits during the course of storage at RT and in CC have been presented in the Table 7 and 8 respectively.

The data presented in the Table 7 revealed that at all the stages (days) of storage at RT, the fruit skin shrinkage was significantly affected by various chemicals, packaging and their interactions. In respect of chemicals, the fruits without chemical treatment recorded constantly high skin shrinkage than all the chemically treated fruits.6% waxol treated fruits showed the lowest shrinkage score. Even on 8^{th} day of storage at RT, 6 % waxol treated fruits recorded only 2.67 fruit skin shrinkage score as against 3.84 score recorded by untreated fruits. Among the packagings, fruit skin shrinkage was very rapid in open fruits than in polyethylene packed fruits and fruits packed in CFB boxes. On 8^{th} day of storage at RT, fruits packed in PE bags recorded the lowest fruit skin shrinkage score (2.94) as against 3.24 score in fruits packed in CFB boxes and 3.80 in unpacked fruits.

Table 7. Effect of various chemicals and packaging materials on the changes in fruit skin shrinkage of sapota fruits at RT storage conditions

Treatment combinations	Days to storage			
	2nd	4th	6th	8th
Initial value	0.00	0.00	0.00	0.00
T_1	1.10	3.48	4.00	4.00
T_2	0.78	2.39	3.24	3.65
T_3	0.86	2.57	3.41	3.87
T_4	0.71	2.22	3.28	4.00
T_5	0.53	1.52	2.06	2.55
T_6	0.62	1.79	2.29	3.22
T_7	0.88	2.63	3.58	4.00
T_8	0.64	1.66	2.27	3.02
T_9	0.80	1.96	2.50	3.25
T_{10}	0.63	1.35	2.20	3.20
T_{11}	0.42	1.05	1.71	2.28
T_{12}	0.51	1.22	1.96	2.63
A. Means for chemicals				
1. Untreated	0.91	2.81	3.55	3.84
2. GA (75 ppm)	0.62	1.84	2.54	3.35
3. Cycocel (500 ppm)	0.77	2.08	2.78	3.42
4. Waxol (6 %)	0.52	1.22	1.96	2.67
B. Means for packagings				
1. Unpacked	0.83	2.42	3.27	3.80
2. PE bags	0.59	1.66	2.32	2.94
3. CFB boxes	0.70	1.89	2.54	3.24
Chemicals				
S.E. ±	0.014	0.066	0.022	0.014
CD at 5 %	0.042	0.191	0.064	0.041
Packagings				
S.E. ±	0.013	0.057	0.019	0.012
CD at 5 %	0.037	0.165	0.056	0.035
Interactions				
S.E. ±	0.025	0.113	0.038	0.024
CD at 5 %	0.073	0.331	0.111	0.070

Table 8. Effect of various chemicals and packaging materials on the changes in fruit skin shrinkage of sapota fruits in CC storage conditions

Treatment combinations	Days to storage							
	2nd	4th	6th	8th	10th	12th	14th	16th
Initial value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T_1	-	0.34	0.56	1.39	2.32	3.53	3.69	4.00
T_2	-	0.22	0.35	0.81	1.59	2.63	3.03	3.48
T_3	-	0.29	0.42	0.96	1.81	2.88	3.20	3.71
T_4	-	0.25	0.40	0.90	1.36	2.02	3.16	4.00
T_5	-	0.13	0.29	0.53	0.96	1.21	1.85	2.65
T_6	-	0.19	0.32	0.74	1.15	1.65	2.61	3.38
T_7	-	0.30	0.51	1.25	1.90	2.69	3.57	4.00
T_8	-	0.18	0.32	0.73	1.38	1.94	2.88	3.26
T_9	-	0.21	0.36	0.80	1.52	2.09	3.05	3.52
T_{10}	-	0.20	0.32	0.75	1.17	1.80	2.52	3.33
T_{11}	-	0.05	0.20	0.41	0.72	1.10	1.63	2.32
T_{12}	-	0.10	0.26	0.52	0.83	1.33	2.34	3.06
A. Means for chemicals								
1. Untreated	-	0.28	0.44	1.05	1.91	3.01	3.31	3.73
2. GA (75 ppm)	-	0.19	0.34	0.72	1.16	1.63	2.54	3.34
3. Cycocel (500 ppm)	-	0.23	0.40	0.93	1.60	2.24	3.17	3.59
4. Waxol (6 %)	-	0.12	0.26	0.56	0.91	1.41	2.16	2.90
B. Means for packagings								
1. Unpacked	-	0.27	0.45	1.07	1.69	2.51	3.24	3.83
2. PE bags	-	0.15	0.29	0.62	1.16	1.72	2.35	2.92
3. CFB boxes	-	0.20	0.34	0.76	1.33	1.99	2.80	3.42
Chemicals								
S.E. ±	-	0.013	0.012	0.015	0.014	0.014	0.014	0.013
CD at 5 %	-	0.039	0.034	0.043	0.042	0.042	0.041	0.039
Packagings								
S.E. ±	-	0.012	0.010	0.013	0.012	0.012	0.012	0.012
CD at 5 %	-	0.034	0.029	0.037	0.036	0.036	0.035	0.034
Interactions								
S.E. ±	-	0.023	0.020	0.025	0.025	0.025	0.024	0.024
CD at 5 %	-	N.S.	N.S.	0.074	0.072	0.073	0.071	0.069

Regarding various treatment combinations, by the end of 2nd day, skin shrinkage was noticed in all the treatment combinations, however, it was at higher side in unpacked fruits as against packed fruits and in untreated fruits as against treated fruits. Complete fruit skin shrinkage (score : 4.0) was first observed at the end of 6th day in the untreated + unpacked (T_1) fruits. By the end of 8th day, all the treated fruits kept open (T_1, T_4 and T_7) except 6 % waxol treated fruits kept open (T_{10}) had full skin shrinkage (Score : 4). But even on 8th day storage at RT, fruits treated with 6 % waxol and packed in PE bags (T_{11}) had recorded the lowest skin shrinkage score (2.28) followed by 75 ppm GA treated fruits packed in PE bags (T_5) scored 2.55 and 6 per cent waxol treated fruits packed in CFB boxes scored 2.63 skin shrinkage score, which was considered acceptable for consumption and marketing.

The data presented in the Table 8 revealed that at all the stages of storage in CC, the fruit skin shrinkage was significantly influenced by various chemicals, packaging. Their interactions were found to be significant most of the times. By the end of 2nd day storage in CC, no skin shrinkage was recorded in any treatment combinations. Among chemicals, the untreated fruits recorded constantly high skin shrinkage at all the days of storage. The 6 per cent waxol treated fruits showed the lowest skin shrinkage. Even on 16th day of storage in CC, 6 per cent waxol treated fruits recorded the lowest (2.90) score for skin shrinkage as against untreated fruits recorded 3.73 score. In case of packaging, unpacked fruits recorded the rapid skin shrinkage than fruits packed in PE bags and CFB boxes. Even on 16th day of storage in CC, fruits packed in PE bags recorded the lowest skin shrinkage score (2.92) as against 3.42 score by fruits packed in CFB boxes and 3.83 score by unpacked fruits.

In respect of various treatment combinations, by the end of 2nd day, no skin shrinkage was observed in any treatment combinations. On 4th day skin shrinkage was evident in all the treatment combinations, however, it was at higher side in untreated fruits as against treated fruits and in unpacked fruits as against packed fruits. Complete fruit skin shrinkage (score 4.0) was first observed at the end of 16th day in untreated + unpacked fruits (T_1) and 500 ppm cycocel + unpacked fruits (T_7). But even on the 16th day of storage in CC, fruits treated with 6 % waxol and packed in PE bags (T_{11}) had recorded the lowest (2.32) score followed by 75 ppm GA treated fruits packed in PE bags (T_5) recorded 2.65 score and 6 per cent waxol treated fruits packed in CFB boxes (T_{12}) recorded 3.06 score for skin shrinkage, which was considered acceptable for consumption and marketing.

An overall assessment in respect of fruit skin shrinkage during the course of storage, both at RT and CC storage conditions, it was found that with the advancement of storage period, fruit skin shrinkage was increased irrespective of storage treatments. The progress of fruit skin shrinkage was faster in untreated fruits than in treated fruits and in unpacked fruits than in packed fruits. It was also clear from the data that the progress of fruit skin shrinkage was found to be slower in CC storage as against RT storage conditions. Among all the treatment combinations, 6 % waxol + PE bags (T_{11}) was the best combination wherein the progress of fruit skin shrinkage at all the stages (days) was the lowest, under both the storage conditions.

4.5 Total soluble solids (TSS %)

The data on effect of various chemicals and packagings on the changes in TSS content of sapota fruits at RT and in CC have been given in Table 9 and 10 respectively.

At the beginning of storage, the TSS content of the fruits was 17.95 per cent. After 2 days of storage at RT, the fruits under all the treatment combinations had more TSS than they had initially as fresh fruits (17.95 %). There were significant differences due to chemicals but packagings and interaction effects were non-significant. As regards the chemicals, the untreated fruits had the highest TSS (19.46 %) and the lowest value was seen in 6 per cent waxol treated fruits (18.34 %). The treatments viz., 75 ppm GA and 500 pm cycocel, 500 ppm cycocel and untreated fruits were at par. Among the packagings the fruits packed in polyethylene bags (18.93 %) and in CFB boxes (19.06 %) showed less TSS than that of the open fruits (19.21 %).

Table 9. Effect of various chemicals and packaging materials on the changes in total soluble solids (TSS %) content of sapota fruits at RT storage conditions

Treatment combinations	Days to storage			
	2nd	4th	6th	8th
Initial value	17.95	17.95	17.95	17.95
T_1	19.65	23.52	21.65	18.09
T_2	19.29	22.75	21.89	19.52
T_3	19.45	23.32	21.72	19.35
T_4	19.22	22.58	21.69	20.89
T_5	19.02	22.22	22.89	23.79
T_6	19.15	22.45	22.12	21.25
T_7	19.42	22.88	21.82	20.15
T_8	19.25	22.55	21.98	21.59
T_9	19.32	22.82	21.92	20.95
T_{10}	18.55	21.05	22.82	22.12
T_{11}	18.15	20.22	22.62	24.09
T_{12}	18.32	20.42	23.32	23.02
A. Means for chemicals				
1. Untreated	19.46	23.19	21.75	18.99
2. GA (75 ppm)	19.13	22.41	22.23	22.64
3. Cycocel (500 ppm)	19.33	22.75	21.91	20.90
4. Waxol (6 %)	18.34	20.56	22.92	23.08
B. Means for packagings				
1. Unpacked	19.21	22.50	21.99	20.31
2. PE bags	18.93	21.93	22.34	21.99
3. CFB boxes	19.06	22.25	22.27	21.15
Chemicals				
S.E. ±	0.105	0.106	0.100	0.043
CD at 5 %	0.307	0.320	0.293	0.125
Packagings				
S.E. ±	0.091	0.064	0.087	0.037
CD at 5 %	N.S.	0.192	0.254	0.108
Interactions				
S.E. ±	0.182	0.152	0.174	0.074
CD at 5 %	N.S.	0.452	0.508	0.217

Table 10. Effect of various chemicals and packaging materials on the changes in total soluble solids (TSS %) content of sapota fruits CC storage conditions

Treatment combinations	Days to storage							
	2nd	4th	6th	8th	10th	12th	14th	16th
Initial value	17.95	17.95	17.95	17.95	17.95	17.95	17.95	17.95
T_1	18.85	21.22	22.89	23.29	24.29	21.35	19.89	18.52
T_2	18.75	20.95	22.09	23.02	24.15	23.79	21.29	20.00
T_3	18.82	21.05	22.19	23.12	24.22	23.52	20.99	19.79
T_4	18.45	20.58	21.09	22.39	23.29	24.09	23.82	23.12
T_5	18.22	20.15	20.78	22.02	22.68	23.89	23.99	24.12
T_6	18.35	20.28	20.99	22.15	23.12	23.99	23.92	23.99
T_7	18.72	20.68	21.32	22.59	23.49	22.95	23.52	21.52
T_8	18.45	20.25	20.92	22.29	23.15	24.12	23.95	22.89
T_9	18.59	20.42	21.22	22.42	22.92	24.02	23.82	21.12
T_{10}	18.32	19.98	20.32	21.89	22.65	23.86	24.19	23.58
T_{11}	18.08	19.58	20.05	21.62	22.22	23.12	23.95	24.22
T_{12}	18.22	19.68	20.19	21.75	22.42	23.29	24.05	24.09
A. Means for chemicals								
1. Untreated	18.81	21.07	22.38	23.14	24.63	22.89	20.72	19.46
2. GA (75 ppm)	18.34	20.34	20.95	22.19	23.03	23.99	23.91	23.74
3. Cycocel (500 ppm)	18.59	20.45	21.15	22.43	23.31	23.70	23.76	21.84
4. Waxol (6 %)	18.21	19.75	20.19	21.75	22.43	23.42	24.06	23.94
B. Means for packagings								
1. Unpacked	18.56	20.61	21.40	22.54	23.38	23.06	22.85	21.69
2. PE bags	18.44	20.23	20.96	22.24	23.07	23.73	23.29	22.83
3. CFB boxes	18.46	20.35	21.14	22.36	23.15	23.70	23.19	22.23
Chemicals								
S.E. ±	0.006	0.051	0.044	0.035	0.085	0.032	0.037	0.034
CD at 5 %	0.193	0.150	0.128	0.103	0.247	0.093	0.107	0.099
Packagings								
S.E. ±	0.057	0.044	0.038	0.030	0.074	0.028	0.032	0.030
CD at 5 %	N.S.	0.130	0.110	0.089	0.214	0.081	0.093	0.086
Interactions								
S.E. ±	0.114	0.088	0.076	0.061	0.147	0.055	0.064	0.059
CD at 5 %	N.S.	0.259	0.221	N.S.	N.S.	0.161	0.185	0.172

After 2 days of storage in CC, the fruits under all the treatment combinations had more TSS than they had initially as fresh fruits (17.95 %). There was significant differences due to various chemicals but packaging and interaction effects were non-significant. Among the various chemicals the untreated fruits had the highest TSS (18.81 %) and the lowest TSS (18.21 %) was recorded in 6 % waxol treated fruits. The treatments 6 % waxol and 75 ppm GA were at par. As regards the packagings, the fruits packed in PE bags (18.44 %) and CFB box (18.46 %) showed less TSS than that of open fruits (18.56 %).

After 4 days of storage at RT fruits under all the treatment combinations had increased TSS than they had on 2nd day of storage. There were significant differences due to chemicals, packagings and interactions. Among the chemicals, the highest TSS (23.19 %) was recorded in untreated fruits while lowest TSS (20.56 %) was recorded in 6 per cent waxol treated fruits. The fruits packed in PE bags (21.93 %) and in CFB box (22.25 %) had significantly low TSS than that of open fruits (22.50 %). Among the various treatment combinations, the highest TSS (23.52 %) was recorded in untreated and unpacked fruits (T_1) while the lowest TSS (20.22 %) in 6 % waxol treated + PE bags packed fruits (T_{11}).

After 4 days of storage in CC, fruits under all the treatment combinations had increased TSS than they had on 2nd day of storage. There were significant differences due to chemicals, packagings and interactions. As regards the chemicals, the highest TSS (21.07 %) was recorded in untreated fruits while the lowest (19.75 %) in 6 % waxol treated fruits. The treatments 75 ppm GA and 500 ppm cycocel were at par. Among the packagings, the fruits packed in PE bags had lowest (20.23 %) TSS while unpacked fruits recorded highest (20.61 %) TSS. The packaging treatment of PE bags and CFB boxes were at par. As regards interaction effects, after 4th day of storage, the highest TSS (21.22 %) was observed in untreated fruits kept open (T_1) and the lowest in 6 per cent waxol treated fruits packed PE bags (19.58 %) (T_{11}).

After 6 days of storage at RT all other treatment combinations except GA treated + PE packed (T_5), 6 % waxol + unpacked (T_{10}), 6 % waxol + PE bags (T_{11}) and 6 % waxol + CFB box (T_{12}) had decreased TSS than they had on 4th day of storage. There were significant differences due to chemicals, packagings and interactions. Among the chemicals 6 % waxol treated fruits recorded the highest TSS (22.92 %) and the lowest TSS (21.75 %) was recorded in untreated fruits. The treatments viz., untreated and cycocel, cycocel and GA were at par. As regards the packagings, the fruits packed in PE bags (22.34 %) and CFB boxes (22.27 %) had significantly higher TSS than unpacked fruits (21.99 %). The packagings, CFB box and PE bags were at par. Among the various interactions, the highest TSS (23.32 %) was recorded in 6 % waxol treated and CFB box packed fruits (T_{12}) while lowest TSS (21.65 %) in untreated fruits kept open (T_1).

After 6 days of storage at CC, all the treatment combinations had increased TSS than they had on 4th day of storage. There were significant differences due to chemicals, packagings and interactions. As regards chemicals, the highest TSS was recorded in untreated fruits (22.38 %) while the lowest in 6 % waxol treated fruits (20.19 %). In case of packagings, the fruits packed in PE bags (20.96 %) and in CFB box (21.14 %) had significantly lower TSS than unpacked fruits (21.40 %). The packagings PE bags and CFB box were at par. In respect of treatment combinations, the highest TSS (22.89 %) was recorded in untreated fruits kept open (T_1) while the lowest (20.05 %) in 6 % waxol treated and PE bags packed fruits (T_{11}).

After 8 days of storage at RT, all the treatment combinations except 75 ppm GA + PE bag (T_5), 6 % waxol + PE bags (T_{11}) and 6 % waxol + CFB box (T_{12}) had decreased TSS than they had on 6th day of storage. There were significant differences due to various chemicals, packagings and interactions. Among the chemicals, the highest TSS (23.08 %) was recorded in 6 % waxol treated fruits while the lowest (18.99 %) in untreated fruits. Regarding packagings, fruits packed in PE bags (21.99 %) and in CFB box (21.15 %) had significantly higher TSS than unpacked fruits (20.31 %). Among the various treatment combinations, the 6 % waxol treated and PE bag packed fruits (T_{11}) recorded the highest TSS

(24.09 %) while lowest TSS (18.09 %) was recorded in untreated fruits kept open (T_1).

After 8th day of storage in CC, fruits under all the treatment combinations recorded increased TSS values than they had on 6th day of storage. There were significant differences due to various chemicals and packagings but the interaction effects were non-significant. In respect of chemicals, the untreated fruits recorded highest TSS (23.14 %) while fruits recorded with 6 % waxol recorded the lowest TSS (21.75 %). Among the packagings the fruits in PE bags (22.24 %) and in CFB box (22.36 %) had significantly lower TSS than unpacked fruits (22.54 %).

At the end of storage life of 8 days at RT conditions, sapota fruits under most of the treatment combinations had lost its shelf life. Therefore, the storage experiment at RT conditions was terminated for further physico-chemicals analysis. However, the fruits in CC storage conditions were still found to be in better conditions. Hence, further observations of TSS (%) content of sapota fruits on 10th, 12th, 14th and 16th days were recorded for CC storage only.

After 10th day of storage in CC, the fruits under all the treatment combinations had increased TSS content than they had on 8th day storage. There were significant differences due to various chemicals and packagings but interactions were found to be non-significant. As regards the chemicals the highest TSS (24.63 %) was recorded in untreated fruits while the lowest (22.43 %) in 6 % waxol treated fruits. In case of packagings, the fruits packed in PE bags recorded significantly lower (23.07 %) TSS than unpacked fruits (23.38 %). The packagings PE bags and CFB boxes were at par.

After 12[th] day of storage in CC, the fruits under all the treatment combinations except untreated + unpacked (T_1), untreated + PE bags (T_2), untreated + CFB box (T_3) and cycocel + unpacked (T_7) had increased TSS than they had on 10[th] day of storage. There were significant differences due to various chemicals, packagings and interactions. Regarding the chemicals, highest TSS (23.99 %) was observed in 75 ppm GA treated fruits while the lowest TSS (22.89 %) was observed in untreated fruits. As regards the packaging, the PE bag packed fruits recorded significantly higher TSS (23.73 %) than unpacked fruits (23.06 %). The packaging treatment CFB box and PE bags were at par. In respect of various treatment combinations, the highest TSS (24.12 %) was observed in 500 ppm cycocel treated + PE bags packed fruits (T_8) and the lowest TSS (21.35 %) in untreated fruits kept open (T_1).

After 14[th] day of storage in CC, all the treatment combinations except 75 ppm GA + PE bags (T_5), 6 % waxol + unpacked (T_{10}), 6 % waxol + PE bags (T_{11}) and 6 % waxol + CFB box (T_{12}) had decreased TSS than they had on 12[th] day of storage. There were significant differences due to various chemicals, packagings and interactions. Among the chemicals, the highest TSS (24.06 %) was recorded in 6 % waxol treated fruits while the lowest TSS (20.72 %) was observed in untreated fruits. As regards the packagings, the fruits packed in PE bags (23.29 %) and CFB box (23.19 %) had significantly higher TSS than unpacked fruits (22.85 %). In case of various treatment combinations, the highest TSS (24.19 %) was recorded in 6 % waxol treated + unpacked fruit (T_{10}) while the lowest TSS (19.89 %) was recorded in unpacked fruits kept open (T_1).

After 16th day of storage in CC, all the treatment combinations except 75 ppm GA + PE bags (T_5), 6 % waxol + PE bags (T_{11}) and 6 % waxol + CFB box (T_{12}) had decreased TSS than they had on 14th day storage. There were significant differences due to various chemicals, packagings and interactions. Among the various chemicals, the highest TSS (23.94 %) was recorded in 6% waxol treated fruits while the lowest TSS (19.46 %) in untreated fruits. As regards the packagings, fruits packed in PE bags (22.83 %) and in CFB boxes (22.23 %) had significantly higher TSS than unpacked fruits (21.69 %). In respect of various treatment combinations, the highest TSS (24.22 %) was observed in 6 % waxol + PE bags packed fruits (T_{11}) while the lowest TSS (18.52 %) in untreated fruits kept open (T_1).

To sum up the changes in TSS content during the course of storage, it was found that with the advancement of storage period, there was a significant increase in TSS content till it reached the peak, followed by a gradual decline irrespective of storage treatments. The rate of increase in TSS content was faster in untreated fruits than in treated fruits and in unpacked fruits than in packed fruits. It was also clear from the data that the rise in TSS content was at slower rate in CC storage as compared to that at RT storage. Among all the treatment combinations, increase in TSS content was slower and continuous in 6 % waxol treated + PE bags packed fruits (T_{11}) under both the storage conditions. This treatment combination registered the highest TSS content (24.09 and 24.22 %) at the end of storage life at RT and CC respectively.

4.6 Total titratable acidity (%)

The data on effect of various chemicals and packaging materials on the changes in total titratable acidity (%) of sapota fruits at RT and in CC have been given in Table 11 and 12 respectively.

The data presented in Table 11 and 12 reveal that total titratable acidity (%) was significantly influenced by various chemicals and packaging materials both at RT and CC. But interaction between chemicals and packaging was found to be non-significant most of the times.

The data regarding total titratable acidity (%) indicated that, with the advancement of storage period, total titratable acidity (%) of sapota fruits was continuously decreased irrespective of storage treatments. At all the stages (days) of storage, both at RT and in CC, all the chemical treated fruits showed significantly higher acidity than untreated fruits. Among all the chemicals, fruits treated with 6 % waxol registered the highest acidity. As regards packaging,

Table 11. Effect of various chemicals and packaging materials on the changes in total titratable acidity (%) content of sapota fruits at RT storage conditions

Treatment combinations	Days to storage			
	2nd	4th	6th	8th
Initial value	0.280	0.280	0.280	0.280
T_1	0.160	0.070	0.050	0.030
T_2	0.190	0.100	0.070	0.040
T_3	0.180	0.090	0.060	0.040
T_4	0.210	0.120	0.080	0.050
T_5	0.260	0.180	0.110	0.080
T_6	0.240	0.150	0.090	0.060
T_7	0.200	0.100	0.060	0.040
T_8	0.240	0.160	0.090	0.060
T_9	0.230	0.140	0.080	0.050
T_{10}	0.220	0.150	0.090	0.060
T_{11}	0.270	0.210	0.150	0.090
T_{12}	0.250	0.180	0.100	0.080
A. Means for chemicals				
1. Untreated	0.177	0.087	0.060	0.037
2. GA (75 ppm)	0.237	0.150	0.093	0.063
3. Cycocel (500 ppm)	0.223	0.133	0.077	0.050
4. Waxol (6 %)	0.247	0.180	0.113	0.077
B. Means for packagings				
1. Unpacked	0.198	0.110	0.070	0.045
2. PE bags	0.240	0.163	0.105	0.068
3. CFB boxes	0.225	0.140	0.083	0.058
Chemicals				
S.E. ±	0.0055	0.0045	0.0037	0.0036
CD at 5 %	0.0161	0.0131	0.0108	0.0104
Packagings				
S.E. ±	0.0048	0.0039	0.0032	0.0032
CD at 5 %	0.0139	0.0114	0.0094	0.0092
Interactions				
S.E. ±	0.0096	0.0079	0.0065	0.0063
CD at 5 %	N.S.	N.S.	0.0188	N.S.

Table 12. Effect of various chemicals and packaging materials on the changes in total titratable acidity (%) content of sapota fruits in CC storage conditions

Treatment combinations	Days to storage							
	2nd	4th	6th	8th	10th	12th	14th	16th
Initial value	0.280	0.280	0.280	0.280	0.280	0.280	0.280	0.280
T_1	0.210	0.170	0.140	0.090	0.050	0.040	0.030	0.020
T_2	0.230	0.190	0.160	0.120	0.090	0.070	0.050	0.030
T_3	0.220	0.180	0.130	0.110	0.070	0.060	0.040	0.020
T_4	0.230	0.190	0.160	0.120	0.090	0.070	0.040	0.030
T_5	0.250	0.210	0.180	0.140	0.110	0.090	0.060	0.040
T_6	0.240	0.200	0.170	0.130	0.100	0.080	0.040	0.040
T_7	0.220	0.180	0.150	0.100	0.080	0.050	0.030	0.020
T_8	0.240	0.190	0.170	0.120	0.090	0.080	0.050	0.040
T_9	0.230	0.180	0.140	0.110	0.070	0.070	0.040	0.020
T_{10}	0.230	0.200	0.170	0.130	0.100	0.080	0.050	0.040
T_{11}	0.270	0.230	0.200	0.160	0.130	0.100	0.070	0.050
T_{12}	0.250	0.210	0.190	0.150	0.110	0.090	0.060	0.040
A. Means for chemicals								
1. Untreated	0.220	0.018	0.143	0.107	0.070	0.057	0.040	0.023
2. GA (75 ppm)	0.240	0.200	0.170	0.130	0.100	0.080	0.047	0.037
3. Cycocel (500 ppm)	0.230	0.183	0.153	0.110	0.080	0.067	0.040	0.027
4. Waxol (6 %)	0.250	0.213	0.187	0.147	0.113	0.090	0.060	0.043
B. Means for packagings								
1. Unpacked	0.223	0.185	0.155	0.110	0.080	0.060	0.037	0.028
2. PE bags	0.247	0.205	0.178	0.135	0.105	0.085	0.058	0.040
3. CFB boxes	0.235	0.193	0.158	0.125	0.088	0.075	0.045	0.030
Chemicals								
S.E. ±	0.0059	0.0046	0.0045	0.0050	0.0040	0.0036	0.0032	0.0032
CD at 5 %	0.0170	0.0134	0.0131	0.0147	0.0116	0.0105	0.0093	0.0093
Packagings								
S.E. ±	0.0051	0.0040	0.0039	0.0043	0.0034	0.0031	0.0028	0.0028
CD at 5 %	0.0147	0.0116	0.0114	0.0126	0.0100	0.0090	0.0081	0.0081
Interactions								
S.E. ±	0.0101	0.0080	0.0078	0.0087	0.069	0.0062	0.0055	0.0055
CD at 5 %	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

at all the stages (days) of storage both at RT and in CC, the fruits packed in PE bags and CFB boxes registered significantly higher titratable acidity than in unpacked fruits. Fruits packed in PE bags recorded the highest titratable acidity throughout the storage period of the fruits. In respect of treatment combinations, fruits treated with 6 % waxol and packed in PE bags (T_{11}) registered the highest total titratable acidity while the untreated fruits kept open (T_1) registered the lowest acidity content at all the stages (days) of storage.

At the end of storage period at RT, i.e. on 8th day, total titratable acidity was the highest (0.077 %) in 6 % waxol treated fruits and the lowest (0.037 %) in untreated fruits. Regarding packagings, fruits packed in PE bags recorded the highest (0.068 %) titrable acidity while the lowest (0.045 %) in unpacked fruits. As regards treatment combinations, the highest titratable acidity (0.090 %) was recorded in fruits treated with 6 % waxol + packed in PE bags (T_{11}), while the lowest titratable acidity (0.030 %) was recorded in untreated fruits kept open (T_1).

Similarly, at the end of storage period in CC, i.e. on 16th day, 6 % waxol treated fruits recorded the highest titratable acidity (0.043 %) and the lowest (0.023 %) in untreated fruits. Among the packaging, the highest titratable acidity (0.040 %) was recorded in fruits packed in PE bags while the lowest (0.028 %) in unpacked fruits. In case of treatment combinations, fruits treated with 6 % waxol and packed in PE bags (T_{11}) recorded the highest titratable acidity (0.050 %). While the lowest (0.020 %) titratable acidity was recorded in untreated fruits kept open (T_1).

An overall assessment of the data in respect of total titratable acidity (%) during the course of storage, both at RT and CC indicated that with the advancement of storage period, titratable acidity (%) of sapota fruits was decreased irrespective of storage treatments. It was also observed that rate of decrease in titratable acidity was at slower in CC storage as against in RT storage conditions. Among all the treatment combinations, decrease in titratable acidity was found to be slow in fruits treated with 6 % waxol and packed in PE bags (T_{11}). This treatment combination (T_{11}) also registered the highest titratable acidity content (0.090 % and 0.05 %) at the end of storage life of fruits at RT and CC respectively.

4.7 Reducing sugars (%)

The data on effect of various chemicals and packagings on the changes in reducing sugars (%) content of sapota fruits at RT and in CC have been given in Table 13 and 14 respectively.

At the beginning of storage, the reducing sugars (%) content of the fruit was 3.86 per cent. After 2 days of storage at RT, the fruits under all the treatment combinations had more reducing sugars than they had initially as fresh fruits (3.86 %). There were significant differences due to various chemicals and packagings but the interactions were non-significant. As regards the chemicals, the untreated fruits had highest reducing sugars (4.70 %) and the lowest

Table 13. Effect of various chemicals and packaging materials on the changes in reducing sugars (%) content of sapota fruits at RT storage conditions

Treatment combinations	Days to storage			
	2nd	4th	6th	8th
Initial value	3.86	3.86	3.86	3.86
T_1	4.92	7.85	6.12	5.82
T_2	4.52	7.28	6.91	6.17
T_3	4.66	7.46	6.34	5.91
T_4	4.43	6.17	7.68	6.55
T_5	4.24	5.80	7.16	8.03
T_6	4.32	5.98	7.35	7.81
T_7	4.56	6.27	7.79	6.42
T_8	4.36	5.92	7.30	6.71
T_9	4.43	6.23	7.48	6.50
T_{10}	4.28	6.03	7.48	6.78
T_{11}	4.02	5.62	6.96	8.12
T_{12}	4.16	5.86	7.26	8.01
A. Means for chemicals				
1. Untreated	4.70	7.53	6.46	5.96
2. GA (75 ppm)	4.33	5.98	7.40	7.46
3. Cycocel (500 ppm)	4.45	6.14	7.52	6.54
4. Waxol (6 %)	4.15	5.83	7.23	7.63
B. Means for packagings				
1. Unpacked	4.55	6.58	7.26	6.39
2. PE bags	4.28	6.15	7.08	7.25
3. CFB boxes	4.39	6.38	7.10	7.05
Chemicals				
S.E. ±	0.036	0.036	0.034	0.070
CD at 5 %	0.105	0.106	0.099	0.205
Packagings				
S.E. ±	0.031	0.032	0.029	0.061
CD at 5 %	0.090	0.092	0.085	0.177
Interactions				
S.E. ±	0.062	0.063	0.059	0.122
CD at 5 %	N.S.	N.S.	0.170	0.355

Table 14. Effect of various chemicals and packaging materials on the changes in reducing sugars (%) content of sapota fruits in CC storage conditions

Treatment combinations	Days to storage							
	2nd	4th	6th	8th	10th	12th	14th	16th
Initial value	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86
T_1	4.38	5.43	6.19	7.61	8.36	7.17	6.27	5.52
T_2	4.21	5.32	6.00	7.17	8.04	7.52	7.18	6.21
T_3	4.23	5.39	6.10	7.28	8.15	7.32	6.98	6.13
T_4	4.23	4.69	5.58	5.90	6.69	7.93	8.30	8.05
T_5	4.12	4.47	5.21	5.52	6.31	7.75	8.18	8.40
T_6	4.18	4.53	5.33	5.68	6.43	7.89	8.25	8.18
T_7	4.25	4.72	5.72	5.98	6.81	8.00	7.65	6.27
T_8	4.15	4.59	5.36	5.69	6.53	7.88	7.98	7.15
T_9	4.21	4.65	5.50	5.79	6.70	7.95	7.81	6.78
T_{10}	4.20	4.59	5.24	5.71	6.39	7.89	8.24	8.10
T_{11}	4.01	4.42	4.90	5.42	6.10	7.68	8.08	8.47
T_{12}	4.17	4.50	5.02	5.53	6.27	7.81	8.19	8.23
A. Means for chemicals								
1. Untreated	4.27	5.38	6.10	7.35	8.18	7.34	6.81	5.95
2. GA (75 ppm)	4.18	4.55	5.37	5.70	6.48	7.85	8.24	8.21
3. Cycocel (500 ppm)	4.20	4.65	5.53	5.82	6.68	7.94	7.81	6.73
4. Waxol (6 %)	4.13	4.50	5.05	5.55	6.25	7.79	8.17	8.26
B. Means for packagings								
1. Unpacked	4.27	4.86	5.68	6.30	7.06	7.75	7.61	6.99
2. PE bags	4.13	4.70	5.37	5.95	6.74	7.71	7.85	7.55
3. CFB boxes	4.20	4.77	5.49	6.06	6.89	7.74	7.80	7.33
Chemicals								
S.E. ±	0.030	0.032	0.034	0.035	0.059	0.033	0.031	0.035
CD at 5 %	0.087	0.094	0.099	0.102	0.171	0.095	0.092	0.103
Packagings								
S.E. ±	0.026	0.028	0.030	0.031	0.051	0.028	0.027	0.031
CD at 5 %	0.075	0.081	0.086	0.089	0.148	N.S.	0.079	0.089
Interactions								
S.E. ±	0.052	0.056	0.059	0.061	0.101	0.057	0.054	0.062
CD at 5 %	N.S.	N.S.	N.S.	N.S.	N.S.	0.165	0.158	0.179

value (4.15 %) was recorded in 6 % waxol treated fruits. All the chemical treatments significantly differed from each other. Regarding packagings, unpacked fruits recorded highest reducing sugars (4.55 %) while lowest in fruits packed in PE bags (4.28 %). All the packaging treatments differed significantly from each others.

At 2 days of storage in CC also all the treatment combinations had increased reducing sugars content than they had initially as fresh fruits (3.86 %). There were significant differences due to various chemicals and packagings but interactions were found to be non-significant. In case of chemicals, untreated fruits recorded the highest reducing sugars content (4.27 %), while the lowest (4.13 %) in 6 % waxol treated fruits. The chemical treatments viz., untreated and GA, GA and cycocel were at par. As regards the packagings, highest reducing sugars content (4.27 %) was recorded in unpacked fruits while the lowest (4.13 %) in fruits packed in PE bags. The packaging treatments, PE bags and CFB box were at par.

On 4^{th} day of storage at RT, all the treatment combinations had increased reducing sugars than they had on 2^{nd} day of storage. There were significant differences due to chemicals and packagings while the interactions were non-significant. In respect of chemicals, the highest reducing sugars (7.53 %) was recorded in untreated fruits while the lowest (5.83 %) was recorded in fruits treated with 6 % waxol. All the chemical treatments differed significantly from each other. Among the packagings, the highest reducing sugars content (6.58 %) was recorded in unpacked fruits while fruits packed in PE bags recorded the lowest reducing sugars content (6.15 %). All the packaging treatments differed significantly from each other.

On 4th day of storage in CC also all the treatment combinations had increased reducing sugars content than they had on 2nd day. There were significant differences due to various chemicals and packagings while the interactions were found to be non-significant. Among the chemicals the untreated fruits recorded the highest reducing sugars content (5.38 %) while the lowest (4.50 %) was recorded in 6 % waxol treated fruits. The treatments 6 % waxol and 75 ppm GA were at par. Regarding packaging, unpacked fruits recorded highest reducing sugars content (4.86 %) and the lowest value was recorded in fruits packed in PE bags (4.70 %). The packagings PE bags and CFB box were at par.

After 6 day of storage at RT the fruits under all the treatment combinations except untreated + unpacked (T_1), untreated + PE bags (T_2) and untreated + CFB box (T_3) had increased reducing sugars content than they had on 4th day of storage. There were significant differences due to various chemicals, packagings and their interactions. As regards chemicals, 500 ppm cycocel treated fruits recorded the highest reducing sugars content (7.52 %), while the lowest reducing sugars (6.46 %) content was recorded in untreated fruits. All the chemical treatments were significantly differed from each other. In case of packagings, the unpacked fruits recorded highest reducing sugars content (7.26 %) while the lowest reducing sugars (7.08 %) was recorded in fruits packed in PE bags. The packagings, PE bags and CFB boxes were at par. Among the various treatment combinations, the highest reducing sugars content (7.79 %) was recorded in 500 ppm cycocel treated fruits and kept open (T_7), while the lowest reducing sugars content (6.12 %) was recorded in untreated fruits kept open (T_1).

After 6 days storage in CC, all the treatment combinations had increased reducing sugars content than they had on 4th day storage. There were significant differences due to chemicals and packagings but their interactions were found to be non-significant. As regards chemicals, the highest reducing sugars content (6.10 %) was recorded in untreated fruits and the lowest (5.05 %) in 6 % waxol treated fruits. All the chemical treatments were significantly differed from each other. Among the packagings, the unpacked fruits recorded the highest reducing sugars content (5.68 %) and the lowest (5.37 %) in fruits packed in PE bags. All the packaging were significantly differed from each other.

After 8th day storage at RT, all the treatment combinations except 75 ppm GA + PE bags (T_5), 75 ppm GA + CFB box (T_6), 6 % waxol + PE bags (T_{11}) and 6 % waxol + CFB boxes (T_{12}) had decreased TSS than they had on 6th day of storage. There were significant differences due to various chemicals, packagings and their interactions. As regards the chemicals, the highest reducing sugars content (7.63 %) was recorded in 6 % waxol treated fruits, while the lowest (5.96 %) in untreated fruits. The chemical treatments, 75 ppm GA and 6 % waxol were at par. Among the packagings, the fruits packed in PE bags recorded highest reducing sugars content (7.25 %) and the lowest (6.39 %) in unpacked fruits. All the packaging treatments were significantly differed from each other. Among the various treatment combinations, fruits treated with 6 % waxol and packed in PE bags (T_{11}) recorded the highest reducing sugars content (8.12 %) while untreated fruits kept open (T_1) recorded the lowest reducing sugars content (5.82 %).

After 8th day of storage in CC, all the treatment combinations had increased reducing sugars content than they had on 6th day of storage. There were significant differences due to chemicals and packagings while their interactions were found to be non-significant. Among the chemicals, the highest reducing sugars content (7.35 %) was recorded in untreated fruits and the lowest (5.55 %) in 6 % waxol treated fruits. All the chemical treatments differed significantly from each other. As regards the packagings, the unpacked fruits had the highest reducing sugars content (6.30 %) and the lowest (5.95 %) in PE bags. All the packagings differed significantly from each other.

At the end of storage life of 8 days at RT conditions, sapota fruits under most of the treatment combinations had lost its shelf-life. Therefore, the storage experiment at RT conditions was terminated for the further physico-chemical analysis. However, the fruits in CC storage conditions were still found to be in better conditions. Hence, further observations of reducing sugars (%) content of sapota fruits on 10th, 12th, 14th and 16th days were recorded for CC storage only.

After 10th day of storage in CC, all the treatment combinations had increased reducing sugars content than they had on 8th day of storage. There were significant differences due to chemicals, packagings while their interactions were found to be non-significant. Among the chemicals, untreated fruits recorded the highest reducing sugars content (8.18 %) while the lowest (6.25 %) in fruits treated with 6 % waxol. All the chemical treatments differed significantly from each other. As regards the packagings, the highest reducing sugars (7.06 %) was recorded in unpacked fruits and the lowest (6.74 %) in fruits packed PE bags. The treatments PE bags and CFB boxes were at par.

After 12 days of storage in CC, all the treatment combinations except untreated + unpacked (T_1), untreated + PE bags (T_2), and untreated + CFB boxes (T_3) had increased reducing sugars than they had on 10th day of storage. There were significant differences due to various chemicals and interactions but packaging effects were non-significant. As regards the chemicals, the highest reducing sugars (7.94 %) was observed in fruits treated with 500 ppm cycocel, while the lowest (7.34 %) in untreated fruits. The chemical treatments 6 % waxol and 75 ppm GA were at par. Among the packagings, unpacked fruits recorded the highest reducing sugars (7.75 %) and the lowest (7.71 %) in fruits packed in PE bags. As regards the various treatment combinations, fruits treated with 500 ppm cycocel and kept open (T_7) recorded the highest reducing sugars content (8.00 %), while the lowest (7.17 %) in untreated fruits kept open (T_1).

After 14th day of storage in CC, all the treatment combinations except untreated + unpacked (T_1), untreated + PE bags (T_2), untreated + CFB boxes (T_3), 500 ppm cycocel + unpacked (T_7), 500 ppm cycocel + CFB boxes (T_9) had increased reducing sugars content than they had on 12th day of storage. There were significant differences due to various chemicals, packagings and their interactions. As regards the chemicals, 75 ppm GA treated fruits recorded the highest reducing sugars content (8.24 %) while the lowest (6.81 %) in untreated fruits. The treatments 6 % waxol and 75 ppm GA were at par. Among the packagings, the fruits packed in PE bags recorded the highest reducing sugars content (7.85 %) and the lowest (7.61 %) in unpacked fruits. The packagings CFB boxes and PE bags were at par. As regards the various treatment combinations, 75 ppm GA treated fruits kept open (T_4) showed the highest reducing sugars (8.30 %) content and the lowest (6.27 %) in untreated and unpacked (T_1) fruits.

After 16th day of storage in CC, all the treatment combinations except 75 ppm GA + PE bags (T_5), 6 % waxol + PE bags (T_{11}) and 6 % waxol + CFB box (T_{12}) had decreased their reducing sugars content than they had on 14th day of storage. There were significant differences due to various chemicals, packagings and their interactions. As regards chemicals, 6 % waxol treated fruits recorded the highest reducing sugars content (8.26 %) while the lowest in (5.95 %) untreated fruits. The chemical treatments 6 % waxol and 75 ppm GA were at par. Regarding packagings, the highest reducing sugars content (7.55 %) was recorded in fruits packed in PE bags while the lowest (6.99 %) in unpacked fruits. All the packagings differed significantly from each other. In case of various treatment combinations, 6 % waxol treatment fruits and packed in PE bags (T_{11}) recorded the highest reducing sugars content (8.47 %) followed by 75 ppm GA treated + packed in PE bags (T_5) (8.40 %) fruits while the lowest (5.52 %) in untreated and unpacked (T_1) fruits.

To sum up the changes in reducing sugars content during the course of storage, it was found that with the advancement of storage period, there was a significant increase in reducing sugars content till it reached the peak, followed by a gradual decline irrespective of storage treatments. The rate of increase in reducing sugars content was faster in untreated fruits than in treated fruits and in unpacked fruits than in packed fruits. It was clear from the data that the rise in reducing sugars content was at slower rate in CC storage as compared to that at RT storage. Among all the treatment combinations, increase in reducing sugars content was slower and continuos in 6 % waxol treated + PE bag packed fruits (T_{11}) under both the storage conditions (RT and CC). This treatment combination registered the highest reducing sugars content (8.12 % and 8.47 %) at the end of storage life of fruits at RT and in CC respectively.

4.8 Non-reducing sugars (%)

The data on effect of various chemicals and packagings on the changes in non-reducing sugars (%) content of sapota fruits at RT and in CC have been given in Table 15 and 16, respectively.

At the beginning of storage, the non-reducing sugar (%) content of the fruit was 4.19 per cent. After 2 days of storage at RT, the fruits under all the treatments combinations had more non-reducing sugars content than they had initially as fresh fruit (4.19 %). There were significant differences due to various chemical and packagings while interactions were non-significant. As regards chemicals, the untreated fruits recorded the highest non-reducing sugars (5.49 %) and the lowest non-reducing sugars was recorded (5.13 %) in 6 % waxol treatment. The treatments 75 ppm GA and 500 ppm cycocel were at par. In respect of packagings, the highest non-reducing sugars content (5.38 %) was recorded in unpacked and the lowest (5.23 %) in fruits packed in PE bags. The packagings CFB boxes and unpacked fruits were at par.

Table 15. Effect of various chemicals and packaging materials on the changes in non reducing sugars (%) content of sapota fruits at RT storage conditions

Treatment combinations	Days to storage			
	2nd	4th	6th	8th
Initial value	4.19	4.19	4.19	4.19
T_1	5.55	6.68	6.35	5.38
T_2	5.41	6.35	6.64	6.14
T_3	5.50	6.44	6.45	6.02
T_4	5.32	6.31	7.41	6.78
T_5	5.21	6.13	7.14	7.26
T_6	5.57	6.19	7.26	6.95
T_7	5.44	6.38	6.53	5.45
T_8	5.26	6.21	6.74	6.27
T_9	5.33	6.27	6.66	6.12
T_{10}	5.22	5.87	7.28	7.20
T_{11}	5.03	5.62	7.09	7.35
T_{12}	5.15	5.78	7.19	7.23
A. Means for chemicals				
1. Untreated	5.49	6.49	6.48	5.85
2. GA (75 ppm)	5.27	6.21	7.27	7.00
3. Cycocel (500 ppm)	5.34	6.29	6.64	5.95
4. Waxol (6 %)	5.13	5.76	7.19	7.26
B. Means for packagings				
1. Unpacked	5.38	6.31	6.89	6.20
2. PE bags	5.23	6.08	6.90	6.75
3. CFB boxes	5.31	6.17	6.89	6.58
Chemicals				
S.E. ±	0.0278	0.024	0.025	0.025
CD at 5 %	0.081	0.069	0.072	0.073
Packagings				
S.E. ±	0.024	0.020	0.021	0.022
CD at 5 %	0.071	0.060	N.S.	0.063
Interactions				
S.E. ±	0.048	0.041	0.043	0.044
CD at 5 %	N.S.	N.S.	0.125	0.127

Table 16. Effect of various chemicals and packaging materials on the changes in non reducing sugar (%) content of sapota fruits in CC storage conditions

Treatment combinations	Days to storage							
	2nd	4th	6th	8th	10th	12th	14th	16th
Initial value	4.19	4.19	4.19	4.19	4.19	4.19	4.19	4.19
T_1	5.28	5.41	5.98	6.37	6.81	6.46	6.08	5.57
T_2	5.11	5.22	5.57	5.89	6.44	6.69	6.80	6.15
T_3	5.20	5.30	5.72	6.12	6.68	6.50	6.45	6.02
T_4	4.67	4.82	5.25	5.56	5.91	6.50	6.85	6.50
T_5	4.30	4.45	4.85	5.19	5.64	6.21	6.58	6.81
T_6	4.36	4.50	5.18	5.31	5.77	6.35	6.76	6.69
T_7	4.87	5.02	5.70	6.28	6.68	6.84	6.26	5.70
T_8	4.54	4.69	5.19	5.77	6.22	6.63	6.83	6.28
T_9	4.61	4.78	5.38	5.96	6.35	6.68	6.40	6.55
T_{10}	4.38	4.53	5.16	5.36	5.82	6.39	6.80	6.61
T_{11}	4.27	4.39	4.80	5.13	5.58	6.14	6.52	6.85
T_{12}	4.34	4.35	5.09	5.25	5.71	6.27	6.63	6.75
A. Means for chemicals								
1. Untreated	5.20	5.31	5.76	6.13	6.64	6.55	6.45	5.91
2. GA (75 ppm)	4.44	4.59	5.09	5.35	5.77	6.35	6.73	6.67
3. Cycocel (500 ppm)	4.67	4.83	5.42	6.00	6.42	6.72	6.50	6.18
4. Waxol (6 %)	4.33	4.42	5.02	5.25	5.70	6.27	6.65	6.74
B. Means for packagings								
1. Unpacked	4.80	4.95	5.52	5.89	6.31	6.55	6.50	6.10
2. PE bags	4.56	4.69	5.10	5.49	5.97	6.43	6.68	6.52
3. CFB boxes	4.63	4.73	5.34	5.66	6.12	6.44	6.61	6.50
Chemicals								
S.E. ±	0.024	0.055	0.023	0.025	0.022	0.025	0.024	0.033
CD at 5 %	0.700	0.161	0.068	0.073	0.064	0.072	0.070	0.097
Packagings								
S.E. ±	0.021	0.048	0.020	0.022	0.019	0.021	0.021	0.029
CD at 5 %	0.061	0.140	0.059	0.063	0.055	0.062	0.061	0.084
Interactions								
S.E. ±	0.042	0.096	0.040	0.043	0.038	0.043	0.042	0.058
CD at 5 %	0.122	N.S.	0.117	N.S.	0.111	0.125	0.122	0.168

After 2 days storage in CC also the fruits under all the treatment combinations had increased non-reducing sugars content than they had initially as fresh fruits. There were significant differences due to chemicals, packagings, and interactions. Regarding chemicals the untreated fruits recorded the highest non-reducing sugars content (5.20 %) and the lowest non-reducing sugars content (4.33 %) was recorded in fruits treated with 6 % waxol. All the chemical treatments differed significantly from each other. Among the packagings, the unpacked fruits had the highest (4.80 %) non-reducing sugars content and the lowest (4.56 %) in fruits packed in PE bags. All the packagings differed significantly from each other. In case of the various treatment combinations, the untreated fruits kept open (T_1) had the highest non-reducing sugars content (5.28 %) and the lowest non-reducing sugars (4.27 %) was recorded in 6 % waxol + PE bags fruits (T_{11}).

After 4 days storage at RT, all the treatment combination had increased non-reducing sugars content than they had on 2nd day of storage. There were significant differences due to chemicals and packagings but interactions effect were non-significant. As regards chemicals, the highest non-reducing sugars content (6.49 %) was recorded in untreated fruits and the lowest (5.76 %) in fruits treated with 6 % waxol. All the chemicals differed significantly from each other. Among the packagings, the unpacked fruits recorded the highest (6.31 %) non-reducing sugars content while the lowest non-reducing sugars (6.08 %) was recorded in fruits packed in PE bags. All the packagings had significant effect.

After 4 days of storage in CC, all the treatment combinations had more non-reducing sugars content than they had on 2nd day of storage. There were significant differences due to chemicals and packagings but the interaction were non-significant. Among the chemicals, the untreated fruits had the highest (5.31 %) non-reducing sugars content and the lowest non-reducing sugars (4.42 %) was observed in 6 % waxol treated fruits. All the chemicals differed significantly from each other. Regarding packagings, the highest non-reducing sugars (4.95 %) was observed in unpacked fruits while the fruits packed in PE bags recorded the lowest (4.69 %) non-reducing sugars content. The packaging treatments, PE bags and CFB boxes were at par.

After 6 days of storage at RT all the treatment combinations except untreated + unpacked (T_1) had increased non-reducing sugars content than they had on 4th day of storage. There were significant differences due to chemicals and interactions, while packaging effects were non-significant. Among the chemicals 75 ppm GA treated fruits recorded the highest (7.27 %) non-reducing sugars content while the lowest non-reducing sugars (6.48 %) was recorded in untreated fruits. All the chemicals differed significantly from each other. As regards packagings, the highest non-reducing sugars content was observed (6.90 %) in fruits packed in PE bags. In case of various treatment combinations, 500 ppm cycocel treated fruits and kept open (T_4) recorded the highest (7.41 %) non-reducing sugars content, while the lowest (6.35 %) in untreated fruits kept open (T_1).

After 6 days of storage in CC, all the treatment combinations had more non-reducing sugars content than they had on 4th day of storage. There were significant differences due to chemicals, packagings and interactions. As regards chemicals, the untreated fruits recorded the highest non-reducing sugars (5.76 %) content while the lowest non-reducing sugars (5.02 %) content was observed in fruits treated with 6 % waxol. All the chemicals had significant effect. Among the packagings the unpacked fruits recorded the highest non-reducing sugars (5.52 %) content and the lowest (5.10 %) in fruits packed in PE bags. All the packagings had significant effect. In respect of various treatment combinations, untreated fruits kept open (T_1) recorded the highest (5.98 %) non-reducing sugars content while the lowest (4.80 %) non-reducing sugars content was observed in fruits treated with 6 % waxol and packed in PE bags (T_{11}).

After 8 days storage at RT, all the treatment combinations except 75 ppm GA + PE bags (T_5), 6 % waxol + PE bags (T_{11}) and 6 % waxol + CFB boxes (T_{12}) had decreased non-reducing sugars content than they had on 6th day of storage. There were significant differences due to chemicals, packagings and interactions. Regarding chemicals, fruit treated with 6 % waxol recorded the highest (7.26 %) non-reducing sugars content while the lowest (5.85 %) non-reducing sugars was observed in untreated fruits. All the chemicals differed significantly from each other. Among the packagings, fruits packed in PE bags had the highest non-reducing sugars (6.75 %) content and the unpacked fruits recorded the lowest non-reducing sugars (6.20 %) content. All the packagings differed significantly from each other. In case of the various treatment combinations, the fruits treated with 6% waxol + packed in PE bags (T_{11}) recorded the highest non-reducing sugars content (7.35 %) followed by 75 ppm GA + PE bags (T_5) recorded (7.26 %) non-reducing sugars, while the lowest non-reducing sugars content was recorded (5.38 %) in untreated fruits kept open (T_1).

After 8th day of storage in CC, all the treatment combinations, had increased non-reducing sugars content than they had on 6th day of storage. There were significant differences due to chemicals and packagings but the interactions were non-significant. Among the chemicals, the highest non-reducing sugars content (6.13 %) was registered in untreated fruits while the lowest (5.25 %) was registered in 6 % waxol of treated fruits. All the chemicals differed significantly from each other. Regarding packagings, the unpacked fruits recorded the highest non-reducing sugars (5.89 %) content while the fruits packed in PE bags recorded the lowest (5.49 %) non-reducing sugars content. All the packagings had significant effect.

At the end of storage life of 8 days at RT conditions, sapota fruits under most of the treatment combination had lost its shelf-life. Therefore, the storage experiment at RT conditions was terminated for the further physico-chemical analysis. However, the fruits in CC storage conditions were still found to be in better conditions. Hence, further observations of non-reducing sugars (%) content of sapota fruits on 10^{th}, 12^{th}, 14^{th} and 16^{th} days were recorded for CC storage only.

After 10 days of storage in CC, all the treatment combinations had more non-reducing sugars content than they had on 8^{th} day of storage. There were significant differences due to various chemicals, packagings and their interactions. As regards chemicals, the untreated fruits recorded the highest non-reducing sugars (6.64 %) content while the fruits treated with 6 % waxol recorded the lowest non-reducing sugars (5.70 %) content. All the chemicals differed significantly from each other. In case of packagings, the unpacked fruits recorded the highest non-reducing sugars (6.31 %) content while the lowest non-reducing sugars (5.97 %) was recorded by fruits packed in PE bags. All the packagings had significant effects. As regards treatment combinations, untreated fruits kept open (T_1) recorded the highest non-reducing sugars (6.81 %) content and the lowest non-reducing sugars (5.58 %) content was recorded in fruits treated with 6 % waxol and packed in PE bags (T_{11}).

After 12 days storage in CC, all the treatment combinations except untreated + unpacked (T_1) and untreated + CFB boxes (T_3) had increased non-reducing sugars content than they had on 10th day of storage. There were significant differences due to chemicals, packagings and interactions. As regards chemicals, fruits treated with 500 ppm cycocel recorded the highest non-reducing sugars (6.72 %) content and the lowest (6.27 %) was observed in 6 % waxol treatment. All the chemicals differed significantly from each other. In respect of packagings, the unpacked fruits registered the highest non-reducing sugars (6.55 %) content and the lowest (6.43 %) non-reducing sugars was registered in fruits packed in PE bags. The packagings, PE bags and CFB boxes were at par. In regards to the various treatment combinations, fruits treated with 500 ppm cycocel and kept open (T_7) recorded the highest non-reducing sugars (6.84 %) while the lowest (6.14 %) was recorded in 6 % waxol treated fruis and packed in PE bags (T_{11}).

After 14 days of storage in CC all the treatment combinations except untreated + unpacked (T_1), untreated + CFB boxes (T_3), 500 ppm cycocel + unpacked (T_7) and 500 ppm cycocel + CFB boxes (T_9) had increased non-reducing sugars content than they had on 12th day of storage. There were significant differences due to various chemicals, packagings and their interactions. Regarding the chemicals, the highest non-reducing sugars (6.73 %) was recorded in 75 ppm GA treatment while the lowest non-reducing sugars (6.45 %)

was recorded in untreated fruits. The chemicals, untreated and 500 ppm cycocel were at par. Among the packagings, the fruits packed in PE bags recorded the highest (6.68 %) non-reducing sugars content while the lowest (6.50 %) non-reducing sugars content was observed in unpacked fruits. All the packagings had significant effects. As regards various treatment combinations, the fruits treated with 75 ppm GA + unpacked (T_4) recorded the highest non-reducing sugars (6.85 %) content while the fruits that were untreated and kept open (T_1) recorded the lowest non-reducing sugars (6.08 %) content.

After 16th day of storage in CC, all the treatment combinations except 75 ppm GA + PE bags (T_5), 6 % waxol + PE bags (T_{11}) and 6 % waxol + CFB box (T_{12}) had decreased non-reducing sugars content than they had on 14th day of storage. There were significant differences due to chemicals, packagings and their interactions. As regards chemicals, fruits treated with 6 % waxol had the highest non-reducing sugars (6.74 %) content and the lowest non-reducing sugars (5.91 %) was recorded in untreated fruits. The chemical treatments, 75 ppm GA and 6 % waxol were at par. Among the packagings, fruits packed in PE bags recorded the highest non-reducing sugars (6.52 %)and the lowest (6.10 %) in unpacked fruits. The packagings PE bags and CFB boxes were at par. In respect of the treatment combinations, at the end of storage experiment in CC on 18th day, the fruits treated with 6 % waxol + packed in PE bags (T_{11}) recorded the highest non-reducing sugars (6.85 %) content followed by 75 ppm GA + PE bags (T_5) recorded 6.81 per cent non-reducing sugars content, while the untreated + unpacked (T_1) fruits recorded the lowest (5.57 %) non-reducing sugars content.

To sum up the changes in non-reducing sugars (%) content during the course of storage, it was found that with the advancement of storage period, there was a significant increase in non-reducing sugars content till it reached the peak, followed by a gradual decline irrespective of storage treatments. The rate of increase in non-reducing sugars was faster in untreated fruits than in treated fruits and in unpacked fruits than in packed fruits. It was clear from the data that the rise in non-reducing sugars content was at slower rate in CC storage as compared to that at RT storage. Among all the treatment combinations, increase in non-reducing sugars content was slower and continuos in fruits treated with 6 % waxol + packed in PE bags (T_{11}) under both the storage conditions (RT and CC). This treatment combination registered the highest non-reducing sugar content (7.35 % and 6.85 %) at the end of storage life of fruits at RT and in CC respectively.

4.9 Total sugars (%)

The data on effect of various chemicals and packagings on the changes in total sugars (%) content of sapota fruits at RT and in CC have been given in Table 17 and 18, respectively.

At the beginning of storage, the total sugars (%) content of the fruit was 8.05 per cent. After 2 days of storage at RT, the fruits

Table 17. Effect of various chemicals and packaging materials on the changes in total sugars (%) content of sapota fruits at RT storage conditions

Treatment combinations	Days to storage			
	2nd	4th	6th	8th
Initial value	8.05	8.05	8.05	8.05
T_1	10.47	14.53	12.47	11.20
T_2	9.93	13.63	13.55	12.31
T_3	10.16	13.90	12.79	11.93
T_4	9.75	12.48	15.09	13.33
T_5	9.45	11.93	14.30	15.29
T_6	9.59	12.17	14.61	14.75
T_7	10.0	12.65	14.32	11.87
T_8	9.62	12.13	14.04	12.98
T_9	9.76	12.50	14.14	12.60
T_{10}	9.50	11.90	14.77	13.98
T_{11}	9.05	11.24	14.05	15.47
T_{12}	9.31	11.64	14.45	15.24
A. Means for chemicals				
1. Untreated	10.19	14.02	12.94	11.81
2. GA (75 ppm)	9.58	12.19	14.65	14.46
3. Cycocel (500 ppm)	9.79	12.43	14.17	12.48
4. Waxol (6 %)	9.29	11.60	14.42	14.90
B. Means for packagings				
1. Unpacked	9.93	12.89	14.16	12.60
2. PE bags	9.50	12.23	13.99	14.01
3. CFB boxes	9.70	12.55	14.00	13.63
Chemicals				
S.E. ±	0.107	0.168	0.111	0.116
CD at 5 %	0.313	0.491	0.323	0.337
Packagings				
S.E. ±	0.093	0.146	0.096	0.100
CD at 5 %	0.271	0.425	N.S.	0.292
Interactions				
S.E. ±	0.186	0.292	0.192	0.201
CD at 5 %	N.S.	N.S.	0.560	0.584

Table 18. Effect of various chemicals and packaging materials on the changes in total sugars (%) content of sapota fruits in CC storage conditions

Treatment combinations	Days to storage							
	2nd	4th	6th	8th	10th	12th	14th	16th
Initial value	8.05	8.05	8.05	8.05	8.05	8.05	8.05	8.05
T_1	9.66	10.84	12.17	13.98	15.17	13.63	12.35	11.09
T_2	9.32	10.54	11.58	13.06	14.48	14.21	13.98	12.36
T_3	9.43	10.69	11.82	13.40	14.84	13.82	13.63	12.15
T_4	8.90	9.51	10.83	11.46	12.60	14.43	15.14	14.55
T_5	8.42	8.92	10.06	10.71	11.95	13.96	14.76	15.21
T_6	8.54	9.03	10.51	10.99	12.20	14.24	15.01	14.87
T_7	9.12	9.74	11.42	12.26	13.49	14.84	13.91	11.97
T_8	8.69	9.28	10.55	11.46	12.75	14.51	14.81	13.43
T_9	8.82	9.43	10.88	11.75	13.05	14.63	14.21	13.33
T_{10}	8.58	9.12	10.40	11.07	12.21	14.28	15.04	14.72
T_{11}	8.28	8.81	9.70	10.55	11.68	13.82	14.60	15.32
T_{12}	8.51	8.95	10.10	10.78	11.98	14.06	14.82	14.98
A. Means for chemicals								
1. Untreated	9.47	10.69	11.86	13.48	14.83	13.88	13.82	11.87
2. GA (75 ppm)	8.62	9.15	10.47	11.05	12.25	14.21	14.97	14.88
3. Cycocel (500 ppm)	8.88	9.48	10.95	11.82	13.10	14.66	14.31	12.91
4. Waxol (6 %)	8.46	8.96	10.08	10.80	11.96	14.06	14.82	15.00
B. Means for packagings								
1. Unpacked	9.07	9.80	11.21	12.19	13.36	14.29	14.11	13.08
2. PE bags	8.68	9.39	10.49	11.45	12.72	14.13	14.53	14.08
3. CFB boxes	8.82	9.53	10.83	11.73	13.02	14.18	14.42	13.83
Chemicals								
S.E. ±	0.111	0.094	0.120	0.080	0.329	0.140	0.145	0.193
CD at 5 %	0.323	0.274	0.350	0.233	0.958	0.423	0.422	0.561
Packagings								
S.E. ±	0.096	0.082	0.104	0.069	0.285	0.210	0.125	0.167
CD at 5 %	N.S.	0.237	0.303	0.202	N.S.	N.S.	N.S.	0.486
Interactions								
S.E. ±	0.192	0.163	0.208	0.139	0.570	0.420	0.250	0.334
CD at 5 %	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	0.730	N.S.

under all the treatment combinations had more total sugars (%) than they had initially as fresh fruits (8.05 %). There were significant differences due to chemicals and packagings but interaction effects were non-significant. As regards chemicals, the untreated fruits recorded the highest total sugars content (10.19 %), while the lowest (9.29 %) in 6 % waxol treated fruits. The chemical treatments viz., 6 % waxol and 75 ppm GA, 75 ppm GA and 500 ppm cycocel were at par. Among the packagings, the highest total sugars content was observed in unpacked fruits (9.93 %) while the lowest (9.50 %) in fruits packed in PE bags. The packagings PE bags and CFB box were at par.

After 2 days of storage in CC all the treatment combinations had increased total sugars (%) than they had initially as fresh fruits (8.05 %). There were significant differences due to various chemicals but packagings and interaction effects were found to be non-significant. Regarding chemicals, the highest total sugars content (9.47 %) was recorded in untreated fruits, while the lowest (8.46 %) in 6 % waxol treated fruits. The chemicals viz., 6 % waxol and 75 ppm GA, 75 ppm GA and 500 ppm cycocel were at par. In case of packagings, the unpacked fruits recorded the highest total sugars (9.07 %) content and the lowest (8.68 %) in fruits packed in PE bags.

After 4 day of storage at RT, all the treatment combinations had more total sugars (%) content than they had on 2nd day storage. There were significant differences due to various chemicals and packagings but their interactions were non-significant. Among the chemicals the untreated fruits recorded the highest total sugars (14.02 %) content while 6 % waxol treated fruits recorded the lowest total sugars (11.60 %) content. The chemicals 75 ppm GA and 500 ppm cycocel were at par. In case of packagings, the highest total sugars (12.89 %) was recorded in unpacked fruits, while the fruits packed in PE bags recorded the lowest (12.23 %) total sugars content. The packagings, PE bags and CFB boxes were at par.

After 4 days of storage in CC, all the treatment combinations had more total sugars (%) content than they had on 2nd day of storage. There were significant differences due to chemicals and packagings while their interactions were found to be non-significant. Among the chemicals, the untreated fruits recorded the highest (10.69 %) total sugars content while the lowest (8.96 %) in 6 % waxol treated fruits. The chemicals 6 % waxol and 75 ppm GA were at par. As regards packagings, the highest total sugar content (9.80 %) was recorded in unpacked fruits, while the lowest (9.39 %) in fruits packed in PE bags. The packagings, PE bags and CFB boxes were at par.

After 6 days of storage at RT, all the treatment combinations except untreated + unpacked (T_1), untreated + PE bags (T_2) and untreated + CFB box (T_3) had increased total sugars content than they had on 4th day of storage. There were significant differences due to chemicals and interactions, while the packaging effects were found to be non-significant. Between the chemicals, 75 ppm GA treated fruits recorded the highest total sugars (14.65 %) content while the lowest (12.94 %) in untreated fruits. The chemicals viz., 500 ppm cycocel and 6 % waxol, 6 % waxol and 75 ppm GA were at par. As regards the packagings, the unpacked fruits recorded the highest total sugars content (14.16 %) and the lowest (13.99 %) in fruits packed in PE bags. In respect of various treatment combinations, fruits treated with 75 ppm GA and kept open(T_4) had recorded the highest total sugars (15.09 %) and the lowest (12.47 %) in untreated + unpacked (T_1) fruits.

After 6 days of storage in CC, all the treatment combinations had more total sugar content than they had on 4th day of storage. There were significant differences due to various chemicals and packagings but the interactions were non-significant. Regarding chemicals the untreated fruits recorded the highest (11.86 %) total sugars content and the lowest (10.08 %) in 6 % waxol treated fruits. All the chemicals differed significantly from each other. As regards the packaging the highest total sugars (11.21 %) content was observed in unpacked fruits and the lowest (10.49 %) was observed in fruits packed in PE bags. All the packagings had significant effects.

After 8 days of storage at RT, all the treatment combinations, except 75 ppm GA + PE bags (T_5), 75 ppm GA + CFB box (T_6), 6 % waxol + PE bags (T_{11}) and 6 % waxol + CFB box (T_{12})

had decreased total sugars content than they had on 6th day of storage. There were significant differences due to various chemicals, packagings and their interactions. As regards chemicals, the fruits treated with 6 % waxol recorded the highest (14.90 %) total sugars content and untreated fruits recorded the lowest (11.81 %) total sugars content. All the chemicals differed significantly from each other. Among the packaging, the fruits packed in PE bags recorded the highest (14.01 %) total sugars content and the lowest (12.60 %) in unpacked fruits. All the packagings had significant effects. In respect of various treatment combinations, the fruits treated with 6 % waxol and packed in PE bags (T_{11}) recorded the highest total sugars (15.47 %) followed by 75 ppm GA treated fruits packed in PE bags (T_5) recorded 15.29 per cent while the lowest total sugars (11.20 %) was recorded in untreated + unpacked (T_1) fruits.

After 8 days storage in CC, all the treatment combinations had increased total sugars content than they had on 6th day of storage. There were significant differences due to chemicals and packagings but the interaction effects were non-significant. Among the chemicals, the untreated fruits recorded the highest total sugars (13.48 %) content and the lowest (10.80 %) in fruits treated with 6 % waxol. All the chemicals differed significantly from each other. As regards the packagings, the highest total sugars content (12.19 %) was recorded in unpacked fruits while the lowest (11.45 %) in fruits packed in PE bags. All packagings differed significantly from each other.

At the end of storage life of 8 days at RT conditions, sapota fruits under most of the treatment combinations had lost its shelf-life. Therefore, the storage experiment at RT conditions was terminated for further physico-chemical analysis. However, the fruits in CC storage conditions were still found to be in better conditions. Hence, further observations on total sugars content (%) of sapota fruits on 10^{th}, 12^{th} 14^{th} and 16^{th} day were recorded for CC storage only.

After 10 days of storage in CC, all the treatment combinations had increased total sugars content than they had on 8^{th} day of storage. There were significant differences due to chemicals but packagings and interaction effects were found to be non-significant. Between the chemicals, the untreated fruits recorded the highest (14.83 %) total sugars content while the lowest (11.96 %) in fruits treated with 6 % waxol. The chemicals viz., 6 % waxol and 75 ppm GA, 75 ppm GA and 500 ppm cycocel were at par. As regards the packagings, the unpacked fruit recorded the highest (13.36 %) total sugars content while the lowest (12.72 %) in fruits packed in PE bags.

After 12 days of storage in CC, all the treatment combinations except untreated + unpacked (T_1), untreated + PE bags (T_2) and untreated + CFB boxes (T_3) had increased total sugars content than they had on 10[th] day of storage. There were significant differences due to chemicals but packaging and interactions were non-significant. Among the chemicals, the highest total sugar (14.66 %) was recorded in 500 ppm cycocel treated fruits while the lowest (13.88 %) in untreated fruits. The chemical treatments viz., untreated and 6 % waxol, 6 % waxol and 75 ppm GA were at par. In case of packagings, the unpacked fruits recorded the highest (14.29 %) total sugars content and the lowest (14.13 %) in fruits packed in PE bags.

After 14[th] day of storage in CC, all the treatment combinations, except untreated + unpacked (T_1), untreated + PE bags (T_2), untreated + CFB box (T_3), 500 ppm cycocel + unpacked (T_7) and 500 ppm cycocel + CFB box (T_9) had decreased total sugars content than they had on 12[th] day of storage. There were significant difference due to chemicals and interactions while the packaging effects were non-significant. Regarding the chemicals, 75 ppm GA treated fruits recorded the highest (14.97 %) total sugars content while the lowest (13.82 %) in untreated fruits. The chemicals, 6 % waxol and 75 ppm GA were at par. Among the packagings, the fruits packed in PE bags recorded the highest total sugars (14.53 %) while the lowest (14.11 %) in unpacked fruits. In respect of various treatment combinations, fruits treated with 75 ppm GA and kept open (T_4) recorded the highest total sugars (15.14 %) and the lowest (12.35 %) in untreated fruits kept open (T_1).

After 16^{th} day of storage in CC, all the treatment combinations except 75 ppm GA treated fruits packed in PE bags (T_5), 6 % waxol treated fruits packed in PE bags (T_{11}) and 6 % waxol treated fruits packed in CFB box (T_{12}) had decreased total sugars content than they had on 14^{th} day of storage. There were significant differences due to chemicals and packagings while interactions were non-significant. Among the chemicals, fruits treated with 6 % waxol registered the highest total sugars (15.00 %), while the lowest (11.87 %) in untreated fruits. The chemical treatments, 6 % waxol and 75 ppm GA were at par. As regards packagings, fruits packed in PE bags recorded the highest (14.08 %) total sugars content while the lowest (13.08 %) in unpacked fruits. In respect of various treatment combinations, at the end of storage experiment in CC on 18^{th} day, the fruits treated with 6 % waxol and packed in PE bags (T_{11}) recorded the highest total sugars (15.32 %) followed by fruits treated with 75 ppm GA and packed in PE bags (T_5) recorded 15.21 per cent total sugar content while the untreated and unpacked (T_1) fruits recorded the lowest total sugars (11.09 %) content.

An overall assessment of the reducing sugars, non-reducing sugars and total sugar (%) content of sapota fruits during the course of storage period, it was observed that with the advancement of storage period, there was a significant increase in all these sugars content till it reached the peak, followed by a gradual decline irrespective of storage treatments. The rate of increase in these sugars was faster in untreated fruits than in treated fruits and in unpacked fruits than in packed fruits. It was also clear from the data that, the rise in these sugars was at slower rate in CC storage as compared to that RT storage. Among all the treatment combinations, increase in these sugars content was at slower rate and continuos in 6 % waxol treated fruits and packed in PE bags (T_{11}) under both the storage conditions (RT and CC). This treatment combinations registered the highest reducing, non-reducing and total sugars (%) content at the end of storage life of fruits at RT and in CC respectively.

4.10 Shelf life and organolpetic evaluation

The data in respect of various chemicals and packaging materials on the shelf life of sapota fruits at RT and in CC have been given in Table 19. It was obvious from the data that the shelf life of fruits stored in CC was better than that fruits stored at RT.

At RT, the treatment combination of 6 % waxol + PE bags (T_{11}) could extend the shelf life of sapota fruit upto 8 days while the untreated + unpacked (T_1) combination had recorded the lowest shelf life of 5 days in sapota fruits. The remaining treatment combinations viz., T_2, T_3, T_4, T_7 and T_9 registered the shelf life of 6 days and treatment combinations T_6, T_8, T_{10} and T_{12} registered the shelf life of 7 days.

In CC, it was interesting to note that the shelf - life of sapota fruits under the same treatment combinations i.e. 6 % waxol

Table 19. Effect of various chemicals and packaging materials on the shelf-life and organoleptic evaluation of sapota fruits at RT and in CC storage conditions

Treatment combinations	At RT				In CC					
	Shelf-life (days)	Organoleptic evaluation			Shelf-life (days)	Organoleptic evaluation				
		4th	6th	8th		8th	10th	12th	14th	16th
T_1	5	7.75	4.34	-	11	6.32	7.85	4.38	-	-
T_2	6	7.92	5.15	4.10	13	6.04	7.16	8.10	4.57	-
T_3	6	7.84	4.88	3.75	12	6.15	7.98	5.10	4.45	-
T_4	6	8.27	5.29	4.18	12	6.85	8.24	5.26	4.41	-
T_5	8	6.44	8.43	5.28	16	-	6.03	7.15	8.44	5.75
T_6	7	6.20	8.21	5.10	14	-	6.76	8.05	5.45	5.20
T_7	6	7.90	4.85	4.00	12	6.48	7.90	4.95	3.65	-
T_8	7	6.07	7.86	4.75	14	-	6.27	8.20	5.06	-
T_9	6	8.11	5.03	4.38	13	5.18	8.16	5.95	4.24	-
T_{10}	7	6.11	8.00	5.00	15	-	5.37	6.45	8.05	4.90
T_{11}	8	6.52	8.65	5.40	16	-	6.15	7.36	8.75	6.00
T_{12}	7	6.32	8.32	5.20	15	-	5.85	6.95	8.25	5.50

Treatment showing organoleptic score less than 5.5 was terminated

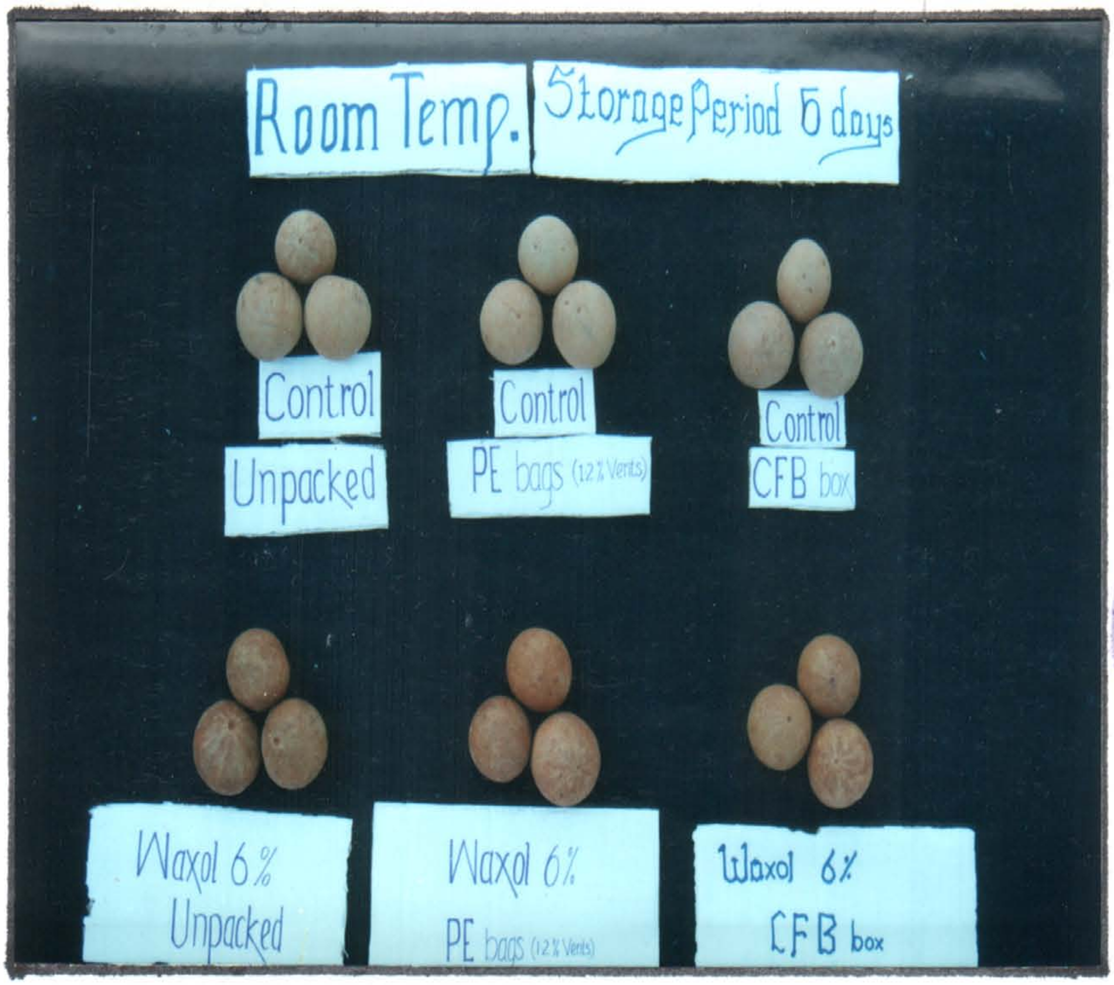

Plate 3. 6 % waxol treated sapota fruits stored room temperature 6 days after storage

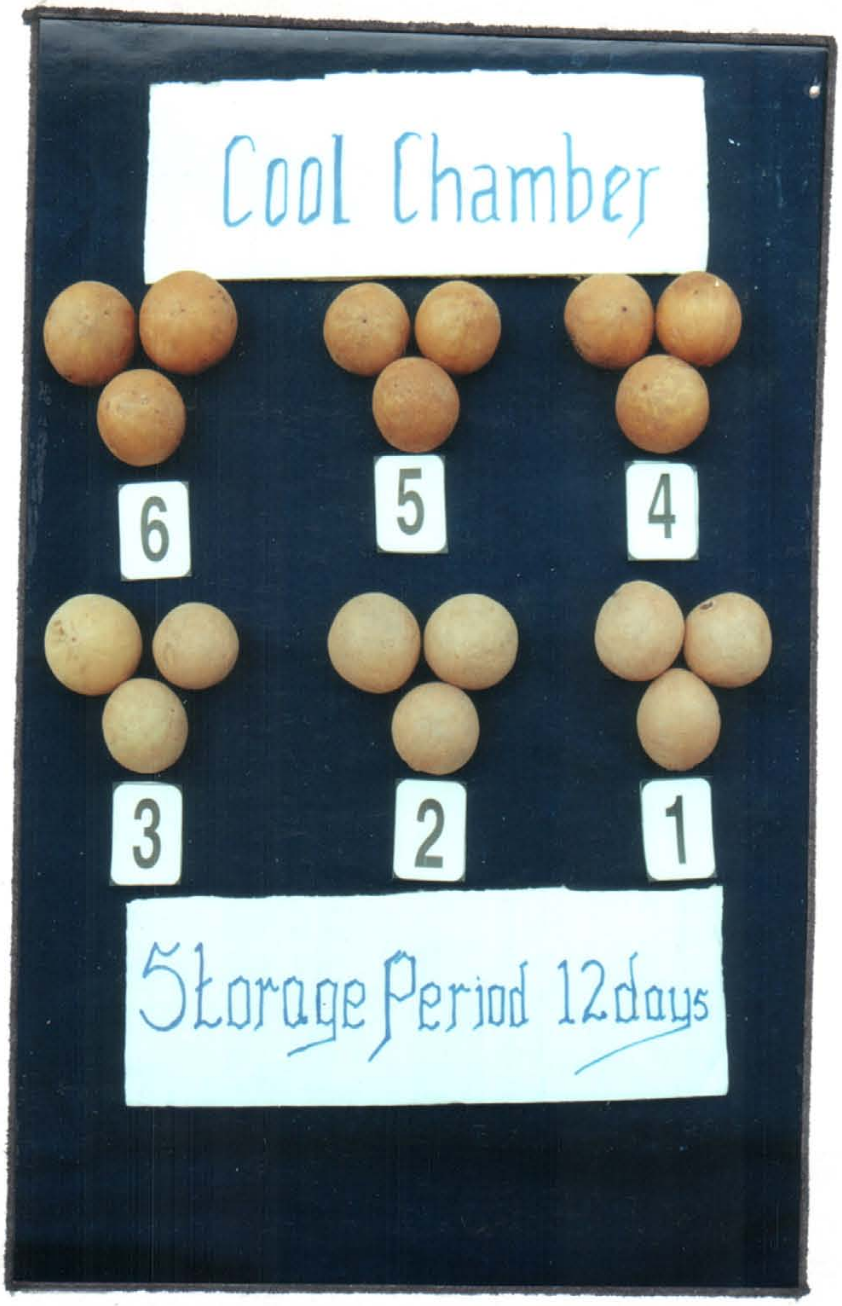

Plate 4. 6 % waxol treated sapota fruits stored in zero energy cool chamber 12 days after storage

1. Control + unpacked
2. Control + PE bags
3. Control + CFB box
4. 6 % waxol + Unpacked
5. 6 % waxol + PE bags
6. 6 % waxol + CFB box

+ PE bags (T_{11}) and 75 ppm GA + PE bags (T_5) could be extended upto 16 days. The lowest shelf life in CC was recorded 11 days in untreated fruits kept open (T_1). The remaining treatment combinations T_3, T_4 and T_7 recorded shelf life of 12 days, T_2 and T_9 recorded shelf life of 13 days, T_6 and T_8 recorded shelf life of 14 days and T_{10} and T_{12} recorded the shelf life of 15 days respectively.

As regards organolpetic evaluation at RT, it was observed from Table 19 that treatment T_1, T_2, T_3, T_4, T_7 and T_9 only attended the highest edible quality on 4th day. However T_5, T_6, T_8, T_{10}, T_{11} and T_{12} were not sufficiently ripe and recorded low score for organolpetic evaluation. On 6th day T_1, T_2, T_3, T_4, T_7 and T_9 had lost their edible qualities and recorded decreased organoleptic scores over that observed on 4th day. On 6th day, 75 ppm GA treated fruits packed in PE bags and CFB boxes (T_5 and T_6) and 6 % waxol treated fruits kept open, packed in PE bags and CFB boxes (T_{10}, T_{11} and T_{12}) had the highest edible qualities. On 8th day, all the untreated (T_1, T_2 and T_3) and chemical treated but unpacked (T_4, T_7 and T_{10}) fruits were little worth for their edible qualities. But 6 % waxol treated fruits packed in PE bags (T_{11}) and CFB boxes (T_{12}), similarly 75 ppm GA treated fruits packed in PE bags (T_5) and CFB boxes (T_6) had recorded better organolpetic scores and were still excellent for consumption and marketing purpose.

As regards organolpetic evaluation in CC, on 8th day of storage, all the untreated fruits (T_1, T_2, T_3), 75 ppm GA and 500 ppm cycocel treated fruits but kept open (T_4 and T_7) had only attended the edible qualities. Hence, organoleptic scores for only that combinations on 8th day was recorded. On 12th day, T_1, T_3, T_4 and T_7 treatment combinations had lost their edible qualities. Hence, their shelf-life was terminated on 12th day. On 14th day, 75 ppm GA + PE bags (T_5), 6 % waxol + unpacked (T_{10}), 6 % waxol + PE bags (T_{11}) and 6 % waxol + CFB boxes (T_{12}) had attended their highest edible qualities. On 16th day of storage in CC, only 6 % waxol + PE bags (T_{11}), 75 ppm GA + PE bags (T_5), 6 % waxol + CFB box (T_{12}) and 75 ppm GA + CFB box (T_6) had recorded better organoleptic scores and were still excellent for consumption and marketing purpose.

DISCUSSION

5. DISCUSSION

The results obtained in respect of various physical and chemical characters of sapota as influenced by various chemicals and packaging treatments during the course of storage and presented in preceeding chapter are discussed here under.

5.1 Chemicals

Ripening and senescence processes in fruits occur after harvest. Role of plant harmones, that are produced by plant, has now been well established in these processes. As long as the fruit is attached to the plant, it takes its nutritional requirements from the parent plant. Once it get harvested or detatched, these sources are cut off (Purohit, 1993). The artificially synthesised chemicals can substitute for the natural plant harmones and can control the ripening process to some extent. These compound either delay or hasten the ripening process. It was inferred that the catabolism of these harmones is a prerequisite to ethylene mediated events in fruit ripening. These includes all categories of plant harmones viz., auxins, gibberellins, cytokinins, inhibitors and other chemicals. Among these chemicals, gibberellic acid, cycocel and wax coating have been tried in present investigation for prolongation of shelf-life of sapota fruits.

Gibberellin, one of the important plant growth regulator was first reported to retard ripening in fruits by Coggins and Lewis (1962). The exogenous application of gibberellins are known to resist senescence changes in plant tissues by opposing the actions of ethylene. Beneficial effects of GA application in retarding ripening of different fruits have been observed by Kumbhar and Desai (1986), Banik *et al.* (1988), Gautam and Chudawat (1990), Avaiya and Singh (1991), Bhanja and Lenka (1994) Patel and Katrodia (1998) in sapota fruits; Saha (1971) in guava; Sandbhor and Desai (1991) and Bandopadhayay and Sen (1995) in ber; Singh and Kumar (1997) in aonla; Rao and Chundawat (1988) and Patil and Hulamani (1998) in banana; Kumar and Nagpal (1996) and Ahmed and Singh (1999) in mango fruits.

Cycocel (CCC) is one of the important plant growth retardant when applied exogenously in higher concentrations (500 ppm and above) were reported to inhibit senescence in fruits and this chemical was expected to act by opposing the actions of ethylene (Clifford and Lenton, 1980). Beneficial effects of cycocel in extending the shelf life of different fruits have been reported by Garg *et al.* (1978) and Mitra *et al.* (1981) in guava; Murthy and Rao (1982) in mango; Siddiqui and Gupta (1995) in ber; Patel and Sachan (1995) in aonla and Kumar and Prasad (1997) in papaya fruits.

It is well documented that, the application of wax emulsion to freshly harvested, healthy and mature fruits, protects them against excessive moisture loss, reduces rate of respiration, do not leave any residue, do not impart any undesirable odour or flavour or interfere with natural appearance of fruits and its quality as reported by Ingale *et al.*, 1982 in sapota and Jagdeesh and

Rokhade, 1998 in gauva. The beneficial effects of wax coating in different crops have been reported by Banik *et al.* (1988) in Sapota; Bhullar and Farmahan (1980); Singh *et al.* (1984); Patel *et al.* (1993), and Singh (2000) in guava; Jawanda *et al.* (1980); Baviskar (1993), Naik and Rokhade (1994) and Bhadra *et al.* (1999) in ber; Sadasivam *et al.* (1971) and Sarkar *et al.* (1995) in banana and Bhullar *et al.* (1984) in mango fruits.

It is appeared from Fig. 1 and 2 that loss in weight increased significantly irrespective of storage treatments at both the storage conditions (RT and CC). Loss in weight was constantly high in untreated fruits. Among the chemicals, fruits treated with 6 % waxol were found to be significantly superior over the other chemicals in reducing weight loss. The 6 % waxol treated fruits recorded the lowest weight loss 22.06 and 24.83 per cent at the end of storage life at RT and in CC respectively (Table 2 and 3). This reduction in PLW in waxol treated fruits could be due to slow release of free water due to reduced metabolism and reduced rate of transpiration as reported by Gautam and Chundawat (1990) in sapota. It was also observed that fruit softening and skin shrinkage in all the treatments increased with the progress of storage. Fruits treated with 6 % waxol significantly arrested the fruit softening and fruit skin shrinkage under both the storage conditions i.e. at RT and in CC. This would be probably due to slower break down of pectins in cell wall due to wax emulsion as reported by Ingale et al. (1982) in sapota fruits. The finding in present study are in line with the observations made by Kumbhar and Desai (1986), who recorded only 13.89 per cent PLW, lowest fruit softening and skin shrinkage score when sapota fruits were treated with 75 ppm GA and packed in PE bags and Jagdeesh and Rokhade (1998) in guava fruits recorded only 15.65 per cent PLW with 6 % waxol.

In present study, it was observed that, the percentage of TSS and total sugars increased in all the treatments till it reached the peak and then declines gradually irrespective of storage treatments. These findings are in conformity with Kumbhar (1984); Reddy and Nagaraju (1993) and Nikam (1994) in sapota fruits. However, contravertial results regarding decrease in TSS with advancement of storage period was observed in sapota fruits by Ingale *et al.* (1982). In present study, 6 % waxol treated fruits recorded slower rate of rise in TSS and sugars and registered maximum TSS of 23.08 and 23.94 per cent at RT and in CC respectively at the end of storage life as compared to untreated fruits (Table 9 and 10). This accumulation of TSS and sugars during ripening in fruits is a consequence of hydrolysis of insoluble polysaccharides into soluble sugars as reported by Patel and Katrodia (1998) in sapota fruits. Further decline of TSS and sugars on the advanced storage was due to their utilization in respiration (Nagaraju, 1991). These observations are in line with Jagadeesh and Rokhade (1994) in guava fruits.

The observations on acidity (%) indicated the decrease in per cent titratable acidity in all the treatments with the advancement of storage period irrespective of storage treatments under both the storage conditions i.e. at RT and in CC. The decrease was significantly more in untreated fruits than treated fruits. Fruits treated with 6 % waxol recorded the maximum acidity 0.077 and 0.043 per cent at the end of storage life at RT and in CC, respectively (Table 11 and 12). This decrease in acidity on prolonged storage might be due to rapid utilization of organic acids during respiration as reported by Bhanja and Lenka (1994) in sapota fruits. Similar results in respect of decreased acidity were also recorded by Avaiya and Singh (1991), Patel and Katrodia (1998) in sapota, Bhadra *et al.* (1999) in ber. However Dhoot *et al.* (1984) and Patel *et al.* (1993) in guava fruits recorded different trend of increase in acidity during initial storage period and then decreased afterwards.

5.2 Packagings

Sapota fruits are very high in moisture (75-85 %) and equillibrium humidity (about 98 %) content (Gopalan *et al.*, 1971). Under ambient conditions, such commodities lose moisture rapidly causing skin shrinkage and loss of turgidity (Banik *et al.*, 1988). The loss of water and gaseous exchange, if prevented would extended its shelf-life. A semipermeable polyethylene packaging material modifies the gaseous atmosphere around the fruit and also controls the secondary infection. Polyethylene helps in arresting the moisture loss and maintains turgidity. Polyethylene is easy for handling, heat sealable, transparent, moisture proof, easily reused, easily transportable, with suitable percentage of venting and standardization can be done for each commodity. The beneficial effects of polyethylene packing in extending shelf-life of different fruits have been reported by Kumbhar and Desai (1986); Banik *et al.* (1988); Kariyanna *et al.* (1993) and Nikam (1994) in sapota; Singh *et al.* (1976); Khedkar *et al.* (1982); Dhoot *et al.* (1984); Venkatesha and Reddy (1994) and Singh (2000) in guava; Jain *et al.* (1981) in ber; Ben-Yehoushua (1966) and Chamara *et al.* (2000) banana; Reddy and Thimma (1981) and Singh and Narayana (1995) in mango fruits.

In present study, the weight loss was found to be significantly increased with the advancement of storage period irrespective of storage treatments under both the storage condition (Table 2 and 3). However, the rate of reduction in weight loss was slower in CC that at RT. The highest weight loss was observed in unpacked fruits and the lowest weight loss 20.75 and 24.78 per cent was recorded in fruits packed in PE bags at the end of storage life at RT (8 days) and in CC (16 days) respectively (Table 2 and 3). It could be inferred that reduced weight loss was mainly due to PE bags as it controlled the transpiration and respiration of sapota fruits during storage (Kariyanna *et al.*, 1993). The same trend for rotting, fruit softening and skin shrinkage of sapota fruits for all the treatments was observed under both the storage conditions. The results in respect of reduction in PLW, softening and shrinkage as observed for sapota in present study are in conformity with Banik *et al.* (1988) in sapota who observed reduced PLW (1.91) and minimum spoilage (30.00 %) when fruits were kept in PE bags with paramagnet silica-gel at 10-12^{0}C and Kumbhar and Desai (1986) observed reduced PLW (13.89 %), rotting (5.34 %) and the lowest softening and shrinkage score in sapota fruits treated with 75 ppm GA and kept in perforated PE bags.

As the fruits started ripening, TSS and sugars increased continuously till they reached the peak followed by gradual decline was observed under both storage conditions i.e. RT and CC irrespective of storage treatments. This increase is attributed to conversion of starch and other insoluble carbohydrates into soluble sugars as reported by Patel and Katrodia (1998) in sapota. Further decrease in TSS and sugars with prolonged storage was attributed to utilization of them during respiration (Nagaraju, 1991). Similar trend was observed by Nikam (1994) in sapota fruits. However, different trend of continuous increase in TSS and sugars throughout the storage period was observed by Banik *et al.* (1988) in sapota.

The rise and fall in TSS and sugars were found to be delayed in polyethylene packaging which recorded the highest TSS 21.99 and 22.83 per cent at the end of storage life at RT and in CC respectively (Table 9 and 10). Thus, values of TSS and sugars indicated that polyethylene packaging of sapota fruits retained more

TSS and sugars as compared to fruits in CFB boxes and unpacked fruits.

The data presented in Table 11 and 12 indicated that the titratable acidity percentage of sapota fruit significantly decrease with the advancement of storage period irrespective of storage treatments under both the storage condition i.e. RT and CC. However, under CC conditions, rate of decrease in acidity was slower. Similar results regarding decrease in acidity was recorded by Gautam and Chundawat (1990), Bhanja and Lenka (1994) and Patel and Katrodia (1998) in sapota fruits; Bhullar and Farmahan (1980) in guava fruits. However, Dhoot *et al.* (1984) and Venketesha and Reddy (1994) in guava fruits observed increase in acidity during initial period of storage and continuous decrease thereafter. This decrease in acidity may be attributed to conversion of acids to sugars or it may be due to utilization of acids during respiration as reported by Venkatesha and Reddy (1994) in guava fruits.

In present study the highest level of acidity 0.068 and 0.040 per cent was recorded in fruits packed in polyethylene bags at the end of storage period at RT and CC respectively (Table 11 and 12). In addition polyethylene packed fruits were better in quality even with extended storage life as compared to fruits packed in CFB boxes and unpacked fruits.

The gauge, size and perforation of polyethylene for packaging of fruits depend upon weight of commodity, stage of maturity, temperature and light. The type of commodity is important because the injury of O_2 depletion and CO_2 increase depend upon the tissue and better results could be achieved by standardising the perforations (Scott *et al.*, 1971). The extended shelf life was obtained by packaging the sapota fruit in 100 gauge polyethylene bag with 1.2 per cent vents (Kumbhar and Desai, 1986). The results obtained in the present study are in conformity with the observations of these workers.

Now-a-days, CFB boxes are becoming more popular for storage and transport of fruits as they are lighter in weight, easy to stack and handle. In present study these boxes substantially reduced the weight loss of sapota fruit in it than that of control fruits. In addition, at the time of packaging, there is often a vapour pressure difference between the fruit and the package. So that water is evaporated from the produce and is absorbed by packing materials (Damodaran *et al.*, 1999). This could be the reason that at high temperature and low humidity conditions at RT, the CFB boxes were not much effective in checking the weight loss and arresting the ripening. The beneficial effects of CFB boxes for storage and transport have been reported by Anand and Maini (1982) and Kaushal and Anand (1986) for apple; Joshi and Roy (1986) for mango; Gupta *et al.* (1981); Singh (1987) and Baviskar (1993) for ber and Damodaran *et al.* (1999) and Waskar *et al.* (1997) for sapota fruits. The results obtained in the present investigation are analougous with findings of these workers.

5.3 Storage environments

The post-harvest life of fruits and quality of preserved fruit products are primarily dependent on storage temperature. The temperature not only regulates all the physiological activities such as respiration, transpiration and ripening of fresh produce but also affects the physico-chemical changes of the processed products during storage. The harvested fruits continue to lose moisture and rapidly become wilted, tough or mushy and consequently inedible. Hence, high humidity (over 90 %) is essential to avoid shrivelling, weight loss and loss of other quality components. Thus, high humidity and low temperature have major effects on storage life of many fruits (Roy and Khurdiya, 1986).

Recently based on evaporative cooling principle a zero energy cool chamber has been developed at IARI, New Delhi. Inside cool chamber, temperature is maintained about 18-25^{0}C and relative humidity about 90-95 % during the peak summer months (Roy, 1982). The effective use of such cool chamber for extending the shelf life have been reported by Reddy and Nagaraju (1993); Joshi and Paralkar (1991); Nikam (1994); Chatopadhyay *et al.* (1994) for sapota; Gupta (1985); Singh (1987) and Baviskar (1993) for ber; Waskar (1989) for banana; Singh and Kumar (1997) for aonla and Khedkar (1997) for pomegranate fruits.

The results obtained in respect of total loss in weight (Table 2 and 3) revealed that, under ambient conditions, sapota fruits lost significantly more weight than in cool chamber irrespective of storage treatments. At the end of storage life at RT i.e. on 8th day, the fruits treated with 6 % waxol and packed in PE bags (the best treatment T_{11}) recorded 17.90 per cent weight loss while on 14th day of storage in CC the same treatment (T_{11}) recorded only 9.54 per cent weight loss. This lower weight loss might be due to lower rate of transpiration in fruits stored in cool chamber that could be attributed to lower temperature (18-25 ^{0}C) and higher relative humidity (90 %) maintained in cool chamber as reported by Reddy and Nagaraju (1993).

The fruits stored in cool chamber recorded less score for fruit softening, skin shrinkage at the end of storage life. This would be probably due to slower break down of pectins in cool chamber because of lower temperature and high relative humidity as reported by Gautam and Chundawat (1990) in sapota fruits. These findings are in accordance with Chattopadhayay *et al.* (1994) recorded only 15.5 per cent PLW and 10.55 per cent rotting and less softening and skin shrinkage in sapota under cool chamber. Similar trend was observed for softening and skin shrinkage during present study. The rotting (%) was found to be lower in CC storage than at RT storage. The isolation and culturing of micro-organisms associated with rotting was done and it was clear that *Fusarium* sp. and *Aspergillus niger* were responsible for rotting of sapota fruits under both the storage conditions. These micro-organisms were also reported by Kumbhar (1984) and Nikam (1994) in sapota.

It is apparent from the data regarding TSS and sugars that, there was initial rise in TSS and sugars and gradual decline afterwards under both the storage condition. But slower rate of increase in TSS and sugar in CC was attributed to lower temperature and higher relative humidities prevailed in CC which resulted in slower rate of respiration, lower enzymatic activities which helps in slow build up of sugars with reduced utilization in respiration. The present results are in line with those reported by other researchers as Joshi and Sawant (1991) and Nikam (1994) in sapota fruits. However, Reddy and Nagaraju (1993) in sapota did not find any declining trend in CC storage but reported continuous increase in TSS and sugars throughout the storage period.

The results obtained in respect of titratable acidity (%) (Table 11 and 12) revealed that, acidity of the fruits declined with advancement of storage period in both the conditions irrespective of storage treatments. But this decline was at faster rate at RT than in CC. Decline in acidity at faster rate at RT, could be because of higher rate of respiration as reported by Chattopadhayay *et al.* (1994) in sapota fruits. The results obtained in present study are in conformity with the observations of Gautam and Chundawat (1990) and Nikam (1994) in sapota and Baviskar (1993) in ber.

Higher organoleptic score was recorded in fruits treated with 6 % waxol and packed in 150 gauge polyethylene bags with 1.2 per cent vents than other treatments with the advancement of storage period. This combination recorded the highest organoleptic scores (5.40 and 6.00) at the end of storage life at RT and CC storage conditions respectively (Table 19). The fruits in cool chamber recorded higher organoleptic score than stored at room temperature. This may be due to relatively low temperature and higher humidity in cool chamber which lead to slow build up of sugars and acids which reflect the flavour, taste and uniform colour development of pulp upto end of storage period (16 days) in CC.

Since cool chamber could delay ripening and maintain freshness for short period more than at ambient conditions, it can be conveniently used by farmers at their orchards to store the sapota fruits for few days after harvest in glut seasons.

As regards the various treatment combinations, fruits treated with 6 per cent waxol and packed in polyethylene bags (T_{11}) showed the best results throughout the storage period at RT and in CC. However, this treatment recorded the less weight loss, rotting, fruit softening and shrinkage. It also recorded the highest TSS and sugars with higher levels of acidity at both the storage conditions. It is therefore, concluded that sapota fruits treated with 6 % waxol and packed in 150 gauge polyethylene bags with 1.2 % vents could extend the shelf-life upto 16 days without much deterioration of physico chemical characteristics and organoleptic qualities in CC storage conditions.

SUMMARY AND CONCLUSIONS

6. SUMMARY AND CONCLUSIONS

The present investigation entitled, "Studies on extension of shelf-life of sapota [*Manilkara achras* (Mill.) Fosberg] fruits Cv. Kalipatti was undertaken in the Post-harvest Technology Laboratory, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri during March 2000. The sapota fruits were obtained from the Instructional Cum Research Orchard of Department of Horticulture, M.P.K.V., Rahuri. During these studies, attempts were made to study (i) the effect of various chemicals and packaging materials on physico-chemical characteristics, shelf life and organoleptic qualities of sapota fruits under different storage conditions and (ii) to develop the suitable method to extend the shelf-life of sapota fruits.

Sapota fruits were treated with four chemical and three packaging treatments making in all 12 treatment combinations with three replications. The experiment was conducted in two sets in Factorial Completely Randomised Design (FCRD). The fruits of above mentioned treatments were stored at two different storage conditions i.e. at RT and in CC respectively.

The data regarding cumulative total weight loss, roting, fruit softening and fruit skin shrinkage were recorded at every alternate day. Similarly data for chemical parameters viz., TSS, reducing, non-reducing and total sugars and titratable acidity were recorded at one day interval while organoleptic evaluation was recorded only at edible ripe stage. The results obtained are summarised in the following paragraphs.

With the advancement of storage period, there was progressive increase in the total weight loss, rotting, fruit softening and fruit skin shrinkage under both the storage conditions (RT and CC). These losses were quite heavy in untreated fruits than in treated fruits. The fruits under CC storage recorded the same trend but at a slower rate. Among the chemicals, 6 % waxol treated fruits recorded significantly lowest weight losses (22.06 and 24.83 %), less rotting (12.51 and 8.43 %) and lowest scores for fruits softening and skin shrinkage at RT and in CC respectively at the end of storage life. As regards packagings, in present study it was observed that, polyethylene packaging of 150 gauge thickness with 1.2 % vents was effective in reducing weight loss and rotting as compared to CFB boxes and unpacked fruits. In respect to various treatment combinations, treatment of sapota fruits with 6 % waxol and packed in 150 gauge polyethylene bags with 1.2 % vents was the best and recorded the lowest weight loss (17.90 and 19.20 %), less rotting (10.15 and 7.28 %) and better physical qualities than any other treatment combinations at RT and in CC respectively. The isolation and culturing of micro-organisms associated with rotting of sapota was done and it was observed that *Aspergillus niger* and *Fusarium* sp. were responsible for rotting under both the storage conditions.

Sapota fruits under all the treatments recorded the initial rise in TSS and sugars till they reached the peak value and gradual decline thereafter with the progress of storage period. The rise and fall in TSS and sugars was found to be delayed in treated fruits as compared to untreated fruits. Titratable acidity content was continuously decreased throughout the storage period irrespective of storage treatments. The same trend of rise and fall in TSS and sugars content and decreasing acidity was also observed in fruits stored in cool chamber but at a slower rate. The 6 % waxol treated fruits recorded the highest TSS, sugars and acidity levels at the end of storage life at RT and in CC respectively. As regards packagings, 150 gauge polyethylene bags with 1.2 % vents was found to be the best in retaining maximum TSS, sugars and acidity content in sapota fruits. The treatment combination of 6 % waxol + 150 gauge PE bags with 1.2 % vents was the best in this regard.

The shelf-life of sapota fruits was extended upto 16 days in cool chamber when fruits were treated with 6 % waxol and packed in 150 gauge polyethylene bags with 1.2 % vents. The 6 % waxol treated fruits and packed in 150 gauge PE bags with 1.2 % vents recorded the highest organoleptic qualities than any other treatment. Thus, treatment combination of 6 % waxol and packing in 150 gauge polyethylene bags with 1.2 % vents was the best under both the storage conditions.

It is therefore observed that, the ripening process as indicated by total weight loss, rotting, fruit softening, skin shrinkage and chemical changes were faster in untreated fruits than in treated fruits and in unpacked fruits than in packed fruits. It was slower in 6 % waxol treated and packed in PE bags. Considering overall results, the treatment combination 6 % waxol + 150 gauge polyethylene packing with 1.2 % vents was the best one under both the storage conditions. However, under cool chamber conditions, this combination could extend shelf-life sapota fruits upto 16 days with minimum deterioration of physico-chemical characteristics and highest marketable appearance. Low temperature (10-22^{0}C) and higher relative humidities (80-95 %) in zero energy cool chamber in turn influenced the retention of maximum freshness of fruits upto 16 days.

To conclude, it may be stated that the storage of sapota fruits in cool chamber with 6 % waxol treatment and packaging in 150 gauge polyethylene bags with 1.2 % vents should be recommended. The present study indicated that the zero energy cool chamber could be a possible solution to the problem of storage of sapota fruits in glut season in India. This could help in a big way for the domestic as well as distant marketing of sapota fruits.

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*** Originals not seen**

APPENDICES

8. APPENDICES

Appendix-I : Data showing temperature (^{0}C) and relative humidity (%) during the period of experimentation under ambient conditions (RT)

Date	Temperature (^{0}C)		Relative humidity (%)	
	Maximum	Minimum	Morning (10.00 am.)	Evening (4.00 pm.)
11.3.2000	33.8	9.5	74	22
12.3.2000	34.0	10.4	73	21
13.3.2000	35.8	8.7	72	29
14.3.2000	36.1	10.5	68	20
15.3.2000	33.2	8.5	70	23
16.3.2000	32.9	8.5	76	18
17.3.2000	35.6	7.6	75	19
18.3.2000	35.0	8.4	76	29
19.3.2000	34.5	11.4	69	27
20.3.2000	34.5	9.0	74	29
21.3.2000	35.5	11.1	61	30
22.3.2000	36.1	11.2	57	31
23.3.2000	35.0	9.6	62	24
24.3.2000	33.4	10.6	59	19
25.3.2000	34.3	11.3	59	23
26.3.2000	34.6	14.5	58	24
27.3.2000	36.2	13.6	62	18
28.3.2000	35.4	14.0	53	20
29.3.2000	36.2	14.6	69	19
30.3.2000	36.9	13.5	58	17
31.3.2000	37.6	12.8	57	14

Period of experimentation : 13.3.2000 to 28.3.2000

Appendix-II: Data showing temperature (^0C) and relative humidity (%) during the period of experimentation inside the cool chamber (CC)

Date	Temperature (^0C)		Relative humidity (%)	
	Maximum	Minimum	Morning (10.00 am.)	Evening (4.00 pm.)
11.3.2000	20.1	11.3	92	89
12.3.2000	21.3	10.5	90	87
13.3.2000	21.6	9.0	91	88
14.3.2000	21.7	9.6	92	89
15.3.2000	19.2	8.9	90	85
16.3.2000	18.8	8.5	91	88
17.3.2000	20.5	8.0	88	86
18.3.2000	19.6	10.2	89	85
19.3.2000	18.5	10.0	90	86
20.3.2000	19.3	10.3	87	85
21.3.2000	21.2	10.2	90	83
22.3.2000	20.6	11.0	88	82
23.3.2000	19.2	9.4	88	84
24.3.2000	18.4	10.2	89	82
25.3.2000	18.7	11.8	86	81
26.3.2000	20.1	12.2	87	80
27.3.2000	19.0	11.1	88	82
28.3.2000	18.9	13.2	90	84
29.3.2000	19.6	11.2	92	88
30.3.2000	20.1	10.3	91	85
31.3.2000	19.8	10.7	93	88

Period of experimentation : 13.3.2000 to 28.3.2000

VITA

9. VITA

Tushar Tukaram Mali

Candidate for the degree

of

MASTER OF SCIENCE (AGRICULURE)

in

HORTICULTURE

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