EVALUATION OF SAPOTA [*Manilkara achras* (Mill.) Forberg] FOR POSTHARVEST QUALITIES

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "**Evaluation of sapota [*Manilkara achras* (Mill.) Forberg] for postharvest qualities**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously fonned the basis for the award to me of any degree, diploma, fellowship or other similar title of any other University or Society.

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CONTENTS

Chapter	Title	Page No.
1	INTRODUCTION	1
2	REVIEW OF LITERATURE	3
3	MATERIALS AND METHODS	16
4	RESULT	25
5	DISCUSSION	43
6	SUMMARY	57
	REFERENCES	i-x
	ABSTRACT	

LIST OF TABLES

Table No.	Title	Page No.
1	Physical parameters of sapota varieties	25
2	Chemical characters of sapota varieties	27
3	Sensory qualities of sapota varieties	28
4	Days to ripening and physiological loss in weight of sapota under different storage techniques	29
5	Percentage decay of sapota under different storage techniques	30
6	Marketability of sapota under different storage techniques	31
7	Firmness and Tannin content of sapota under different storage techniques	32
8	TSS and reducing sugar content of sapota under different storage techniques	33
9	Acidity and brix:acid ratio of sapota under different storage techniques	34
10	Sensory evaluation of stored sapota	35
11	Osmotic dehydration of sapota varieties	37
12	Reducing sugar content of osmo-oven dried and oven dried sapota slices under ambient storage conditions	38
13	Non-reducing sugar content of osmo-oven dried and oven dried sapota slices under ambient storage conditions	39
14	Acidity of osmo-oven dried and oven dried sapota slices under ambient storage conditions	39
15	Tannin content of osmo-oven dried and oven dried sapota slices under ambient storage conditions	40
16	Total sugar content of osmo-oven dried and oven dried sapota slices under ambient storage conditions	41
17	Sugar:acid ratio of osmo-oven dried and oven dried sapota slices under ambient storage conditions	41
18	Sensory evaluation of the dried products	42

LIST OF FIGURES

Fig. No.	Title	Page No.
1	Effect of fruit:sugar ratio on osmotic dehydration of sapota under ambient conditions	36
2	Effect of temperature on osmotic dehydration of sapota with 1:1 fruit:sugar ratio	36
3	Reconstitution of dehydrated sapota in 20°Brix syrup under ambient conditions	38
4	Physiological loss in weight of sapota varieties under different storage techniques	48
5	Marketability of sapota varieties under different storage techniques	49

LIST OF PLATES

Plate No.	Title	After Page No.
1	Source of fruits: sapota block in the college orchard	17
2	Varietal variation in fruit characters	44
3	Fruits after six days of storage in moistened saw dust (T_4) and cling film (T_3) against the control (T_5)	50
4	Directly oven dried sapota chunks (T_2) against osmo-oven dried with and without sugar coating (T_1 and T_3)	53

Introduction

INTRODUCTION

Sapota, a highly delicious dessert fruit with a slight flavour of astringency enjoys much popularity throughout India as '*Chikku*'. Sapota a native of Mexico and Central America, is now grown commercially in most of the countries endowed with tropical climate. The crop once grown only in peninsular India is presently extended on a larger scale to dry arid regions also. In many regions this hardy crop is preferred over mango due to its wide adaptability, low cost of production and high economic returns with minimum inputs. Hence the crop is considered as highly versatile and economical for saline and marginal lands.

By and large, sapota produced in India is consumed only in domestic market. Being a climacteric fruit, it is short lived, with a life of only three to five days during summer and hence achieved little popularity in the world trade. Keeping in view of its immense potential for export as a tropical item, sapota has been included as a priority item under horticultural produce.

Limited shelf-life and marketing period pose great challenge before sapota growers and distributors alike. Besides, the growing trend in area and production warrants a market glut, necessitating to develop suitable techniques to extend storage life either in fresh or processed form.

Extension of shelf-life even by one or two days will provide adequate time to the farmers either for storage or distant marketing, thus helps to escape a market glut. Modified/controlled atmosphere packaging and storage can go a long way towards solving these problems.

Sapota has not been promising for large-scale industrial processing owing to thermo-labile delicate flavour, undesirable pulp colour and intensive labour in peeling and deseeding of fruit. However, many products were tried so far viz. dehydrated chunks (sapota fig), canned sapota in syrup, ready to serve beverage, sweet chutney, wine and osmo-air dried sapota.

Hence the study was taken up with the following objectives.

1. To evaluate sapota varieties for fruit qualities, storability and product development.
2. To develop a cheap and simple storage technique.
3. To improve quality of dehydrated product through osmotic dehydration.

Review of Literature

REVIEW OF LITERATURE

Sapota (*Manilkara achras* (Mill.) Forberg syn. *Achras zapota* L.), a native of Mexico and Central America belonging to the family Sapotaceae is widely cultivated throughout the tropics. In India it is primarily grown for its edible part, whereas in Mexico, Venezuela and Guatemala it is for the gum extracted from the bark. Sapota being a climacteric fruit results in high degree of perishability and hence needs careful handling to minimise losses after harvest. Extension of shelf-life even by one or two days itself is significant as it enables distant marketing.

Literature on related works hitherto carried out at different places is reviewed and presented here under the following titles.

2.1 Fruit characters

2.2 Handling and storage

2.3 Osmotic dehydration

2.1 Fruit characters

Though India is considered to be the largest producer of sapota still it is considered as a minor fruit. Most of the varieties grown are selections with respect to shape, size and quality. Over eleven selected cultivars are commercially grown in India.

Varietal collections were made systematically at Pune, Coimbatore and Kodur during 1940. At Kodur variety 'Guthi' with oval shaped fruits was found to be the most prolific and superior in eating quality. In 1964 a trial with five varieties was laid out at Periyakulam in Tamil Nadu and Junagadh in Gujarat for production and quality evaluation. Results revealed that 'Kalipatti' and 'Pilipatti' were superior in terms of production and quality while 'Cricket Ball' had most attractive and large sized fruits (Chundawat and Bhuva, 1982).

During fifties and seventies efforts were made to introduce hybrids in sapota through planned breeding work which was pioneered by TNAU at Coimbatore and Periyakulam and at Dharward under UAS. At Coimbatore efforts were made to combine large size of 'Cricket Ball' with superior taste of 'Oval' resulting in the release of variety 'Co-1'. At Dharward crosses were made among 'Kalipatti', 'Cricket Ball', 'Calcutta Round' and 'Oval'. Among them 'Kalipatti' and 'Cricket Ball' cross was released. 'PKM 1', known for its high yield, excellent quality and better shelf-life, was released from Periyakulam; however in India fruits are not sold on the basis of variety but sold entirely as *chikku* (Chadha, 1992).

2.1.1 Physical characters

The diversity in fruit shape is an interesting feature in sapota. 'Calcutta Round' and 'Cricket Ball' produce oval or elliptical fruits whereas 'Kalipatti' and 'Chhatri' have a special feature of producing both round and elliptical fruits simultaneously in the same tree during the same season.

A correlation was worked out between the shape index and seed number per fruit and also between fruit weight and seed number. The regression analysis suggested that for every decrease in the seed number by a value of one, there was an increase in the shape index by a value of 0.20 and the fruit tended to be oval in shape. The fruit shape may also be governed by the way of distribution of seeds around the placenta. In round shaped fruits the seeds were more uniformly distributed around the placenta compared with oval fruits. A positive correlation was present between number of seeds per fruit and fruit weight. Round fruits were heavier (101 g) than oval fruits (69.7 g). This indicated the existence of hormonal influence of seeds on fruit development (Tendolkar, 1978).

Sundararajan and Rao (1967) and Ingle *et al.* (1982) observed that mean weight of the fruits varied from 30.8 to 140 g. In general the round fruited varieties recorded more weight than the oval and elliptic ones. According to Lakshminarayana

(1980) the fruits generally weighed about 75 to 200 g but in exceptional case fruits even upto 1 kg was also recorded.

The mean volume of mature fruits of 'Cricket Ball', 'Co-1' and 'Oval', were 305 ml, 115 ml and 62 ml respectively (Shanmugavelu and Srinivasan, 1973).

The specific gravity of the mature graded sapota varied from 1.016 to 1.086 (Sawant, 1989). At maturity 'Guthi' and 'Oval' recorded 0.95 and 1.06 respectively (Durairaj *et al.*, 1991) while in 'Kalipatti' it varied between 1.025 and 1.057 (Shende, 1993).

Regarding the length of the fruits, Lakshminarayana and Rivera (1979) found that it ranged from 5.2 to 9.2 cm, while diameter ranged from 4.8 to 9.3 cm. They studied nine sapota selections for flesh colour at maturity and reported it as yellow brown, light brown, dirty brown, yellowish brown, uniformly light reddish brown and brick red with yellow tinge at the centre. Mone *et al.* (1991) opined that 'Kalipatti' had soft melting delicious flesh with thin skin whereas 'Kirthabarthi' was sweeter but with a thick skin.

2.1.2 Chemical characters

The moisture content of mature sapota pulp varied between 69 and 80 per cent depending on the cultivar and growing conditions (Lakshminarayana *et al.*, 1967). The moisture content of mature sapota fruits ranged between 72.68 and 73.88 which decreased in storage (Shende, 1993).

TSS increased from fruit set to maturity from 13 to 21.6°Brix in 'Kalipatti' (Paralkar *et al.*, 1987) whereas Shende (1993) observed that TSS of 'Kalipatti' from maturity to ripe stage ranged between 21.5 to 24.16°Brix.

The flesh of 'Kalipatti' fruits was mellow and very sweet containing 12 to 14 per cent sugars which were noticed from third month of fruit set. Similarly reducing sugars were also increased from 0.38 per cent to 8.92 per cent at maturity

(Paralkar *et al.*, 1987). During ripening of the fruit, sucrose showed maximum increase followed by glucose and fructose (Lakshminarayana and Subramanyam, 1966).

The acidity in mature 'Calcutta Round' decreased from 0.22 per cent to 0.11 per cent when ripened (Lakshminarayana and Subramanyam, 1967) and in 'Oval' it reduced from 0.38 to 0.18 per cent (Surayanarayana and Goud, 1984). Non-volatile acidity expressed as malic acid constituted 35 to 75 per cent of total acidity at various developmental stages and ripening (Selvaraj and Pal, 1984).

Calcium pectate content in sapota ranged from 1.9 to 3.9 per cent (Shanmugavelu and Srinivasan, 1973); while in ripe sapota it was 1.35 per cent (Das and Mahapatra, 1976) and 0.5 to 0.62 per cent in mature 'Kalipatti' which got reduced during ripening (Shende, 1993).

Polyphenols from 2.4 per cent at harvest decreased to 1.8 per cent when ripened (Lakshminarayana and Subramanyam, 1966) and tannin content ranged from 0.15 to 0.45 per cent in ripened fruits (Sawant, 1989).

2.2 Handling and storage of sapota

Sapota being highly perishable is having only a short shelf-life. Harvesting at correct maturity, controlling respiration and transpiration by modified atmosphere and use of chemicals can reduce the enormous loss during handling and transit.

2.2.1 Maturity at harvest

The maturity of harvest in sapota plays a significant role in the postharvest behaviour of the fruits. Fruits of different stages are available all through the year leading to practical difficulties in harvesting of fruits of definite maturity. Sapota matures 8-10 months after fruit set depending upon the cultivar and available heat units. Fruits harvested earlier than physiological maturity take too long to soften and have poor quality while those harvested later soften quickly resulting in fast spoilage during handling and transport.

The time taken from fruit set to maturity was an important factor with respect to harvesting and maturity. It varied from 120 days to 245 days to mature after anthesis depending on the cultivar, agroclimatic location and available heat units (Purseglove, 1968; Sulladmath, 1975). The maturity of the sapota fruit could be judged on the basis of several external signs viz. peel developed a dull orange or potato colour with a yellowish tinge, a yellow streak rather than a green one was seen on light scratching of the skin, the brown scaly material disappeared from the fruit surface, milky latex content dropped to almost zero and dried spine like stigma fell from the tip of the fruit (Sulladmath and Reddy, 1990).

The TSS, total and reducing sugar content, acidity, pH and tannins which showed distinct trends during fruit growth and development could be considered as chemical indices of maturity (Paralkar *et al.*, 1987).

2.2.2 Ripening

Depending upon the cultivar, stage of maturity and temperature the ripening time will vary; generally it takes three to five days after harvest. On ripening they emit a sweet smell and becomes soft. Fruits are good source of digestable sugars (12-18%). The presence of fairly large quantities of tannin imparts an astringent flavour to the fruit.

Sapota followed a climacteric pattern of respiration and the climacteric peak varied in different varieties viz. fifth day in 'Kalipatti', sixth day for 'Oblong' and eighth day for 'Cricket Ball' (Selvaraj and Pal, 1984).

The level of ethylene production in 'Kalipatti' increased slowly from the beginning of ripening and reached its peak at 144 hrs which was followed by a decline. However, postharvest dips in GA_3 (300 ppm), Kinetin (100 ppm) or silver nitrate (40 ppm) for 20 minutes were found to control the ethylene production (Gautam and Chundamat, 1989).

Kariyanna (1989) observed that ripening and senescence of sapota fruits were characterised by the highly perceivable reduction in weight, volume, firmness, total titrable acidity, ascorbic acid, pectin and phenols whereas pulp to skin ratio, dry matter, TSS and sugar content increased. A study on changes in the activities of pectin methyl esterase (PME) and oxidative enzymes such as catalase, peroxidase and polyphenol oxidase (PPO) revealed that the activity of PME increased five fold upto fifth day after harvest and then gradually declined. Catalase and peroxidase activities showed a continuous four to seven fold increase while PPO activity showed only a three fold increase which was not significant (Rao and Chundawat, 1989).

Ethylene, the ripening hormone, is essential to be present in the required quantities for ripening of the sapota. Application of 1000 and 2000 ppm ethrel at 15 days before and at full maturity followed by storing under ordinary light, proved to be the most appropriate treatment for inducing early and uniform ripening without any deterioration in organoleptic quality and physico-chemical components (Soni *et al.*, 1981).

Among various simple ripening media like paper pack, saw dust and paddy straw, paddy straw was better in accelerating ripening of fruits treated with ethrel and had overall higher organoleptic score (Ingle *et al.*, 1981).

2.2.3 Shelf-life

Correct harvesting maturity decides the quality and shelf-life of fruits. But presence of all the stages of fruit within a tree at any point of time makes it difficult to harvest the fully matured fruits as such. Besides, the climacteric nature of the fruit renders it a short shelf-life.

A. Pretreatments

The best shelf-life was obtained with fruits dipped for 3 minutes in a solution of 75 ppm GA and packed in 100 gauge polyethylene bags with 1.2 per cent vents by arresting the ripening process and weight loss (Kumbhar and Desai, 1986). Postharvest dip for 20 minutes in GA (300 ppm) was the best treatment followed by kinetin (100 ppm) and silver nitrate (40 ppm) to add shelf-life and reduce postharvest losses in 'Kalipatti' fruits without any adverse effect on quality. These treatments extended shelf-life by retarding pre-climacteric respiration rate and ethylene production and shifted the climacteric peaks compared with the control (Gautam and Chundawat, 1989).

Avaiya and Singh (1989) reported that GA_3 (250 ppm) was the most effective in reducing weight loss and spoilage while coating resin (6%) was the most effective in increasing the percentage of marketable fruits in cvs. 'Kalippatti', 'Cricket Ball', 'Calcutta Special', 'Mohargootee' and 'Pilipatti'.

Sapota fruits (cv. 'Kalipatti') when dipped in six per cent waxol, Bavistin (250 or 500 ppm) or hot water (50°C for 10 minutes) and packed in 150 gauge polyethylene bag with one per cent ventillation, waxol treatment reduced PLW and delayed ripening but increased rotting and developed off-flavour. Storage decay was high in all treatments except those dipped in 500 ppm Bavistin (Kariyanna, 1989).

Fruits packed in ventillated cardboard box and held at 28.2-39.2°C at 72-100 per cent RH after the pretreatments with GA (300 ppm), Kinetin (100 ppm) or $AgNO_3$ (40 ppm) extended ripening period by 2.5, 1.5 and 1.0 day respectively over the control fruits which ripened in 5.2 days. These treatments retarded pre-climacteric activities of catalase and pectin methyl esterase enzymes, rate of respiration and ethylene production (Gautam and Chundawat, 1990, 1991).

Rao and Chundawat (1992) reported that 10 minutes postharvest dip in Menadione (1000 or 2000 ppm) and AVG (100 or 200 ppm) delayed ripening by three days by delaying the occurrence of climacteric peak.

Sarkar *et al.* (1995) studied the effect of storing sapota Calcutta Round in a cardboard box or bamboo basket with or without a prior three min dip in Kinetin, GA_3, $AgNO_3$, Bavistin or Waxol. Fruit quality was better in cardboard boxes than in bamboo baskets. Waxol (6%) minimised PLW, increased TSS, sugar and acidity and could be stored in cardboard boxes for 16 days without loss of quality.

Patel and Katrodia (1996) reported that treating sapota with GA 150 ppm for 8-10 minutes followed by shade drying for 30 minutes and subsequent packing in wooden boxes with paddy straw as packaging material, had helped not only in safe transportation but also maintained quality.

B. Packing

Polyethylene packing was highly effective in checking weight loss and maintaining turgidity and freshness of sapota. But unperforated polythene bags resulted in water soaking of the fruits and made them unmarketable. With increased intensity of perforation this disorder was reduced but PLW increased. The best results were obtained with 1.2 per cent venting of polythene bags which gave 100 per cent marketable fruits with only 3.9 per cent total loss on sixth day and 62.5 per cent of fruits lasted for eight days with excellent organoleptic qualities (Desai and Kumbhar, 1986).

The most effective method of transportation was packaging sapota in plastic crates with green pongamea leaves as cushion compared to simply dumping the fruits into the trolly. Packaging in one per cent vented 150 gauge polyethylene bags reduced PLW significantly, but the spoilage due to fungal rot was maximum. This could be reduced by treating with Bavistin (500 ppm) before packaging, however, deterioration could not be stopped beyond nine days (Kariyanna, 1989; Kariyanna *et al.*, 1990).

Sapota cv. 'Pala' were packed within two to four hrs of harvest in polyethylene bags of 100, 150 or 200 gauge with 0, 0.2, 0.4 or 0.6 per cent perforation. After six days of storage under ambient conditions (26-30°C and 50-60% RH) lowest percentage of spoilage (30.1%) was in bags of 100 gauge with 0.4 per cent perforation compared to 88.5 per cent in control. Highest percentage of unripe fruits was also recorded in the same treatment. Least PLW was recorded in unventillated polybags of 200 gauge, but the spoilage was high in all unventillated treatments resulting from accumulation of moisture leading to enhanced fungal growth (Joshua and Sathiyamoorthy, 1993).

In a study conducted by Pathmanabhan *et al.* (1995) sapota fruits were dipped in 4 per cent $CaCl_2$ for one hour and subsequently packed in polybags containing fused $CaCl_2$ at 15 g/kg or fused $CaCO_3$ at 30 g/kg or left untreated. Exposure to fused $CaCl_2$ or $CaCO_3$ in closed polybags retarded ripening and extended shelf-life upto 10 to 12 days compared with 3 to 4 days in control. Minimum water loss was observed in fruits treated with fused calcium salts. Organoleptic rating was also higher for $CaCl_2$ or $CaCO_3$ treated fruits.

C. Low temperature/Modified atmospheric storage

Low temperature can extend the shelf-life of fruits by reducing oxidative metabolism, respiration rate and ethylene evolution.

Flores and Rivas (1975) reported that storing sapota at 12°C tribled the storage period and can be further extended by another 10 days if frozen at 0°C after its full ripening. Broughton and Wong (1979) reported that the optimum storage temperature was near 20°C and storage life at this temperature could be increased further by removing ethylene and adding 5-10 per cent CO_2 (v/v) to the storage atmosphere. Extreme relative humidities or high concentrations of CO_2 impaired the quality of stored fruits.

Institute of Industrial and Technological Research of Central America indicated that refrigerated storage temperature between 6°C and 10°C caused irreversible damage to the ripening mechanism. Even ripe fruits stored under refrigerated temperature did not keep well and were poor in taste and flavour. Refrigeration and treatment with aqueous wax emulsion did not result in satisfactory ripening (Lakshminarayana, 1980). Mohamed *et al.* (1996) reported that fruits stored at 5°C developed chilling injury and they failed to ripen properly even in the presence of 50g CaC_2 per kg.

Joshi and Paralkar (1991), Joshi and Sawant (1991) and Shende (1993) observed that sapota stored in a cool chamber showed better palatability score, higher shelf-life and less shrivelling than that at ambient temperature. Nagaraju *et al.* (1992) observed that storage life of Kalipatti was extended upto 13 days in zero energy cool chamber as compared to 8 days in ambient conditions. The cool chamber storage effectively minimised and delayed rotting and shrivelling and retained more firmness than those in ambient conditions. The cool chamber storage delayed the rate of changes in TSS, titrable acidity and sugars compared to rapid changes in control. However at edible ripe stage there was no significant differences in chemical composition of fruits in cool chamber.

2.3 Osmotic dehydration

Preservation of food for consumption during seasons of shortage is an ancient art. Among all possible preservation methods drying or dehydration of food is probably the oldest industry to thrive. Osmotic dehydration, a novel technique for partial dehydration of fruits, consists of placing fruit pieces in dry or concentrated solution of sugar or salt for a period of time resulting in water loss accompanied by solute impregnation. Literature related to osmotic dehydration of fruits in general is reviewed here.

The fruits immersed either whole or in slices in sugar syrup lost about 50 per cent of its original weight by osmotic dehydration after which it was drained and either frozen or vacuum dried. The resultant product was with superior quality in terms of colour and flavour than conventionally dried food products (Ponting *et al.*, 1966).

Teaotia *et al.* (1976) reported osmo-air dehydration of mango slices steeped in sulphited sugar syrup of 20, 40 and 70°Brix. Mango slices were further dehydrated in a cabinet dryer at 60°C till the moisture content of the slices attained 4.06, 4.34, 4.62 and 3.67 per cent for 20, 40, 70°Brix and unsugared slices respectively. The slices treated with 40°Brix and 3000 ppm SO_2 were superior in colour, flavour and texture.

Osmotic dehydration of banana slices in sugar syrup of concentration varying from 60 to 80°Brix at temperature of 27, 40, 50 and 60°C revealed that fruit weight was reduced to about 50 per cent of its original weight at 50°C. The extent and rate of osmosis was greater when dry sucrose powder was used in the ratio 1:2 (fruit:sugar) than in the syrups, but for convenience in handling and economy a ratio of 1:1 seemed to be suitable. The reconstitution of osmotically dehydrated banana slices was only 50 to 60 per cent as compared to 63-65 per cent for air dried slices (Bongirwar and Sreenivasan, 1977).

Kulkarni and Kapse (1978) achieved 40 and 50 per cent weight reduction in Basrai banana slices by osmosis with 70 per cent sugar solution and dry sugar respectively and concluded that 70 per cent sugar solution was effective for banana.

Ambient temperature did not have any significant effect on quality attributes of stored fruit slices subjected to osmosis in 70 per cent sugar at 50°C for three hrs and dried at 60±2°C and 736 mm vacuum. Freeze dried and osmotically dehydrated products during storage at room temperature did not exhibit significant difference on quality attributes and suggested osmotic dehydration as a best alternative to the expensive freeze drying (Ramamurthy *et al.*, 1978).

According to Setty *et al.* (1978) the main principle involved in osmotic dehydration was partial dehydration of fruits and vegetables by osmosis at comparatively lower temperatures. This reduced the severity of the thermal treatment in the production of dehydrated fruits and vegetables and could be near to fresh produce.

Preparation of intermediate moisture banana by air drying of sulphited banana slices envinced that SO_2 treatment increased the firmness of banana by inactivating the proteolytic enzymes and also increased the dehydration rate by affecting the permeability of certain cellular membrane in banana tissue (Levi *et al.*, 1980).

Thapa (1980) attempted osmotic dehydration of segmented sapota and recommended 25 hours of osmotic dehydration at room temperature with a ratio of 1:3 (fruit:syrup) and subsequent oven drying for eight hrs as the best, among all parameters studied. Sundried product did not retain the flavour, whereas air dried product retained and it was quite acceptable to be eaten as a snack fruit. In order to reconstitute fully six hrs of soaking in 20°Brix syrup was recommended.

According to Contreras and Smyrl (1981) osmotic dehydration was a two stage dehydration process. The first step consisted of immersing fruit pieces in a concentrated osmotic solution or in a dry osmotic agent. In second step osmotically concentrated food was freeze/ vacuum/ air dried to produce a shelf stable product. Drying time needed for cabinet drying after osmotic drying was considerably shortened and significantly saved energy (Levi *et al.*, 1983). Again Levi *et al.*, (1985) reported that retention of ascorbic acid was high in osmo-air dried papaya slices compared to sun dried slices. However, osmosis in boiling syrup caused significant discolouration and heavy losses of ascorbic acid.

Vaghani and Chundawat (1986) cpined that sapota slices steeped in 40 per cent sugar solution containing KMS (1%) for 20 minutes or dipped in KMS 20 per cent for two minutes, when dried in sun gave the most stable and quality product. The yield of dried sapota after 33 hrs of sundrying ranged from 30 to 34 per cent of which woody slices accounted for 0.38-3.75 per cent. Rehydration rate and moisture absorption capacity of the osmo-dehydrated blue-berries were reduced by intake of sugar (Kim and Toledo, 1987).

Tomar *et al.* (1990) osmotically dehydrated 7.5 mm thick pear rings by steeping in sugar syrup of 40, 50, 60 and 70°Brix strength resulted in a weight reduction of 32 to 40 per cent.

Sugar infused into the pineapple acted as a water binding agent and increased the internal resistance to moisture movement and gave lower diffusion coefficients (Rahman and Lamb, 1991).

According to Torreggiani (1993) the effects of osmosis as a pretreatment was mainly related to the improvement of nutritional, sensorial and functional properties by balancing the two main osmotic effects, water loss and soluble solids uptake.

Papaya slices of 15 mm thickness osmotically dehydrated by moisture infusion technique by over night soaking in a solution containing 60 per cent sucrose, 0.1 per cent citric acid and 0.1 per cent potassium sorbate reached equillibrium at 44°Brix (Ahmed and Choudhary, 1995).

Karathanos *et al.* (1995) reported that drying of osmosed and non-osmosed apple samples at 50°C showed reduction in water diffusivity of osmosed samples. They suggested lower water diffusivity had significant application in the use of dehydrated foods as sugar treated foods may exhibit an extended food stability.

Material and Methods

MATERIALS AND METHODS

The present investigation on evaluation of postharvest qualities of sapota varieties was carried out at the Department of Processing Technology, College of Horticulture, Vellanikkara, Thrissur, Kerala during 1998-1999. The temperature and relative humidity prevailed during the period ranged from 32-39°C and 56-73 per cent respectively.

In the present study an attempt has been made to evaluate post-harvest qualities of five varieties viz.

V_1 - Cricket Ball

V_2 - Oval

V_3 - Co-1

V_4 - Co-2

V_5 - PKM 1

The whole programme was divided into three major experiments,

3.1 Evaluation of fruit characters

3.2 Evaluation of storability

3.3 Feasibility of osmotic dehydration

Acquisition of fruits

Sapota fruits were collected from the trees grown in the college orchard maintained as per Package of Practice Recommendations (KAU, 1996) under Department of Pomology and Floriculture, College of Horticulture, Vellanikkara (Plate 1).

Fruits were harvested based on the maturity indices suggested by Sulladmath and Reddy (1990).

Plate 1. Source of fruits: sapota block in the college orchard

3.1 Evaluation of fruit characters

Four trees of each variety and 25 fruits from each tree were harvested during the early hours of the day. Fruits free from injuries were selected, cleaned and allowed for normal ripening.

3.1.1 Observations

Ten fully ripened fruits of each varieties were randomly selected and observations on physical and chemical characters were recorded.

3.1.1.1 Physical parameters

3.1.1.1.1 Fruit shape

Fruits were categorised into round, oval, oblong or obovate shape by visual assessment.

3.1.1.1.2 Fruit weight

Weight of individual fruit was taken using an electronic balance (OHAUS 200 portable standard) with 100 mg accuracy.

3.1.1.1.3 Dimensions

Fruit length was measured in centimeters from the stalk end to the apex and diameter on the equatorial plane using a scale.

3.1.1.1.4 Volume

Fruit volume was determined in millilitres by water displacement method using a measuring cylinder.

3.1.1.1.5 Specific gravity

Specific gravity was computed by dividing weight by volume of the ripe fruit.

3.1.1.1.6 Pulp to seed ratio

The weights of pulp and seeds were recorded separately and pulp to seed ratio was calculated.

3.1.1.1.7 Firmness

Firmness of the ripe fruit was measured by penetrometer method using Effegi fruit pressure tester (Model FT 001 (0-5 kg)) and expressed as kg cm^{-2}.

3.1.1.1.8 Number of days for ripening

Number of days to reach edible ripeness by fully matured fruit indicated by softening was recorded.

3.1.1.2 Chemical characters

3.1.1.2.1 Total soluble solids (TSS)

TSS was determined with Erma hand refractometer (range 0-32°brix) and expressed in degree brix.

3.1.1.2.2 pH

pH of the fruit was directly read using digital pH meter (Model 5652A of Electronics Corporation of India).

3.1.1.2.3 Acidity

Titrable acidity was estimated as per A.O.A.C (1975) method and expressed as percentage citric acid.

3.1.1.2.4 Reducing sugar

Reducing sugar content was determined by Lane and Eynon method (Ranganna, 1986).

3.1.1.2.5 Tannin

Tannin content was determined as tannic acid by colorimetric method (Ranganna, 1986) and expressed as percentage.

3.1.1.2.6 Brix:acid ratio

The ratio was determined by dividing the degrees brix of the sample by the percentage of titrable acidity of the sample and was expressed nearest to the first decimal place (Ranganna, 1986).

3.2 Evaluation of storability

The experiment was aimed at evaluating shelf-life of five sapota varieties with five treatments under both ambient and refrigerated conditions.

3.2.1 Treatments

The following were the treatments

Fully mature fruits after harvest were

*T_1 - packed in poly ethylene (PE) bags with 1.2% venting

*T_2 - dipped in GA 300 ppm for 20 minutes, air dried and packed in PE bags with 1.2% venting

T_3 . Individually wrapped with cling film (klin wrap 300 mm of Flexo Film Wraps (India) Limited, Aurangabad)

T_4 . Packed in 30% moistened saw dust in 2:1 (sapota:saw dust) ratio in CFB boxes of size 30x20x20 cm

T_5 . Open stored (control)

*108 holes of 4 mm diameter were made to get 1.2 per cent ventillation on bags of size 21x27 cm.

*The treatments T_1-T_5 were given to all five varieties (V_1-V_5) under two temperatures viz. ambient and refrigerated (4 to 7°C).

3.2.2 Observations

3.2.2.1 Physical parameters

3.2.2.1.1 Physiological loss in weight (PLW)

PLW was calculated on the initial weight basis as suggested by Srivastava and Tandon (1968) and expressed as percentage.

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

3.2.2.1.2 Decay percentage

The decay percentage was calculated as per the formula given by Bhatnagar *et al.* (1980).

$$\text{Decay percentage} = \frac{\text{Weight of fruits decayed in the pack}}{\text{Total weight of the fruits in the pack}} \times 100$$

3.2.2.1.3 Marketability

Marketability was calculated based on cumulative spoilage and PLW (Onwuzulu *et al.*, 1995).

Percent marketable fruits = 100 - (% spoilage + % PLW)

3.2.2.1.4 Termination of the observations

Observations were terminated when 50 per cent or more of the original sample were discarded as suggested by Kapitsmadi (1989).

3.2.2.1.5 Firmness

Firmness was measured by penetrometer in kg cm^{-2} using Effegi fruit pressure tester of two ranges viz. Model FT 327 (0-13 kg) for unripe fruits and Model FT 011 (0-5 kg) for ripe fruits.

3.2.2.1.6 Number of days for ripening

Number of days taken by fully matured fruit to reach edible ripeness in each treatment was recorded.

3.2.2.2 Chemical characters

Composite samples were drawn at random in respect of each treatment in two days interval for estimation of TSS, titrable acidity, reducing sugar, tannin and brix: acid ratio. The procedures given under 3.1.1.2 were followed here also.

3.3 Osmotic dehydration

Osmotic dehydration, a two stage dehydration process, where in the osmosed fruit pieces were further dehydrated in a cabinet dryer to improve the quality of dehydrated sapota.

3.3.1 Preparation of sapota fruits

Firm ripe fruits were cleaned, peeled and cut into slices of 0.5-1 cm thickness and 3-4 cm length. Samples of 100 g in each replication were taken for the study.

3.3.2 Drying methods

3.3.2.1 Mechanical drying (M.D)

The fresh slices were directly dehydrated in a cabinet dryer with inner dimensions as 0.9 x 1.0 x 0.61 m with 2.5 KW heating capacity for eight hours. Temperature was maintained at 60 to 65°C during the entire drying period.

3.3.2.2 Osmotic dehydration (O.D)

After optimising the fruit to sugar ratio and time of osmosis in a preliminary experiment, osmotic dehydration of all the experimental varieties were carried out. Fruit pieces were immersed in dry sugar (sucrose) in 1:1 ratio containing

1500 ppm SO_2 and 0.3 per cent citric acid as preservative for eight hours. After eight hours of contact time, the slices were taken out and given a quick hot water dip to wash off the excess syrup adhering to the pieces and subsequently wiped with a tissue paper to dryness.

The osmosed fruit slices were further dried in a cabinet dryer at 60-65°C for eight hours by spreading evenly on aluminium trays.

3.3.3 Packing

Dehydrated slices were packed in polyethylene bags of 300 gauge, sealed and labeled.

3.3.4 Observations

3.3.4.1 Physical parameters

3.3.4.1.1 Weight reduction (WR)

Weight reduction by mechanical drying, osmosis and osmo-oven drying, was calculated using the formula,

$$WR (\%) = \frac{\text{Initial weight - Final weight}}{\text{Initial weight}} \times 100$$

3.3.4.1.2 Recovery percentage

Percentage weight of samples after oven drying over the initial fruit weight was calculated and expressed as recovery percentage.

3.3.4.1.3 Rehydration rate

Weighed samples of dried sapota were reconstituted with 20°Brix syrup and at regular intervals and the weight pick up was assessed using an electronic balance.

3.3.4.2 Chemical characters

Dehydrated samples were analysed before and after storage for total, non-reducing and reducing sugars, tannin, titrable acidity and brix:acid ratio.

3.3.4.2.1 Sugars

Total, reducing and non-reducing sugars were determined by Lane and Eynon method (Ranganna, 1986) and expressed as percentage.

3.3.4.2.2 Titrable acidity

Titrable acidity was estimated as described under 3.1.1.2.3.

3.3.4.2.3 Tannin

Tannin content of dehydrated samples were estimated as described under 3.1.1.2.4.

3.3.4.2.4 Sugar:acid ratio

The ratio was calculated using the formula

$$\text{Sugar:acid ratio} = \frac{\text{Total sugar (\%)}}{\text{Titrable acidity (\%)}}$$

3.4 Sensory evaluation

Sensory evaluation was carried out with the help of trained panel consisting of 12 members who were asked to evaluate, fresh, stored and dehydrated samples for appearance, colour, flavour, texture and overall acceptability on a 10 point hedonic scale. The ratings were as follows:

0-2 - Poor

3-5 - Satisfactory

6-8 - Good

9-10 – Excellent

3.5 Tabulation and statistical analysis

Observations under each experiment were tabulated and analysed statistically in a Completely Randomized Design (CRD) or factorial CRD, wherever appropriate as proposed by Panse and Sukhatme (1976). Treatment comparisons were done by F Test or Duncan's Multiple Range Test and scores of organoleptic evaluation were analysed by Kruskal-Wallis one-way Analysis of Variance (Siegel, 1956).

Results

RESULTS

The results of the study "Evaluation of sapota for postharvest qualities" are presented under the following headings,

1. Fruit characters
2. Storability
3. Osmotic dehydration

4.1 Fruit characters

Results of the physical, chemical and sensory evaluation of the sapota varieties namely 'Cricket Ball', 'Oval', 'Co-1', Co-2' and 'PKM 1' are presented below.

4.1.1 Physical parameters

Physical parameters of sapota varieties viz. shape, weight, volume, length, diameter, specific gravity, number of seeds per fruit, pulp to seed ratio, days to ripening and firmness of ripe fruits are given in Table 1.

Table 1. Physical parameters of sapota varieties

Variety / Particulars	Cricket Ball	Oval	Co-1	Co-2	PKM 1
Shape	Round	Oval	Long oval	Compressed round	Oblong
Weight (g)	186.49^{a}	153.94^{b}	182.10^{a}	114.00^{c}	57.49^{d}
Length (cm)	6.44^{b}	7.10^{a}	6.96^{a}	5.10^{d}	5.94^{c}
Diameter (cm)	7.84^{a}	6.43^{bc}	6.66^{b}	6.20^{c}	4.70^{d}
Volume (ml)	194.48^{a}	160.08^{b}	189.20^{a}	120.69^{c}	59.16^{d}
Specific gravity	0.96	0.97	0.96	0.95	0.97
Seed no./fruit	4.70	3.20	2.90	4.40	4.20
Pulp:seed ratio	57.92^{c}	92.07^{ab}	108.06^{a}	65.48^{bc}	25.83^{d}
Firmness (kg cm^{-2})	0.62^{b}	0.60^{b}	0.64^{b}	0.94^{a}	0.44^{c}
Days to ripening	3.50^{a}	2.60^{b}	3.50^{a}	3.70^{a}	3.40^{a}

The values represent mean of 10 replication

The values with different superscripts differ significantly at 5% level

4.1.1.1 Fruit weight

'Cricket Ball' recorded the maximum individual fruit weight (186.49 g) which was on par with 'Co-1' ($P \geq 0.05$) while 'PKM 1' recorded the lowest (57.49 g).

4.1.1.2 Fruit length

Significant difference in fruit length was observed with maximum in 'Oval' (7.1 cm) followed by 'Co-1' (6.96 cm) which was comparable to 'Oval' while the least was in 'Co-2' (5.1 cm).

4.1.1.3 Fruit diameter

'Cricket Ball' recorded the maximum diameter (7.84 cm) and 'PKM 1' the minimum (4.70 cm).

4.1.1.4 Fruit volume

Results were synonymous to fruit weight with maximum fruit volume recorded by 'Cricket Ball' (194.48 ml) which was on par with 'Co-1' (189.2 ml) and the minimum recorded in 'PKM 1' (59.16 ml).

4.1.1.5 Specific gravity

Though varietal variation in specific gravity was not significant, 'PKM 1' and 'Oval' showed the highest value (0.97) and the lowest in 'Co-2' (0.95).

4.1.1.6 Number of seeds per fruit

'Cricket Ball' showed maximum number of seeds per fruit (4.7) and the minimum was by 'Co-1' (2.9). However no significant difference existed between varieties.

4.1.1.7 Pulp:seed ratio

'Co-1' and 'Oval' recorded the maximum pulp:seed ratios of 108.06 and 92.07 respectively and the lowest was in 'PKM 1' (25.83). Higher the values better is the processing quality.

4.1.1.8 Firmness

Maximum firmness was recorded in 'Co-2' (0.94 kg cm^{-2}) and 'PKM 1' recorded the minimum (0.44 kg cm^{-2}) on ripening, higher the value better is the keeping quality.

4.1.1.9 Days to ripening

'Oval' fruits took the minimum days to ripen (2.6 days) and the maximum time required was in 'Co-2' (3.7 days).

4.1.2 **Chemical parameters**

TSS, reducing sugar, acidity, pH, brix:acid ratio and tannin content of the varieties are given in Table 2.

4.1.2.1 Total soluble solids (TSS)

'PKM 1' recorded the highest TSS (24.1°Brix) and was on par with 'Oval' and 'Co-2' while the least was in 'Cricket Ball' (20.79°Brix).

4.1.2.2 Reducing sugar

Reducing sugar content varied significantly among varieties with 'PKM 1' having the highest (13.9%) which was on par with 'Oval' (13.77%) while 'Cricket Ball' recorded the least (10.85%).

Table 2.Chemical characters of sapota varieties

Variety / Particulars	Cricket Ball	Oval	Co-1	Co-2	PKM 1
TSS (°Brix)	20.79^{b}	23.46^{a}	21.33^{b}	23.16^{a}	24.10^{a}
Reducing sugar (%)	10.85^{c}	13.77^{a}	12.10^{b}	12.53^{b}	13.90^{a}
Acidity (%)	0.22^{a}	0.13^{b}	0.14^{b}	0.21^{a}	0.11^{b}
PH	5.22^{c}	5.66^{a}	5.44^{b}	5.25^{c}	5.13^{d}
Brix:acid ratio	99.06^{c}	187.53^{ab}	165.29^{b}	111.07^{c}	214.97^{a}
Tannin (mg g^{-1})	1.97^{a}	1.08^{c}	1.52^{b}	1.06^{c}	1.72^{ab}

The values represent mean of 10 replication
The values with different superscripts differ significantly at 5% level

4.1.2.3 Acidity

Minimum acidity was in 'PKM 1' (0.11%) and was on par with 'Oval' and 'Co-1'. 'Cricket Ball' showed the highest value (0.22%).

4.1.2.4 pH

Significant differences in pH existed between varieties, with least value in 'PKM 1' (5.13) and highest in 'Oval' (5.66).

4.1.2.5 Brix:acid ratio

Brix:acid ratio was maximum in 'PKM 1' (214.97), it was on par with 'Oval' and with a minimum in 'Cricket Ball'.

4.1.2.6 Tannin

Minimum tannin content was in 'Co-2' (1.06 mg g^{-1}) and was comparable with 'Oval' (1.08 mg g^{-1}). The highest was observed in 'Cricket Ball' (1.97 mg g^{-1}).

4.1.3 Sensory evaluation

Sensory quality evaluation of five varieties of sapota was also carried out for appearance, colour, sweetness, flavour, texture and overall acceptability. The results revealed that significant difference existed between varieties. 'Co-2' (6.9) recorded the highest score followed by 'Co-1' (6.7) and 'PKM 1' (6.5) for overall acceptability while 'Cricket Ball' was preferred only for its whole fruit appearance (Table 3).

Table 3. Sensory qualities of sapota varieties

Variety	Mean sensory score values						
	Whole fruit appearance	Cut fruit appearance	Colour	Sweetness	Flavour	Texture	Overall acceptability
Cricket Ball	8.7	5.7	4.5	4.9	5.8	5.6	5.9
Oval	5.0	5.8	6.5	7.1	5.8	7.0	6.2
Co-1	7.2	5.9	6.2	6.8	7.0	7.0	6.7
Co-2	7.3	6.3	7.2	7.3	6.8	6.4	6.9
PKM 1	3.4	5.3	6.5	7.8	7.8	8.2	6.5
Kruskal Wallis (5%)	46.12*	3.10^{NS}	14.85*	23.52*	27.06*	19.99*	15.37*

*- Differ significantly at 5% level;The values represent mean of 12 scores;NS – Non significant

4.2 Storability

The effect of different packaging techniques on shelf-life of the sapota varieties under ambient and refrigerated conditions were evaluated. Since the low temperature storage studies could be carried out only at 4 to 7°C (domestic refrigerator), which caused irreversible chilling injury to the fruits, the experiment was undertaken only under ambient conditions. The tabulated results are presented in Tables 4 to 9.

Table 4. Days to ripening and physiological loss in weight of sapota under different ambient storage techniques

Variety	Treatments	Days to Ripening	PLW (%)		
			2DAS	4DAS	6DAS
Cricket Ball	T_1	4.13	1.59	3.52	7.30
	T_2	3.90	1.47	3.35	6.78
	T_3	4.77	0.76	1.73	2.25
	T_4	4.23	0.30	0.44	0.85
	T_5	3.83	4.98	7.66	11.82
Oval	T_1	4.23	1.65	4.12	5.66
	T_2	4.13	1.38	3.39	4.84
	T_3	4.63	1.18	2.21	2.89
	T_4	5.00	0.55	0.89	2.02
	T_5	2.47	4.80	9.26	13.12
	T_1	4.40	1.25	2.37	5.15
Co-1	T_2	5.13	1.26	2.14	4.89
	T_3	4.90	0.83	1.43	2.48
	T_4	5.33	0.75	1.25	1.78
	T_5	3.47	4.54	8.16	11.28
Co-2	T_1	4.33	2.04	3.47	5.93
	T_2	6.27	2.11	3.95	4.72
	T_3	4.00	0.80	1.39	2.63
	T_4	6.40	0.39	1.03	1.21
	T_5	3.73	5.01	8.86	12.89
PKM 1	T_1	5.30	1.53	3.81	4.68
	T_2	5.90	1.40	3.15	4.22
	T_3	5.70	0.94	1.26	2.15
	T_4	5.30	0.43	0.91	2.02
	T_5	3.43	4.02	7.99	11.09
CD (0.05)	V or T	0.10	0.11	0.17	0.17
	V x T	0.23	0.31	0.48	0.49

DAS - Days after storage ; V – Variety; T – Treatments ; V x T - Interaction effect

4.2.1 Physiological loss in weight (PLW)

Five varieties of sapota when stored under different techniques, minimum PLW after six days of storage was recorded in 'Cricket Ball' when stored in saw dust (0.85%) which was on par with 'Co-2' under the same technique (1.21%) whereas the control fruits of 'Oval' and 'Co-2' recorded the highest PLW (13.12 and 12.9%).

4.2.2 Days to ripening

All the treatments significantly influenced ripening. 'Co-2' when stored in saw dust remained maximum time without ripening (6.4 days) and was on par with those treated with gibberellic acid (6.27 days) while control fruits ripened faster (Table 4).

Table 5. Percentage decay of sapota under different ambient storage techniques

Variety	Treatments	Decay (%)			
		4 DAS	5 DAS	6 DAS	7 DAS
Cricket Ball	T_1	4.67	38.73	76.11	84.99
	T_2	3.51	39.90	61.35	66.36
	T_3	15.71	27.67	43.62	57.83
	T_4	16.23	36.32	51.81	65.62
	T_5	17.28	37.52	73.74	93.74
Oval	T_1	27.37	43.44	61.57	72.61
	T_2	22.25	38.94	54.94	69.41
	T_3	16.35	28.29	37.98	65.02
	T_4	9.01	20.29	28.90	66.80
	T_5	58.63	76.27	91.49	96.16
Co-1	T_1	29.22	39.38	50.27	57.67
	T_2	26.29	37.63	45.34	54.14
	T_3	33.07	35.84	38.66	50.75
	T_4	7.80	15.68	24.87	48.21
	T_5	46.12	57.87	81.29	97.19
Co-2	T_1	19.25	39.12	53.94	66.32
	T_2	4.61	16.72	21.55	26.85
	T_3	24.20	32.37	46.54	73.31
	T_4	8.84	12.73	22.83	28.28
	T_5	19.45	44.90	68.13	77.08
PKM 1	T_1	9.23	17.92	23.88	57.82
	T_2	5.53	10.81	19.93	42.74
	T_3	12.28	16.97	27.86	41.65
	T_4	18.65	25.87	36.79	51.86
	T_5	46.74	61.77	71.61	98.35
CD	V or T	0.78	0.40	0.88	0.24
(0.05)	V x T	1.76	0.90	1.96	0.54

DAS - Days after storage ; V – Variety; T – Treatments ; V x T - Interaction effect

4.2.3 Decay percentage

The spoilage recorded after one week of storage revealed that minimum was observed in GA treated 'Co-2' (26.85%) which was on par with those stored in saw dust (28.28%) while the control fruits recorded the maximum spoilage (93 to 98%).

Table 6. Marketability of sapota under different ambient storage techniques

Variety	Treatments	Marketability (%)			
		4 DAS	5 DAS	6 DAS	7 DAS
Cricket Ball	T_1	91.83	55.86	16.59	7.71
	T_2	93.14	55.03	31.87	26.86
	T_3	82.56	70.35	54.13	39.92
	T_4	83.33	63.04	47.34	34.13
	T_5	75.06	52.74	14.44	–
Oval	T_1	68.51	51.68	33.20	21.74
	T_2	74.36	56.95	40.21	25.75
	T_3	81.43	69.16	59.13	32.09
	T_4	90.11	78.26	69.08	31.18
	T_5	32.12	12.54	–	–
Co-1	T_1	68.41	56.86	44.58	37.19
	T_2	71.57	58.85	49.77	40.97
	T_3	65.50	62.21	58.86	46.77
	T_4	90.96	82.81	73.35	50.01
	T_5	45.72	32.41	7.43	–
Co-2	T_1	77.28	56.18	40.13	27.75
	T_2	91.45	78.95	73.73	68.43
	T_3	74.41	65.62	50.83	24.06
	T_4	90.13	86.15	75.96	70.51
	T_5	71.69	44.22	18.98	10.02
PKM 1	T_1	86.96	77.84	71.43	37.50
	T_2	91.32	85.50	75.86	53.04
	T_3	86.46	51.35	69.99	56.20
	T_4	80.44	72.67	61.19	46.12
	T_5	45.27	28.69	17.30	–
CD (0.05)	V or T	0.835	0.415	1.346	0.786
	V x T	1.866	0.929	3.009	1.758

– Denote completely spoiled samples; DAS - Days after storage;
V – Variety; T – Treatments ; V x T - Interaction effect;

4.2.4 Marketability

All the treatments improved marketability of the fruits significantly. After a week of storage maximum marketability was for 'Co-2' stored in saw dust (70.51%) followed by 'Co-2' treated with gibberellic acid (68.43%) whereas marketability of open stored fruits was nil (Table 6).

Table 7. Firmness and Tannin content of sapota under different ambient storage techniques

Variety	Treatments	Firmness (kg cm^{-2})			Tannin (mg g^{-1})		
		2 DAS	4 DAS	6 DAS	2 DAS	4 DAS	6 DAS
Cricket Ball	T_1	6.20	0.87	-	7.18	2.81	-
	T_2	7.23	1.33	-	7.44	3.22	-
	T_3	8.39	1.83	1.28	9.08	4.97	3.08
	T_4	4.87	1.57	-	9.10	4.82	-
	T_5	4.76	0.70	-	7.11	2.45	-
Oval	T_1	1.00	0.68	-	0.87	0.61	-
	T_2	1.53	1.10	-	0.98	0.72	-
	T_3	2.90	2.83	2.27	2.91	0.10	0.53
	T_4	0.89	0.57	0.50	0.99	0.98	0.61
	T_5	1.23	-	-	0.75	-	-
Co-1	T_1	1.07	0.87	-	1.24	0.92	-
	T_2	1.88	1.00	0.67	1.52	0.53	0.43
	T_3	3.70	2.73	1.97	3.14	1.49	0.97
	T_4	1.00	0.82	0.48	2.68	2.22	1.24
	T_5	1.23	0.97	-	1.84	0.99	-
Co-2	T_1	10.10	6.70	-	2.37	1.06	-
	T_2	10.63	8.09	5.80	2.72	1.37	0.72
	T_3	10.83	9.77	6.13	3.23	1.20	0.91
	T_4	10.17	3.90	2.47	3.59	2.71	1.40
	T_5	8.87	1.38	-	2.09	0.83	-
PKM 1	T_1	9.86	4.33	0.67	3.05	2.00	0.54
	T_2	9.73	4.70	0.98	3.21	1.74	0.62
	T_3	10.20	4.83	0.88	3.58	2.30	0.84
	T_4	9.57	3.20	0.35	3.37	2.17	0.96
	T_5	7.57	2.67	-	2.80	0.87	-
CD (0.05)	V or T	0.51	0.07	0.10	0.23	0.10	0.06
	V x T	1.13	0.16	0.23	0.52	0.23	0.14

– Denote treatments terminated due to >50% spoilage; DAS - Days after storage ;
V – Variety; T – Treatments ; V x T - Interaction effect

4.2.5 Firmness

Irrespective of the treatments firmness showed a progressive reduction with storage. 'Co-2' when wrapped with cling film recorded the highest value (6.13 kg cm^{-2})

whereas none of the control fruits remained till sixth day. Fruits stored in saw dust showed comparatively lower firmness than all other treatments.

4.2.6 Tannin

Tannin content showed a decreasing trend throughout the storage. 'Cricket Ball' when wrapped with cling film showed highest tannin content (3.08 mg g^{-1}) while 'Co-1' treated with GA showed the least (0.43 mg g^{-1}). All the treatments differed significantly (Table 7).

Table 8. TSS and reducing sugar content of sapota stored under different ambient storage techniques

Variety	Treatments	TSS (°Brix)			Reducing sugar (%)		
		2 DAS	4 DAS	6 DAS	2 DAS	4 DAS	6 DAS
Cricket Ball	T_1	21.53	22.60	-	8.82	14.12	-
	T_2	21.87	22.63	-	9.60	12.93	-
	T_3	20.93	21.50	21.93	9.30	8.57	13.04
	T_4	19.67	19.80	-	11.21	13.05	-
	T_5	20.93	22.00	-	10.62	12.81	-
Oval	T_1	22.07	23.93	-	11.21	13.05	-
	T_2	22.13	24.43	-	10.62	12.26	-
	T_3	22.07	23.10	25.07	9.84	11.35	10.43
	T_4	21.07	21.73	23.40	11.57	13.64	15.25
	T_5	22.87	-	-	12.78	-	-
Co-1	T_1	20.93	21.73	-	10.15	13.05	-
	T_2	21.20	23.10	23.13	9.23	13.20	12.32
	T_3	20.40	20.93	21.60	9.16	10.62	10.92
	T_4	20.40	22.05	23.47	10.94	12.85	13.96
	T_5	22.87	23.73	-	12.59	15.01	-
Co-2	T_1	21.83	22.73	-	5.13	8.27	-
	T_2	22.63	23.07	23.57	5.52	8.71	9.78
	T_3	20.30	21.97	22.40	6.93	8.08	8.24
	T_4	20.93	21.67	23.07	5.68	6.20	7.56
	T_5	23.73	25.70	-	5.30	8.59	-
PKM 1	T_1	22.13	23.33	24.00	7.55	10.53	11.73
	T_2	21.73	22.67	23.60	7.28	10.06	11.72
	T_3	21.33	22.83	23.17	5.94	10.57	13.35
	T_4	22.77	23.67	25.43	5.16	12.72	13.96
	T_5	23.67	25.60	-	9.90	14.02	-
CD (0.05)	V or T	0.32	0.28	0.26	0.27	0.60	0.28
	V x T	0.71	0.62	0.58	0.60	1.34	0.62

- Denote treatments terminated due to >50% spoilage; DAS - Days after storage; V – Variety; T – Treatments ; V x T - Interaction effect

4.2.7 Total soluble solids (TSS)

TSS increased in all the treatments with minimum in 'Co-1' when wrapped with cling film (21.6°Brix) at the end of sixth day of storage and maximum in 'PKM 1' when stored in saw dust (25.43°Brix). In control fruits TSS reached the peak with four days of storage.

Table 9. Acidity and brix:acid of sapota stored under different ambient storage techniques

Variety	Treatments	Acidity (%)			Brix:acid ratio		
		2 DAS	4 DAS	6 DAS	2 DAS	4 DAS	6 DAS
Cricket Ball	T_1	0.23	0.14	-	93.6	161.42	-
	T_2	0.21	0.16	-	104.14	141.44	-
	T_3	0.21	0.17	0.12	99.66	126.47	182.75
	T_4	0.21	0.12	-	93.66	165.00	-
	T_5	0.21	0.10	-	99.66	220.00	-
Oval	T_1	0.25	0.14	-	88.28	170.92	-
	T_2	0.22	0.10	-	100.59	244.30	-
	T_3	0.22	0.12	0.09	100.32	192.50	278.56
	T_4	0.23	0.14	0.11	91.61	155.20	212.72
	T_5	0.22	-	-	103.95	-	-
Co-1	T_1	0.23	0.08	-	91.00	271.63	-
	T_2	0.28	0.13	0.09	75.71	177.69	257.00
	T_3	0.22	0.15	0.11	92.73	139.53	196.36
	T_4	0.23	0.14	0.11	88.70	145.71	213.36
	T_5	0.22	0.09	-	103.96	263.67	-
Co-2	T_1	0.26	0.10	-	85.21	222.30	-
	T_2	0.22	0.15	0.12	105.52	150.04	196.41
	T_3	0.23	0.19	0.12	101.7	121.27	168.67
	T_4	0.21	0.15	0.12	99.98	160.14	185.80
	T_5	0.24	0.10	-	106.36	240.76	-
PKM 1	T_1	0.28	0.12	0.10	79.87	197.14	243.32
	T_2	0.27	0.15	0.10	80.22	157.16	226.29
	T_3	0.27	0.16	0.12	78.63	145.38	199.59
	T_4	0.26	0.14	0.11	91.20	179.99	223.82
	T_5	0.21	0.12	-	111.85	225.72	-
CD (0.05)	V or T	0.03	0.01	0.01	1.16	1.94	2.93
	V x T	0.07	0.03	0.03	2.26	4.34	6.54

- Denote treatments terminated due to >50% spoilage; DAS - Days after storage ;
V – Variety; T – Treatments ; V x T - Interaction effect

4.2.8 Reducing sugar

Significant differences in reducing sugar could be observed in all the treatments. 'Co-2' when stored in saw dust showed the least value (7.56%) while 'Oval' in saw dust has the highest value (15.25%) which was on par with 'Oval' (12.26%) treated with gibberellic acid (Table 8).

4.2.9 Acidity

Throughout the storage, acidity showed a gradual decline in all the treatments. Though the differences were not significant, a higher acidity was observed in fruits stored in saw dust and cling film wrapped compared to other treatments (Table 9).

4.2.10 Brix:acid ratio

Brix:acid ratio showed a progressive increase throughout the storage period irrespective of the treatments. Minimum ratio at the end of sixth day was observed in 'Co-2' wrapped with cling film (168.67) and the highest in 'Oval' with the same wrap (278.56) (Table 9).

Table.10. Sensory evalution of stored sapota

Treatments	Mean sensory score values						
	Whole fruit appearance	Cut fruit appearance	Colour	Sweetness	Flavour	Texture	Overall acceptability
Cling film	7.5	6.8	7.2	6.8	6.6	6.9	7.8
Saw dust	7.3	6.5	7.2	7.5	6.3	5.7	7.3
Fresh fruit	7.3	6.5	7.2	7.3	6.8	6.6	7.9
Kruskal Wallis (5%)	4.95^{NS}	3.11^{NS}	$.05^{NS}$	3.35^{NS}	2.83^{NS}	5.91^{NS}	3.2^{NS}

The values represent mean of 12 scores; NS – Non Significant

4.2.11 Sensory evaluation

The efficiency of storage evaluated through sensory analysis, showed that fruits stored either with cling film or saw dust did not differ significantly with that of fresh fruits, in terms of appearance, colour, sweetness flavour, texture and overall acceptability (Table 10).

4.3 Osmotic dehydration

4.3.1 Preliminary experiment

In order to standardise the ratio, time and temperature suited for osmotic

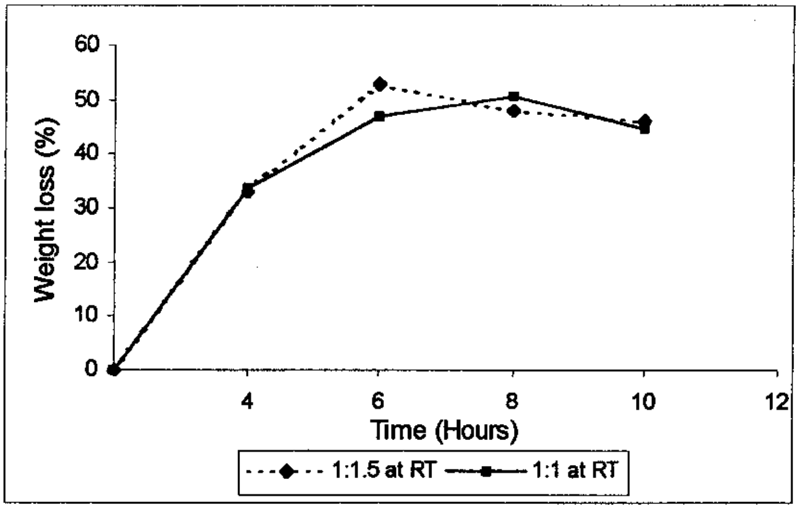

Fig. 1. Effect of fruit:sugar ratio on osmotic dehydration of sapota under ambient conditions

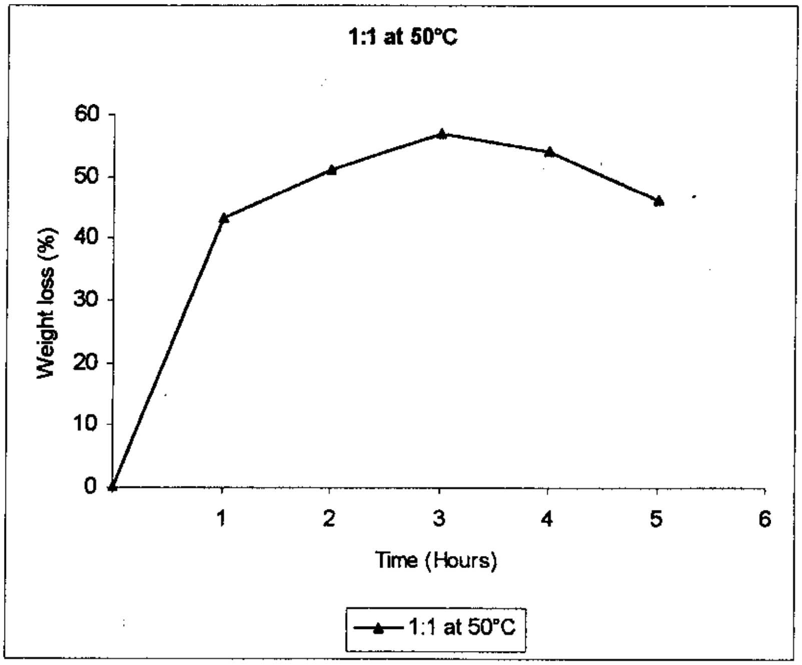

Fig.2. Effect of temperature on osmotic dehydration of sapota with 1:1 fruit:sugar ratio

dehydration of sapota, preliminary study was carried out at two temperatures with two ratios. The results revealed that a ratio of 1:1 at room temperature for eight hours was the optimum to get maximum weight reduction and good quality product (Fig. 1 and Fig.2).

4.3.2 Main experiment

All the five varieties were subjected to osmotic dehydration with 1:1 fruit to sugar ratio under ambient temperature. The results are given in Table 11.

4.3.2.1 Weight reduction

On completion of six hours of osmotic dehydration maximum weight reduction was observed in 'Co-1' (48.66%) and 'Co-2' (41.10%) whereas it took eight hours in the case of 'Cricket Ball', 'Oval' and 'PKM 1' to get the maximum weight reduction (Table 11).

4.3.2.2 Percentage recovery

Percentage recovery of osmo-oven dried was maximum in 'Co-2' (37.7%) and the minimum was recorded in 'Oval' (27.3%).

Table 11. Osmotic dehydration of sapota varieties.

Variety	Weight loss (%) in osmosis		Recovery (%) after osmo-oven drying	
	6 hours	8 hours	6 hours	8 hours
Cricket Ball	38.57^{gh}	48.70^{ab}	34.23^{b}	33.27^{b}
Oval	42.80^{ef}	48.33^{abc}	34.07^{b}	27.37^{d}
Co-1	48.66^{a}	45.50^{cd}	28.10^{cd}	28.90^{c}
Co-2	41.10^{fg}	37.76^{h}	33.67^{b}	37.77^{a}
PKM 1	45.40^{de}	46.67^{bcd}	33.10^{b}	32.90^{b}

The values with different superscripts differ significantly at 5% level

4.3.3 Rehydration of dehydrated sapota slices

Data on rehydration of dehydrated sapota in syrup of 20°Brix showed a faster reconstitution (2 hrs) in those samples dried in oven whereas osmo-oven dried samples were not fully reconstituted even after six hours (Fig.3).

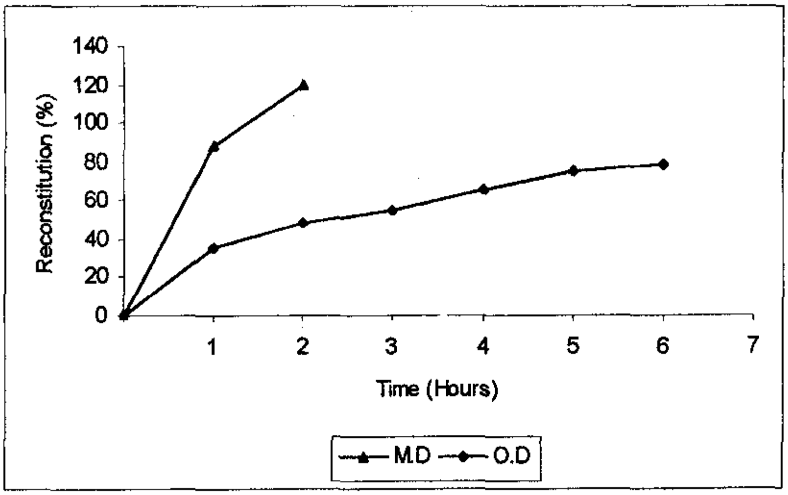

Fig. 3. Rehydration of dehydrated sapota in 20° Brix syrup

4.3.4 Storage studies of dehydrated sapota slices

Changes in sugar, acidity, sugar:acid ratio and tannin content of dehydrated samples stored upto four months are presented below.

4.3.4.1 Reducing sugar

Reducing sugar content immediately after drying showed maximum retention in oven dried samples, irrespective of varieties with the maximum of 48.8 per cent in 'Co-2' and minimum in 'PKM 1' (39.6%).

Table 12. Reducing sugar content of osmo-oven dried and oven dried sapota slices under ambient storage conditions

Treatment	Variety	Reducing sugar (%)				
		0 MAS	1 MAS	2 MAS	3 MAS	4 MAS
Osmo-oven drying	V_1	25.20^{e}	29.04^{e}	30.89^{f}	33.25^{e}	35.99^{d}
	V_2	24.67^{de}	29.61^{e}	34.93^{e}	39.95^{b}	40.48^{bc}
	V_3	25.42^{d}	26.94^{f}	28.56^{g}	29.93^{g}	30.50^{g}
	V_4	23.97^{e}	28.78^{e}	34.17^{e}	36.46^{c}	40.17^{ab}
	V_5	21.18^{f}	25.42^{g}	30.68^{f}	31.90^{f}	33.12^{f}
Oven drying	V_1	40.41^{c}	40.20^{c}	39.82^{c}	39.77^{b}	39.20^{c}
	V_2	42.43^{b}	42.09^{b}	41.55^{ab}	40.70^{a}	39.66^{a}
	V_3	42.45^{b}	41.78^{b}	41.25^{b}	40.88^{a}	40.25^{ab}
	V_4	48.84^{a}	43.51^{a}	42.52^{a}	40.82^{a}	40.29^{ab}
	V_5	39.59^{c}	38.31^{d}	36.49^{d}	35.59^{d}	34.38^{e}

MAS - Months after storage;The values with different superscripts differ significantly at 5% level

With the advancement of storage period reducing sugar content in osmo-oven dried sapota showed increasing trend whereas in oven dried samples there was a gradual decline (Table 12).

4.3.4.2 Non-reducing sugar

Non-reducing sugar progressively declined in both osmo-oven dried and oven dried samples throughout the storage period. However the osmo-oven dried samples maintained higher values throughout the period of storage (Table 13).

Table 13. Non-reducing sugar content of osmo-oven dried and oven dried sapota slices under ambient storage conditions

Treatments	Variety	Non-reducing sugar (%)				
		0 MAS	1 MAS	2 MAS	3 MAS	4 MAS
Osmo-oven drying	V_1	33.33[e]	30.06[d]	27.19[d]	24.85[d]	20.59[e]
	V_2	41.53[b]	37.13[c]	34.64[b]	28.71[c]	27.27[c]
	V_3	40.27[b]	41.72[b]	38.84[a]	37.51[a]	34.96[a]
	V_4	48.95[a]	46.57[a]	39.76[a]	34.01[b]	28.68[b]
	V_5	47.91[a]	37.87[c]	32.03[c]	28.25[c]	27.20[c]
Oven drying	V_1	17.02[h]	13.10[g]	10.20[g]	7.29[h]	4.77[i]
	V_2	15.96[i]	13.40[g]	12.08[f]	11.16[g]	9.89[g]
	V_3	24.70[d]	23.23[f]	21.85[e]	20.38[e]	19.05[f]
	V_4	30.95[c]	28.15[e]	21.54[e]	16.63[f]	7.86[h]
	V_5	30.69[c]	29.13[de]	26.81[d]	24.91[d]	22.72[d]

MAS - Months after storage;The values with different superscripts differ significantly at 5% level

Table 14. Acidity of osmo-oven dried and oven dried sapota slices under ambient storage conditions

Treatments	Variety	*Acidity (%)				
		0 MAS	1 MAS	2 MAS	3 MAS	4 MAS
Osmo-oven drying	V_1	0.326	0.326	0.320	0.320	0.320
	V_2	0.299	0.299	0.256	0.256	0.256
	V_3	0.300	0.300	0.256	0.256	0.256
	V_4	0.256	0.256	0.256	0.256	0.256
	V_5	0.399	0.320	0.303	0.299	0.277
Oven drying	V_1	0.320	0.303	0.299	0.277	0.277
	V_2	0.213	0.213	0.213	0.213	0.213
	V_3	0.299	0.277	0.277	0.256	0.256
	V_4	0.320	0.320	0.303	0.256	0.256
	V_5	0.303	0.303	0.303	0.299	0.299

* - Non significant at 5% level, MAS - Months after storage

4.3.4.3 Acidity

Reduction in acidity of the dried samples with the advancement of storage was non-significant irrespective of varieties or method of drying (Table 14).

4.3.4.4 Tannin

Tannin content showed a gradual decline throughout the storage. Soon after drying tannin content was maximum in oven dried 'Cricket Ball' (3.03 mg g^{-1}) and was on par with oven dried 'Co-1' (3.01 mg g^{-1}). The minimum was observed in osmo-oven dried 'Co-2' (0.93mg g^{-1}) (Table 15).

Table 15. Tannin content of osmo-oven dried and oven dried sapota slices under ambient storage conditions

Treatments	Variety	Tannin (mg g^{-1})				
		0 MAS	1 MAS	2 MAS	3 MAS	4 MAS
Osmo-oven drying	V_1	2.74^{ab}	2.65^{ab}	2.53^{ab}	2.49^{ab}	2.36^{ab}
	V_2	1.23^{e}	1.18^{d}	1.12^{d}	1.09^{c}	0.98^{c}
	V_3	2.34^{bc}	2.26^{bc}	2.15^{b}	1.94^{b}	1.89^{b}
	V_4	0.93^{f}	0.88^{d}	0.82^{d}	0.73^{c}	0.69^{c}
	V_5	2.41^{cd}	2.38^{b}	2.31^{bc}	2.25^{b}	2.19^{b}
Oven drying	V_1	3.03^{a}	2.92^{a}	2.87^{a}	2.80^{a}	2.71^{a}
	V_2	1.53^{e}	1.34^{cd}	1.28^{d}	1.12^{c}	1.07^{c}
	V_3	3.01^{a}	2.89^{a}	2.77^{a}	2.71^{ab}	2.51^{ab}
	V_4	1.95^{de}	1.91^{c}	1.89^{c}	1.82^{b}	1.79^{b}
	V_5	2.12^{cd}	2.10^{bc}	2.22^{b}	2.29^{ab}	2.30^{ab}

MAS - Months after storage; The values with different superscripts differ significantly at 5% level

4.3.4.5 Total sugar

Total sugar content was maximum in osmo-oven dried 'Co-2' (80.31%) and was minimum in oven dried 'Oval' (56.46%). Total sugar content declined gradually and after four months of storage the osmo-oven dried 'Oval' recorded 69.18 per cent sugar content while in 'Cricket Ball' it was 45.18 per cent (Table 16).

Table 16. Total Sugar content of osmo-oven dried and oven dried sapota slices under ambient storage conditions

Treatments	Variety	Total sugar (%)				
		0 MAS	1 MAS	2 MAS	3 MAS	4 MAS
Osmo-oven drying	V_1	64.12 ^{f}	62.54 ^{g}	60.74 ^{e}	59.41 ^{e}	57.67 ^{d}
	V_2	73.22 ^{c}	72.01 ^{bc}	70.76 ^{b}	70.17 ^{a}	69.18 ^{a}
	V_3	69.33 ^{d}	72.48 ^{b}	70.13 ^{b}	69.98 ^{a}	68.98 ^{a}
	V_4	80.31 ^{a}	76.01 ^{a}	72.26 ^{a}	70.36 ^{a}	68.44 ^{a}
	V_5	75.85 ^{b}	67.18 ^{d}	64.40 ^{cd}	61.64 ^{d}	61.75 ^{c}
Oven drying	V_1	57.12 ^{g}	53.56 ^{i}	50.56 ^{g}	47.88 ^{g}	45.18 ^{f}
	V_2	56.46 ^{g}	54.80 ^{h}	54.27 ^{f}	53.84 ^{f}	52.84 ^{e}
	V_3	66.25 ^{e}	65.33 ^{f}	64.21 ^{d}	63.23 ^{c}	62.50 ^{c}
	V_4	72.87 ^{c}	71.45 ^{c}	65.19 ^{c}	61.01 ^{d}	57.11 ^{d}
	V_5	66.69 ^{e}	66.25 ^{e}	64.71 ^{cd}	64.53 ^{b}	63.51 ^{b}

MAS - Months after storage;The values with different superscripts differ significantly at 5% level

4.3.4.5 Sugar:acid ratio

Eventhough variation in sugar:acid ratio was non significant osmo-oven dried 'Co-2' retained the highest sugar:acid ratio (313.71) soon after drying while oven dried 'Cricket Ball' recorded the lowest (178.51). With the advancement of storage period the ratio declined gradually and same samples recorded ratios of 267.33 and 164.88 respectively.

Table 17. Sugar:acid ratio of osmo-oven dried and oven dried sapota slices under ambient storage conditions

Treatments	Variety	Sugar:acid ratio				
		0 MAS	1 MAS	2 MAS	3 MAS	4 MAS
Osmo-oven drying	V_1	196.68 ^{cd}	191.83 ^{cd}	189.91 ^{cd}	185.67 ^{de}	180.21 ^{d}
	V_2	254.54 ^{bc}	249.97 ^{abc}	276.41 ^{a}	274.12 ^{a}	270.23 ^{a}
	V_3	239.71 ^{bcd}	250.25 ^{abc}	273.95 ^{a}	273.35 ^{a}	269.47 ^{a}
	V_4	313.71 ^{a}	313.67 ^{a}	296.95 ^{a}	274.86 ^{a}	267.33 ^{a}
	V_5	233.05 ^{bcd}	209.94 ^{d}	212.54 ^{bcd}	206.15 ^{bc}	225.12 ^{bc}
Oven drying	V_1	178.5i ^{b}	176.76 ^{bcd}	169.10 ^{d}	174.74 ^{e}	164.88 ^{d}
	V_2	269.77 ^{ab}	261.47 ^{ab}	259.29 ^{ab}	256.90 ^{ab}	252.13 ^{ab}
	V_3	224.15 ^{bcd}	235.85 ^{bcd}	231.81 ^{abc}	247.01 ^{abc}	244.15 ^{abc}
	V_4	227.72 ^{bcd}	223.29 ^{bcd}	215.15 ^{bcd}	238.32 ^{bc}	223.09 ^{bc}
	V_5	223.34 ^{bcd}	221.86 ^{bcd}	213.56 ^{bcd}	218.48 ^{cd}	215.05 ^{c}

MAS - Months after storage;The values with different superscripts differ significantly at 5% level

4.3.4.6 Sensory evaluation

Sensory qualities of fresh osmo-oven dried sapota was compared with that of oven dried samples in Kruskal-Wallis one way anova. All the panelists significantly rated osmo-oven dried samples above the oven dried samples for all the quality attributes like appearance, colour, flavour sweetness and overall acceptability. Between varieties osmo-oven dried a preferential rating for 'Co-1' (8.5) was made by the panelists (Table 18).

Table 18. Sensory evaluation dried product

Treatments	Variety	Mean sensory score values				
		Appearance	Colour	Flavour	Sweetness	Overall Acceptability
Osmo-oven drying	V_1	6.3	6.1	6.7	7.8	7.5
	V_2	7.9	8.1	7.3	8.3	8.3
	V_3	8.2	8.5	7.3	8.5	8.5
	V_4	8.0	7.4	6.7	9.1	8.2
	V_5	6.3	6.2	7.9	9.3	7.7
Oven drying	V_1	5.9	5.9	5.8	6.3	6.6
	V_2	6.2	5.8	3.1	4.5	4.2
	V_3	7.6	5.9	5.3	6.5	6.8
	V_4	6.2	6.4	5.3	7.2	6.9
	V_5	4.3	4.5	5.8	6.9	6.0
Kruskal Wallis H (5%)		44.29*	34.09*	49.34*	69.98*	78.16*

Values represent mean of 12 scores   * Significant at 5% level

Discussion

DISCUSSION

Fruit once detached from the mother plant, becomes an independent entity, which continues to respire and transpire exhausting its own resources which are not replenished. This causes wilting and shriveling leading to an ultimate reduction in quality of saleable produce. Being climacteric in nature it is highly perishable under the ambient conditions, hence it is imperative to have a careful handling to minimise the postharvest losses. Alternatives to overcome this are either to add shelflife or to convert into value added products.

More than eleven clonally selected varieties with wide range of fruit characters are grown commercially in India (Singh, 1997). Hitherto negligible work has been done to study sapota varieties with respect to their postharvest qualities. Therefore an attempt has been made to evaluate selected sapota varieties with special reference to postharvest qualities so as to recommend varieties most suited for table purpose, for storage and for processing.

5.1 Fruit characters

Each variety is a distinct genetic entity exhibiting specific and defined physiological traits, which may be manifested at morphological level, reproductive phase and stages of fruit development. The distinct size, shape, volume and other fruit characters of the five selected varieties of sapota can only be attributed to the genetic entity level (Plate 2).

Fruit weight

'Cricket Ball' showed maximum fruit weight and volume followed closely by 'Co-1' classifying them as large fruits. Sensory evaluation also, showed a consumer preference for large sized round to globose fruits with higher fruit weight and volume. This is in conformity with the findings of Sundararajan and Rao (1967) and Tendolkar (1978) that, rounder the fruit, higher will be its weight than oval or elliptic.

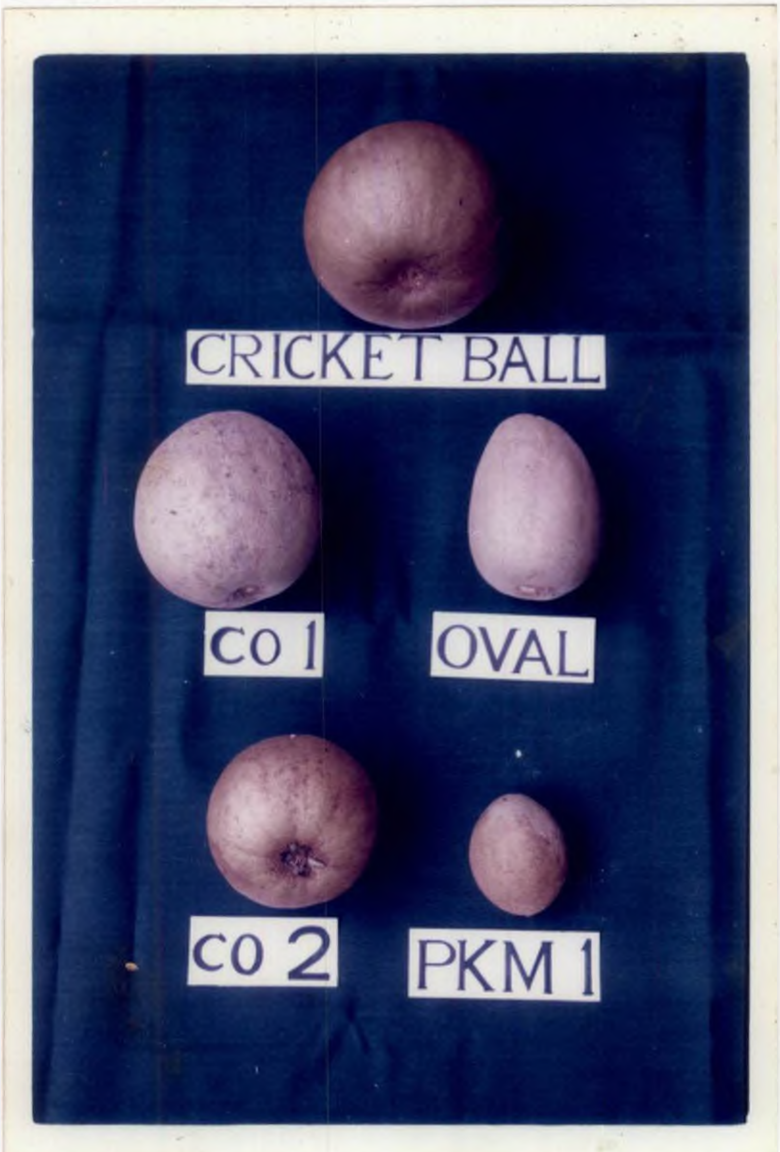

Plate 2. Varietal variation in fruit characters

Specific gravity

The specific gravity of ripe fruits in the present study ranged from 0.95 to 0.97 whereas Sawant (1989), Durairaj *et al.* (1991) and Shende (1993) reported that it ranged between 0.95-1.086. This reduced values of the ripe fruits could be due to the increased inter cellular spaces and metabolic losses during ripening. Similar decrease in specific gravity has been recorded during ripening of apple, pear, peach and ber (Kadam *et al.*, 1993).

Processing Quality

Variety 'Cricket Ball' recorded highest number of seeds per fruit, an undesirable trait for a quality fruit; apart TSS, reducing sugar and brix:acid ratio, the parameters that determine fruit quality were also poor in 'Cricket Ball' and hence rated lowest in overall quality. Seed number was minimum in 'Co-1' and hence recorded highest pulp to seed ratio (108.06). Less seed number and high pulp to seed ratio is one of the acceptable qualities for processing. Higher pulp to seed ratio is consequent to less seed number in 'Co-1'. Hence 'Co-1', the second best rated variety for overall acceptability can be considered as a variety suited for processing.

Days to ripening

Variety 'Co-2' took maximum number of days for ripening (3.7 days) and maintained its firmness for longer period making it suitable for distant transportation, besides 'Co-2' also recorded maximum scores for appearance and overall quality, and retained maximum firmness. In this context it is worthwhile to have an extended market for such fruits having a better storage life.

Chemical qualities

In the experimental varieties TSS ranged from 20.79 to 24.10°Brix, reducing sugar 10.85 to 13.9 per cent, acidity 0.11 to 0.22 per cent as citric acid, pH 5.13 to 5.66, tannin 1.06 to 1.97 mg g^{-1} and brix:acid ratio 99.06 to 214.97. Higher

TSS, reducing sugar and brix:acid ratio was observed in the varieties 'PKM 1', 'Co-2' and 'Oval'. Therefore 'Co-2', 'PKM 1' and 'Oval' can be recommended as the varieties best for table purpose. The distinct variations observed in the chemical indices are again characters typical of a variety and can be only traced back to genetic entity level.

5.2 Storability

Most of the fruits of commerce are harvested unripe, stored and then marketed either when ripening cannot be delayed any longer or deliberately ripened and marketed at an advantageous time. Such commodities present maximum scope for physiological manipulation during storage and should be maintained unripe but capable of ripening after the desired length of time without the development of stress symptoms caused by prolonged storage.

Low temperature storage

Low temperature storage, though a time tested technique known to extend the storage life of fruits and vegetables by lowering the metabolic activities, each commodity needs an optimum low temperature to obtain proper storage life; unless otherwise it will lead to chilling injury and limits the poststorage use of such commodities.

Sapota fruits stored at 4 to 7°C (domestic refrigerator) developed chilling injury and failed to ripen properly even after four days at room temperature. Mohamed *et al.* (1996) also reported that after cold storage, sapota fruits failed to ripen at room temperature even in the presence of 50 g CaC_2/kg of fruits. According to Chadha (1992), storage at 6 to 10°C caused irreversible damage to ripening mechanism and even the ripe fruit stored at refrigerated temperature deteriorated in quality, this further authenticates the present results. Hence the experiments were continued later only under ambient conditions.

Physiological loss in weight

Evaporation loss of water from stored material is the most obvious way in which freshness is lost and it affects the appearance texture and sale ability under open conditions. The shelf-life of fruits and vegetables can be improved if it is stored under low temperature and controlled atmosphere. But such sophisticated expensive and energy intensive technology would be accessible only in developed countries. Keeping in view of various constraints involved in such systems an alternate economical storage technique has to be developed.

The lower PLW observed in fruits kept under moistened saw dust may be due to lowering of the capacity of the surrounding air to take up additional water by reducing the water vapour pressure deficit (wvpd). Physiological loss in weight is the loss of saleable weight and hence has to be minimised either by reducing wvpd of the environment or by decreasing the permeability of the integument of the commodity to water or water vapour. PLW was recorded least in fruits stored in 30 percentage moistened saw dust followed by those in cling film. Again packing in CFB boxes filled with moistened saw dust reduce the volume of air in contact with them there by reducing water loss.

The moistened saw dust in CFB box performed limited gas exchange and prevented temperature built up. The high temperature of 32-39°C and low relative humidity of 56-73 per cent prevailed during storage resulted in higher PLW in control fruits (11-13%).

The cling film with lower water vapour and gas transmission rate, wrapped around individual fruit created a second protective layer, modified the microclimate and thereby reduced the physiological loss in weight (Fig.4).

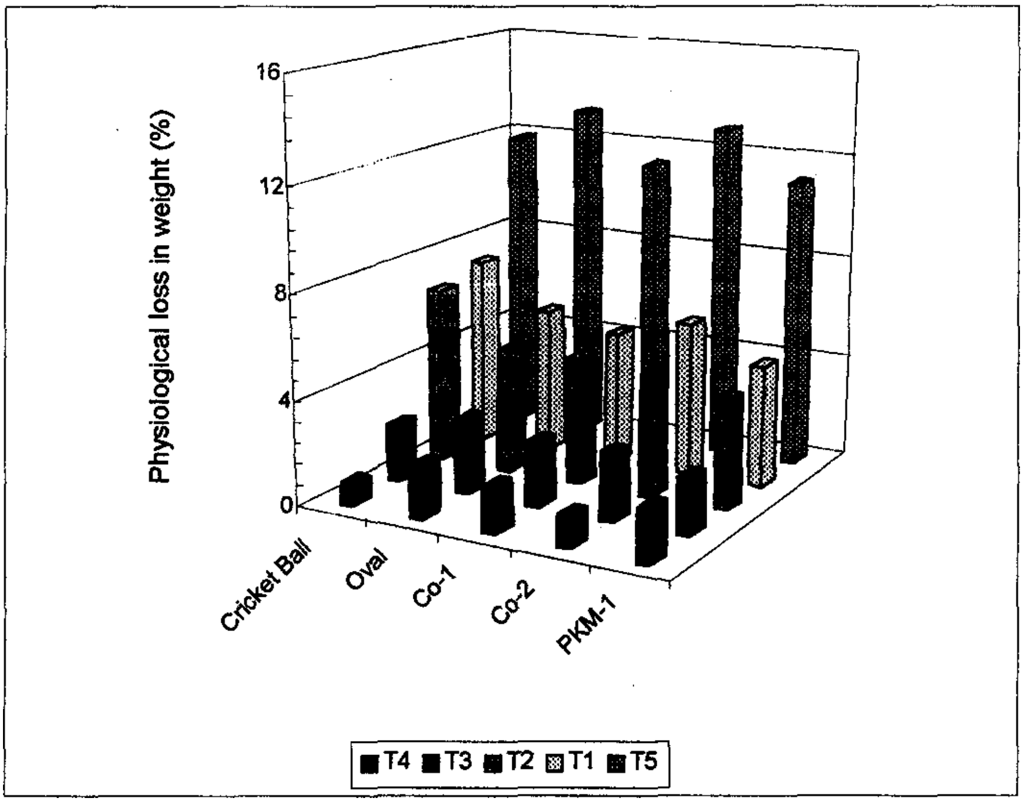

Fig. 4. Physiological loss in weight of sapota varieties under different storage techniques

Days to ripening

Among the treatments tried, cling film wrap, GA 300 ppm dip and saw dust were found effective in extending ripening period. Ethylene is one of the many volatile substances emanated by fruits and vegetables and was finally identified as the active component for stimulation of ripening by Gane (1934). While oxygen has been shown to stimulate ethylene synthesis above a certain minimum level, CO_2 retard ripening exerting itself as a competitive inhibitor of ethylene action (Burg and Burg, 1965). Lower access of O_2 in cling film and saw dust, high CO_2 retention inside cling film and lower temperature inside moistened saw dust medium might have reduced ethylene production and ripening. Postharvest dip of sapota in GA 300 ppm reduced the relative activity of catalase and pectin methyl esterase enzymes and thus postponed their metabolism and pectin break down as reported by Gautam and Chundawat (1989).

Decay percentage

Decay percentage was minimum in fruits stored in cling film, dipped in GA 300 ppm and those stored in saw dust. According to Sacher (1973) a number of enzymes which catalase the degradative aspects of senescence undergo substantial increase during climacteric. Further high temperature activated the enzymes involved in catabolism. The increased internal CO_2 concentration within cling wrap reduced the respiration rate, thereby preventing or delaying the senescence (Kabir *et al.*, 1995). It also prevented secondary infection, the spread of rot from one fruit to other and to other parts of fruit, eliminated the need to maintain high humidity during storage and transit, improved sanitation during handling by consumers and facilitated the pricing and labelling of individual fruit (Risse, 1989).

Moistened saw dust created an evaporative cooling effect within the microclimate, thus efficiently removed the respiration heat, lowered the oxygen accessibility, retarded the degradative metabolism and delayed the decay of the fruits whereas GA_3 reduced decay due to reduced metabolic activities and antisenescence action on fruits.

Cling film reduced decay, but in 'Co-2' fruits wrapped with cling film the decay percentage was higher possibly due to high fungal rot. This may be due to varietal difference, probably a higher rate of respiration which caused overheating and higher humidity inside the wrap favoured the fungal rot (Plate 3).

Marketability

Cling film wrapped fruits retained highest percentage of marketable fruits followed by those packed with moistened saw dust indicating the combined effect of reduced PLW and decay, this findings are in corroboration with the finding of Onwuzulu *et al.* (1989) (Fig.5).

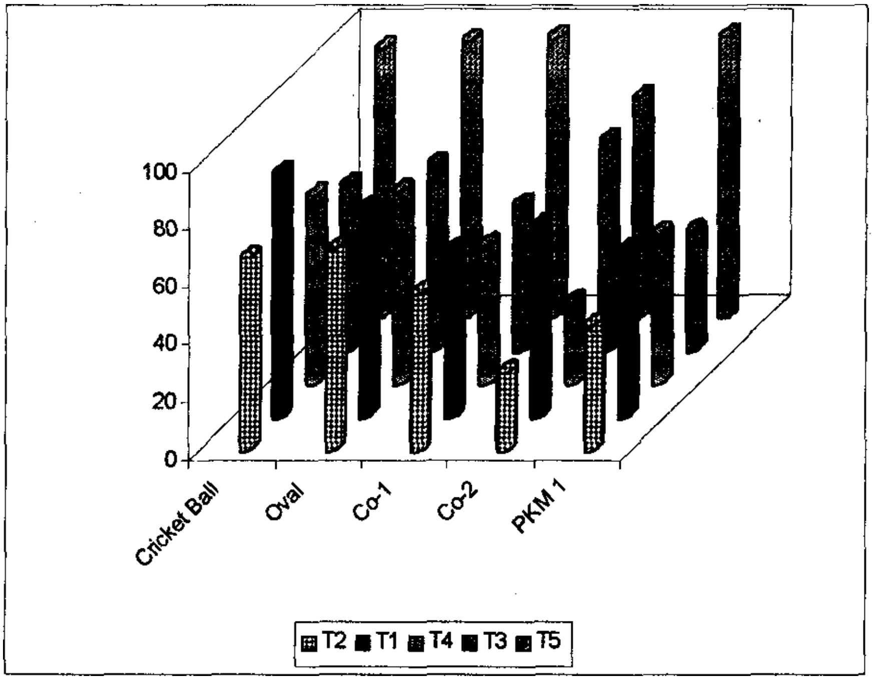

Fig. 5. Marketability of Sapota after six days of storage

Firmness

Firmness showed a significant and continued decrease reflecting the rapid softening of pulp resulting from the biochemical processes such as enzymatic breakdown of protopectin, the insoluble pectins present in unripe fruit into soluble pectin. This is in confirmation with Rao and Chundawat (1988). Firmness in all the treated samples except those in moistened saw dust recorded higher values compared to control. The higher firmness as a result of the above treatments compared to control may be due to their ability to retard fruit respiration and/or ethylene evolution rate. Kumbhar and Desai (1986) also reported that softening of fruit was more in open fruits than the packed fruits. However, lower firmness values of fruits in saw dust was recorded which may be attributed to higher water content in the fruits due to lower rate of evaporation offering less resistance to penetration.

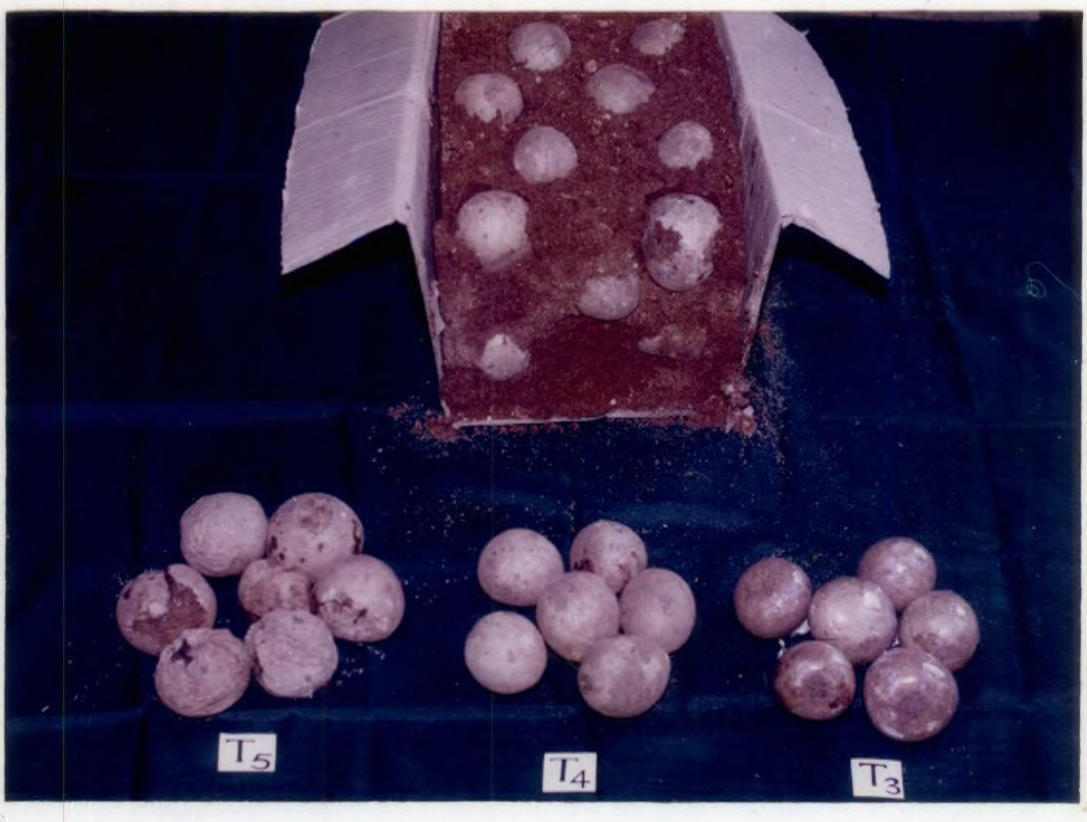

Plate 3. Fruits after six days of storage in moistened saw dust (T_4) and cling film (T_3) against the control (T_5)

increase in sugar content. The brix to acid ratio indicates parts of soluble solids content (mostly fruit sugars) for one part of acid. Hence a higher ratio is an indication of sweeter fruit and *vice versa* (Ranganna, 1986).

The fruits stored in cling film and saw dust after six days was organoleptically on par with fresh fruit sample showing that the two storage techniques didn't affect the quality of fruits.

5.3 Osmotic dehydration

In osmosis, water diffuses through a semipermeable membrane from a dilute solution to a concentrated solution until an equillibrium concentration is reached. Fruit pieces contain sugars and other solutes in dilute solution and their cellular surface acts as an effective semipermeable membrane. Hence osmosis can be used for partial removal of natural water content prior to drying/freezing to the extent of over 50 per cent to the original weight, by immersing the fruit pieces in dry sugar or in concentrated syrup. The advantages like better retention of colour and flavour due to low process temperature and improvement of nutritional, sensorial and functional properties make osmotic dehydration, a quite acceptable technique prior to subsequent dehydration of fruits (Ponting *et al.*, 1966, Torreggiani, 1993).

Preliminary experiment

Sapota fruit, a high sugary low acid fruit, consists of three components viz. peel (15%), edible pulp (81%) and seeds (4%) with moisture content of 71 per cent (Thapa, 1980). As reported by Ponting *et al.* (1966) it is not worthwhile to use osmotic dehydration for weight reduction greater than 50 per cent because of the decline in rate of osmosis with time. The variables studied were fruit to sugar ratio, contact time and temperature. Dry sugar (sucrose) was selected as osmotic agent since the rate of water removal from ripe fruit was extremely faster than in syrup; besides, sucrose was reported to be the best all round dry substance because of its effectiveness, convenience and desirable flavour.

Weight reduction

In the preliminary experiment a ratio of 1:1.5 (fruit:sugar) gave a higher weight reduction after six hours, but larger quantities of sugar remained undissolved causing difficulties in draining. After eight hours with 1:1 ratio the sugar completely got dissolved and the weight reduction was on par with former. Hence from the point of view of convenience in handling and economy, osmotic dehydration with 1:1 ratio for eight hours at room temperature seemed to be most suitable.

Temperature

The rate of osmosis was markedly affected by temperature. A weight reduction of 56.92 per cent was obtained within three hours at temperature of 50°C with 1:1 fruit to sugar ratio. However draining of the syrup, and the discolouration of the product in subsequent oven drying posed problems. This was in conformation with Levi *et al.* (1985) who reported significant discolouration in osmosis of papaya slices in boiling syrup. Ponting *et al.* (1966) stated that the rate of osmosis increased with temperature, but with a limit of 120°F (40°C) above which enzymatic browning and flavour deterioration began to take place.

The present study to improve the quality of dehydrated product showed that osmo-oven drying of sapota took only 16 hours of drying (eight hours of osmosis + eight hours of oven drying) when dry sucrose was used as osmotic agent. Vaghani and Chundawat (1986) when used 40°brix syrup as osmotic agent for 20 minutes followed by sun drying it took 33 hours to complete the drying. Similarly Thapa (1980) when used 70°brix syrup as osmotic agent it took 25 hours for osmosis and eight hours for oven drying. The reduced time in the present study may be due to the use of dry sucrose as the osmotic agent as referred by Ponting *et al.* (1966) and may also be due to the higher drying temperature in the oven (60-65°C) compared to sun drying (Plate 4).

Plate 4. Directly oven dried sapota chunks (T_2) against osmo-oven dried with and without sugar coating (T_1 and T_3)

Main experiment

'Cricket Ball', 'Oval' and 'PKM 1' attained maximum weight reduction in eight hours whereas 'Co-1' and 'Co-2' took only six hours. The recovery percentage of osmo-oven dried sapota varied from 27.3 per cent to 37.7 per cent and is in conformation with Vaghani and Chundawat (1986) who reported 30 to 34 per cent recovery in sun drying. Varietal difference in osmosis in terms of weight reduction and recovery percentage may be due to variation in the initial moisture content of the pulp, difference in the internal air space or textural differences between varieties. Roy and Joshi (1997) reported that the moisture content of the pulp, from mature sapota fruit varied between 69-80 per cent depending on cultivar and growing location.

Weight reduction

The total effect of osmosis is by balancing the two main osmotic effects viz. water loss and soluble solids uptake. During osmosis the solute can move in the reverse direction of water movement. On examining the phenomena of water loss on osmotic dehydration it was clear that the rate of water loss was maximum at the early hours of osmosis, which tends to decline on attaining a peak. This decline in weight loss during later hours is due to the higher rate of sugar impregnation than the water loss.

Rehydration

Reconstitution of osmo-oven dried sample was lower than those dried in oven alone. These samples reconstituted fully within two hours while only 78.5 per cent reconstitution was obtained in osmo-oven dried sample after six hours. Thapa (1980) also reported that to reconstitute osmo-oven dried sapota minimum six hours soaking in 20°brix syrup was necessary and the reconstitution was only 1.89. The report of Ponting *et al.* (1966) that rehydration of osmotically dried fruit is slightly less than that of untreated, both in rate and extent of reconstitution, thus confirming the result.

Lower rehydration and moisture adsorption capacity of the osmo-oven dried product was due to sugar impregnation in the fruit slices. The less hygroscopic nature of osmo-oven dried product as evident from reconstitution is an added advantage in handling and hence can be exposed for several hours without becoming sticky. The osmo-oven dried samples showed lower water activity at higher moisture content since the sugar infused into the fruit acted as water binding agent and increased resistance to moisture movement and gave lower diffusion coefficient.

The reconstituted samples were not relished as fresh sapota probably due to dehydrated odour. In osmosis along with water, some of the fruit acids were removed. On the other hand small amounts of sugar got impregnated into fruit pieces producing a blander and sweeter product than ordinarly dried fruit.

Storage

Reducing sugar

The palatability of dried fruit is directly influenced by its sweetness. Lower reducing sugar level was observed in osmo-oven dried sapota can be due to loss of free sugars (glucose and fructose) along with water during osmotic dehydration. During storage increased reducing sugar can be due to acid hydrolysis of sucrose which was impregnated in high amounts during osmotic dehydration. The increase in reducing sugar was reported in canned apricots, cherries and other processed foods during storage (Dalal and Salunke, 1964, Desrosier, 1977). The decline in reducing sugar in oven dried samples can be due to moisture absorption and hence a dilution effect.

Non-reducing sugar

Both in oven dried and osmo-oven dried samples the decline in non-reducing sugar can be due to its conversion into reducing sugar in an acidic medium. Non-reducing sugar content was also higher in osmo-oven dried samples due to the sugar impregnation during osmotic dehydration. Muralikrishna *et al.* (1969) also reported that the decrease in non-reducing sugar was due to inversion of sugars to monosaccharides by acid hydrolysis.

Acidity

Acidity of dried samples ranged from 0.2-0.39 per cent and no significant difference could be observed between the two drying method viz. oven drying and osmo-oven drying. A slight decrease in acidity during storage may be due to utilization of acids in the break down of polysaccharides and sucrose (Sharma *et al.*, 1998). Similar reduction in acidity of ber preserve was also observed by Dhawan (1990) during storage.

Tannin

Tannin, the astringent factor, was present in higher amounts in both the dried products due to concentration because of less moisture content. The tannin content was comparatively lower in osmosed samples probably due to higher moisture content since sugar acted as a moisture binding agent, but with lower water activity compared to oven dried samples.

Total sugar

Total sugar of the dried product was higher due to concentration in drying. Obviously total sugar recorded higher values in osmosed samples due to sugar impregnation during osmosis. The increased level of total sugars in dried fruits pretreated with sugar syrup was also reported in banana, gauva, papaya and mango (Unde *et al.*, 1998).

Sugar:acid ratio

In all the varieties osmo-oven dried samples had higher sugar:acid ratio compared to oven dried samples. Higher the sugar:acid ratio better was the acceptability. But with the advancement of storage, the ratio showed a slow decline probably due to the decreased total sugar as a result of dilution due to moisture absorption.

Sensory quality

Osmo-oven dried sapota slices were rated superior to oven dried samples. Among osmo-oven dried samples, 'Co-1' recorded the highest overall acceptability which can be due to the advantage of its fruit shape and size which made to obtain better slices for dehydration and hence looked attractive. However reduction in flavour was observed in both the drying techniques which can be due to the enzymatic action initiated by cell wall collapse during slicing and loss of volatile flavour components during drying (Unde *et al.*, 1998).

Based on all the results *wide supra*, it may be concluded that the varieties screened for postharvest qualities, 'Co-2', 'PKM 1' and 'Oval' are rated to be the best for table purpose, whereas 'Co-2' an ideal variety suited for distant marketing and 'Co-1' for processing qualities.

Both the cling film wrap and packaging with moistened saw dust can provide a storage life of six days at ambient temperature. Saw dust being cheap and less labour intensive can be suggested as an appropriate farm level storage technique without the involvement of any chemical, electricity or civil structure.

Osmo-oven drying technique developed could considerably reduce the drying time from the reported 33 hours to 16 hours, there by improving the quality many fold, and reducing the energy requirement.

Summary

SUMMARY

Evaluation of sapota (*Manilkara achras* (Mill.) Forberg) for postharvest qualities was carried out in the Department of Processing Technology, College of Horticulture, Vellanikkara during 1998-99. The main objectives were to study the postharvest qualities of sapota varieties viz. 'Cricket Ball', 'Oval', 'Co-1', 'Co-2' and 'PKM 1' in order to recommend varieties for table purpose, storage and for processing; to develop a simple, cheap and variety specific storage technique under ambient temperature and also to improve the dehydrated product quality.

On screening physical, chemical and sensory qualities, varieties 'Co-2', 'PKM 1' and 'Oval' were best rated for fruit qualities where as 'Co-2' for storage and 'Co-1' for processing.

On storage at low temperature (4-7°C) fruits developed chilling injury and failed to ripen even after three days at room temperature. Fresh fruits stored in moistened saw dust or in cling film recorded more than 50 per cent marketability after six days of storage under ambient temperature compared to nil in open stored samples.

Osmotic dehydration using dry sugar in a ratio of 1:1 for eight hours was found economical and successful in removing moisture up to 50 per cent. For further removal of moisture it was subsequently dried in an oven at temperature 60-65°C for eight hours, thus making the total drying period as 16 hours unlike the reported 33 hours of osmo-air drying. However to improve the appearance of the dried product a coating with icing sugar is advisable. The osmotically dehydrated samples were rated significantly superior to those oven dried in terms of colour, flavour, sweetness and overall acceptability though rehydration was low for osmosed samples. Throughout the storage period of four months osmo-oven dried samples maintained the qualities better than that of oven dried samples.

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EVALUATION OF SAPOTA [*Manilkara achras* (Mill.) Forberg] FOR POSTHARVEST QUALITIES

By

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ABSTRACT OF A THESIS

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ABSTRACT

A study on the screening of post-harvest qualities of five varieties of sapota grown in the college orchard was conducted at the Department of Processing Technology, College of Horticulture, Vellanikkara during 1998-99.

On screening varieties like 'Cricket Ball', 'Co-1', 'Co-2', 'PKM 1' and 'Oval' for physical, chemical and sensory parameters, 'Co-2', 'PKM 1' and 'Oval' were rated best for table purpose, while 'Co-2' for distant marketing and 'Co-1' for processing qualities.

Individually wrapping the fruits with cling film, or packaging fruits with 30 per cent moistened saw dust was evolved as the best storage technique to extend the shelf-life of sapota at ambient temperature. Saw dust being cheap, and less labour intensive can be suggested as an appropriate storage technique at field level without the involvement of any chemical, electricity or civil structure, while cling wrap can be aimed for retail marketing.

Osmotic dehydration of sapota slices of thickness 0.5 to 1 cm using dry sugar containing 1500 ppm SO_2 and 0.3 per cent citric acid in a ratio of 1:1 for eight hours followed by oven drying took only 16 hours to accomplish the drying unlike the reported 33 hours of osmo-air drying. Thus the technique developed can improve the quality of the product many fold and can reduce the energy consumption considerably.