SCREENING OF PAPAYA *(Carica papaya* L.*)* VARIETIES WITH SPECIAL REFERENCE TO POSTHARVEST ATTRIBUTES

By

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THESIS

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DECLARATION

I hereby declare that the thesis entitled "**Screening of papaya (*Carica papaya* L.) varieties with special reference to postharvest attributes**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship, associateship or other similar title, of any other University or society.

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EXTERNAL EXAMINER

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M. RENI

TO THE ETERNAL POWER

GUIDING ME

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ABBREVIATIONS

AM	-	Ambient
DAF	-	Days after flowering
DAS	-	Days after storage
LT	-	Low temperature
MAP	-	Months after planting
MAS	-	Months after storage
PR	-	Plant ripe
PLW	-	Physiological loss in weight
RTS	-	Ready to serve
SO_2	-	Sulphurdioxide
TSS	-	Total soluble solids

INTRODUCTION

INTRODUCTION

Papaya (*Carica papaya* L. F. Caricaceae) known as the wonder fruit of tropics is valued for its nutritious fruits as well as for the proteolytic enzyme 'papain' which has varied applications in the industrial sector. Popular as a common man's fruit, papaya can provide the essential protective nutrition for the poorest section of the society.

India is the largest producer of papaya in the world. The total area and production under papaya in India is estimated at 47,429 ha and 9.05 lakh tonnes, respectively (Chadha, 1995). Eventhough papaya is not grown as a commercial crop of Kerala, it covers an area of 13,226 ha, mainly scattered as stray plants in homesteads, with an annual production of 58,682 tonnes (FIB, 1997).

Papaya cultivation has good economic potential especially due to its multifarious uses as fresh fruits, processed products, production of papain, pectin and carpaine alkaloid. High yielding potential, year round fruiting behaviour and a short prebearing period make papaya unique among fruit crops. Papaya is quite nutritious and has much therapeutic value.

Papaya cultivation in Kerala is mostly confined to the homesteads and plants grown exhibit considerable variability though generally low in productivity due to inadequate management. The awareness of multifold uses of papaya for table, processing and papain extraction purposes is growing steadily and papaya is slowly emerging from the status of a homestead crop to that of a commercial crop in Kerala State.

A large number of papaya varieties have been released from different research institutions in India (Chadha, 1992). Though papaya is highly adaptive crop the performance of a particular cultivar shows variation under varying soil and climatic conditions (Ghanta *et al.*, 1992). Hence location specific performance studies help spread and popularisation of the new varieties bred by the different institutions. An adaptability trial of important released varieties of papaya was thus planned in this background. By identifying promising ones through the proposed study efforts can be taken for seed multiplication and commercial cultivation.

Papaya is considered as a fruit of choice of the processing sector, as the availability of fruit is largely spread through out the year. The comparatively cheaper cost of fruits higher recovery of pulp attractive colour of flesh and the suitability for a wide range of processed products make it more ideal for processing.

Papaya is a delicate fruit, highly perishable when ripe. The postharvest losses of fresh papayas vary from 40 to 100 per cent in different countries with varying climatic conditions (Salunkhe and Desai, 1984). Hence preservation of this fruit in fresh condition without loss of quality for extended period needs immediate attention.

Postharvest losses can be minimised by harvesting fruits at optimum maturity selection of cultivars with longer shelf life and use of proper harvesting, handling, packaging, storage and transport methods. Harvesting fruits at the correct stage of maturity is essential to obtain optimum quantity and quality of the produce. Maturity indices vary with varieties and climatic conditions and hence maturity standards have to be worked out for each variety and location.

Storage losses of fruits in India are high due to high temperature and humidity. Storage at low temperatures reduces the rate of decomposition of fruits and helps in retention of quality and freshness for a longer period (Chadha, 1995).

The quality of the harvested fruit depends on the conditions of growth as well as physico-chemical changes they undergo after harvest and hence an understanding of these changes is of great significance. Changes in the chemical composition of ripening have been reported by Pal *et al.* (1980a).

Ripe papaya fruits in the fresh form cannot be stored for more than a few days whereas in the semi-processed form (pulp) can be stored for one year by the use of chemical preservatives.

A knowledge on the chemical changes that occur during and after storage of pulp, suitability of stored pulp for making value added products will help in identification of the varieties with better acceptability to processing units.

In view of the growing demand of papaya in the processing sector, selection of varieties possessing processing qualities assumes special significance. A variety with high yield and promising postharvest attributes would be need of the farming community.

In this background the present study was planned with the overall objective of evaluating papaya as a commercial fruit crop especially as a raw material for processing units. For this purpose the present study on `Screening of papaya (*Carica papaya* L.) varieties with special reference to postharvest attributes' was carried out under different experiments with the following objectives.

1. To evaluate the performance of papaya varieties under Vellanikkara condition.

2. To study the storage behaviour of papaya under ambient and low temperature conditions.

3. To study the chemical changes during ripening under different conditions.

4. To study the suitability of preserved papaya pulp for product development.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Papaya, which grows luxuriantly under tropical climate, is an important source of vitamins and minerals. A large number of varieties of papaya have been released from different State Agricultural Universities and private seed companies. But knowledge regarding the performance of these varieties under Kerala condition is meagre. The literature related to the study is reviewed here under the following titles:

1. Collection and evaluation of papaya varieties
2. Storage behaviour of papaya under ambient and low temperature conditions
3. Changes in chemical composition under different conditions of ripening
4. Storage stability of fruit pulp and products

2.1 Collection and evaluation of papaya varieties

2.1.1 Biometric characters

Nakasone *et al.* (1974) studied the tree and fruit characteristics of papaya cultivars Higgins and Wilder and observed that their fruiting height was lower and they were precocious compared to Solo.

The characteristics of papaya cultivars CO-1, Coorg Honey Dew and Washington were studied by Shah and Shamugavelu (1975). They reported that stem girth was maximum in Washington which also had the longest petiole whereas CO-1 bore fruits at the lowest height.

Three varieties of Solo papayas, viz., Sunrise Solo, Line 8 Solo and Kapoho Solo introduced from Hawaii were studied for their performance by Selvaraj *et al.* (1975). The bearing height of trees ranged from 1.50 m to 1.70 m which was higher than CO-1. There was not much difference in the time taken for harvest.

Colam-covas (1977) found that in cv. Sunrise Solo the plant attained a height of 309 cm during a five month harvesting period and plant height was maximum at 0.715 m spacing.

In a study conducted at Pantnagar, U.P., Singh and Sirohi (1977) observed that there was significant difference between varieties Washington-1 and Coorg Honey Dew-1 with respect to height, stem girth and petiole length.

Sulikeri *et al.* (1977) reported that variety Solo flowers about 145 days after transplanting and the fruits mature 145 days after flowering.

Subramanyam and Iyer (1981) evaluated five cultivars for morphological and yield parameters and observed that the cultivars differed significantly for height, petiole length, stem girth, leaf area and number of leaves at first flowering.

Breeding work conducted by Ram (1982) resulted in the selection of four varieties, Pusa Delicious, Pusa Majesty, Pusa Giant and Pusa Dwarf, taking 249, 146, 259 and 239 days, respectively, for bearing fruits from planting. Among the fourteen varieties grown, Pusa Giant gave higher yield.

A varietal evaluation study by Ram and Singh (1984) revealed that among the gynodioecious varieties studied, Pusa 1-15 was outstanding, followed by Pusa 22-3. Among the dioecious lines Pusa 1-45 D was outstanding.

Evaluation of 23 selected germplasm lines of papaya at Pantnagar for two seasons by Singh *et al.* (1984) indicated wide variability in the lines. The plant height ranged from 109 to 233 cm, first fruiting height from 51 to 121 cm, stem girth from 4.9 to 10.5 cm, days to first flowering from 212 to 229 and days to first harvest was from 344 to 364. Selection carried out in some open pollinated populations gave rise to three promising strains (Pant Papaya-1, 2 and 3) which was reported to be suitable for commercial cultivation in U.P.

In a papaya improvement programme conducted by Ram (1984) it was found that Pusa 1-15 (Pusa Delicious) was outstanding with respect to yield and quality. He also reported a wide variation in first fruiting height, from 38 to 91 cm between the four varieties included in the study.

Ram and Majumder (1984) undertook a correlation study with papaya lines and observed that the yield was negatively correlated with fruiting height and number of nodes at first fruiting.

Veerannah (1984) in a study on papaya varieties noted wide variation in plant height and classified them into tall, medium and dwarf types (182 to 218.4 cm, 176 to 179.6 cm and 140 to 157.2 cm, respectively).

Among the papaya cultivars studied under Punjab conditions by Singh and Singh (1990), plant height, stem girth and leaf size were highest in Pusa Delicious and bearing height was least in Pusa Nanha.

Ghanta and Mondal (1992) reported that fruit yield per plant was positively correlated with height, girth, number of leaves and north-south spread of the plant.

In another study conducted by Ghanta *et al.* (1992) cultivar CO-6 recorded the maximum height (204 cm) and Coorg Honey Dew, the least (133 cm). They also noted

significant differences between cultivars for plant girth and length of petiole, cultivar CO-6 ranking top in both the above parameters. Cultivar Washington was the earliest to flower (89 days) and Coorg Honey Dew the latest (121 days).

Kashyap and Patel (1993) reported that the average height of Barwani Red was 4 to 5 m with an average fruiting height of 1.16 m.

2.1.2 Yield

A study by Mosqueda Vazquez *et al.* (1973) indicated that number of fruits per plant and maximum fruit weight were the most important yield components.

Kuthe and Spoerhase (1974) reported that a papaya tree gave 15 to 20 fruits annually and a yield of 28 tones per hectare.

Selvaraj *et al* (1975), while comparing the performance of Solo papayas, Sunrise Solo, Line 8 Solo and Kapoho Solo, found that number of fruits per plant was more in all the Solo papayas compared to CO-1. But the mean fruit weight was highest in CO-1 (1100 g) whereas it ranged from 216 to 232 g in Solo papaya.

Soerodimedjo (1978) compared the performance of local and introduced varieties of papaya and crosses between the

two groups in Surinam. He reported that the selection Waimanalo from Hawaii produced large quantities of small fruits (38 kg per plant per year) while local variety yielded large but tasteless fruits (50 kg per plant per year).

Veerannah *et al.* (1982) reported that fruits of CO-3 were superior to CO-2 in quality and to Sunrise Solo in fruit size with high TSS. They also reported that the fruit quality of CO-4 was better than CO-1 and Washington.

In a study of character association in papaya, Ram and Majumder (1984) observed that weight per fruit was negatively correlated with number of fruits per plant. They further reported that the fruit yield per plant was positively correlated with weight of fruit and number of fruits per plant, the latter two having negative correlations, an optimum level should be selected for these two traits.

Ram and Singh (1984) compared the performance of two varieties Pusa 1-15 and Pusa 1-45 D and reported a yield of 37 kg and 31.3 kg fruits per plant with an average fruit weight of 1307 g and 852 g respectively.

In a study conducted in Coorg Honey Dew papaya it was found that number of fruits per plant and yield per plant were significantly correlated while fruit size was not correlated with number of fruits per plant (Purohit, 1984).

Sundararajan and Krishnan (1984) reported that average fruit weight of varieties CO-1, CO-2, CO-3 and CO-4 ranged from 0.8 to 1.0 kg, 1.5 to 2.0 kg, 0.835 to 1.0 kg and 1.3 to 1.5 kg, respectively. They also reported a yield of 150 tones per hectare and 200 tones per hectare in two years for varieties CO-3 and CO-4 respectively.

Mederez-olalde *et al* (1985) studied the influence of shoot diameter on flower and fruit production in papaya and found that at 16 weeks, trees with a shoot diameter of 7 to 7.9 cm had an average 16 flowers and at 29 weeks trees with a shoot diameter of 11 to 11.9 cm had an average 15.84 fruits.

Biswas *et al.* (1990) studied the performance of different varieties of papaya under W. Bengal conditions and reported that the high yielding cultivars were Washington, Ranchi, Pusa 1-15 and CO-1 with 1115.4, 1095.4, 1093.4 and 1015.5 quintals per hectare, respectively. The lowest yielding cultivar was Sunrise Solo (300 quintals per hectare), however, the fruit quality was best, followed by Pusa 1-15, CO-1 and CO-2.

In a varietal evaluation study by Ghanta and Mandal (1992) with seven cultivars of papaya it was observed that the fruit yield per plant varied from 18.67 to 34.00 kg.

Ghanta *et al.* (1992) in a study of papaya varieties reported that the cultivar Farm Selection-1 produced the maximum number of fruits (33.7 per plant) and yield (33.4 kg per plant) while cultivar Coorg Honey Dew produced the lowest number of fruits (17.1 per plant) and yield of 18.6 kg per plant. The cultivars CO-6 (71.8 tones per hectare), Pusa Delicious (72.5 tones per hectare) and Ranchi (69.8 tones per hectare) were also superior in fruit yield compared with Coorg Honey Dew (46.5 tones per hectare).

Wagh *et al.* (1992a) evaluated growth and yield components in fourteen geographically diverse varieties of papaya and observed that Solo had superior colour, flavour and eating quality and produced the greatest number of fruits per plant (47.4) although it gave the lowest yield in terms of weight (15.9 kg per plant).

Among the varieties evaluated by Wagh *et al.* (1992b) CO-2 recorded the maximum number of fruits (25.53) and fruit weight per plant (22.46 kg).

2.1.3 Growth and development of fruit

An investigation on physico-chemical composition of four cultivars of mangoes by Dabhade and Khedkar (1980) revealed that fruit attained maximum size with maximum edible portion and harvest maturity within fourteenth week of fruitset in all the cultivars.

Ingle *et al.* (1982) studied the physico-chemical changes during growth and development of sapota variety Kalipatti and observed that at full maturity the fruit attained maximum size in length, breadth and weight. Specific gravity showed a decreasing trend through out the development. Proportion of pulp continued to increase till harvest maturity.

Selvaraj *et al.* (1982à)reported that fruit development in papaya followed the double sigmoid growth pattern. They also reported that papaya fruit took 145 to 165 days to attain eating ripe stage from the date of flowering. Pulp:peel ratio increased with increasing age of fruit whereas this ratio decreased at ripe stage in all varieties studied and was between 8.5 to 9.5.

Chezhian and Shanker (1982) studied fruit growth and maturity in *Psidium* sp. and found a positive association between fruit length and diameter.

Veerannah *et al.* (1982) reported that the thickness of CO-3 papaya pulp was more than Sunrise Solo, one of its parents.

Investigation on growth and development of CO-2 papaya fruits by Chittiraichelvan *et al.* (1984) revealed that it took 137 days from anthesis to fruit maturity. fruit growth in respect of weight, volume, length and breadth showed a

single sigmoid pattern. The cavity length and breadth in respect of developmental growth of fruit tended to express double sigmoid curve. The growth of the pulp increased at the early stage and it was static between 90 to 120 days.

Magdalita *et al.* (1984) studied the phenotypic variability in some characters of papaya and found that fruit weight was positively and highly correlated with fruit length, width, volume, flesh thickness and cavity volume.

The physico-chemical changes accompanying the development of CO-1 papaya fruits was studied by Veerannah and Selvaraj (1984). The rate of increase in all the physical characters, weight, volume, length, breadth, girth and thickness was observed to be rapid till 105 days and declined thereafter exhibiting sigmoid pattern of growth.

Balakrishnan *et al.* (1986) studied the various fruit characteristics of papaya such as fruit length, circumference, flesh thickness, diameter, volume and weight and found that these characters increased with the age of the fruit. Seed weight had significant positive correlation with all the fruit growth characteristics. Fruit length had negative and significant association with fruit circumference. Fruit length and circumference had positive association with fruit volume and weight.

Studies on the developmental physiology of fruits of guava by Dhillon *et al.* (1987) revealed that length, diameter and weight increased during the development of fruit. The growth pattern followed a double sigmoid curve. Specific gravity of the fruit decreased from fruitset till final harvest.

In a study of physico-chemical changes in sapota variety Kalipatti, Paralkar *et al.* (1987) observed pronounced physico-chemical changes during growth and development. The weight, volume, length, diameter and flesh to seed ratio increased continuously from fruitset till maturity with distinct changes in fruit colour.

Ghanta (1994) reported that the fruits of papaya cultivar Ranchi showed a double sigmoid type of growth curve and reached eating ripe stage in 155 to 160 days. The fruit weight, weight of pulp, peel, seeds and thickness of pulp increased through out the period of fruit development. The pulp per peel ratio of fruit increased upto 140 days of fruit growth and thereafter decreased until ripening.

Veerannah and Rathinakumari (1986) in a study of growth and development of papaya found that as the fruit advanced in maturity the rate of increase in length decreased between 60 and 75 days and after that the length of the fruit increased. The breadth of the fruit showed a curvilinear growth upto 90 days and a linear growth

thereafter indicating slow accumulation of metabolites and then a sudden spurt in the translocation and accumulation of metabolites after 90 days.

Chan and Teo (1992) reported that the fruit cavity of Exotica papaya ranged from two to 45 per cent fruit volume and it was larger in female fruits than hermaphrodite fruits.

Kashyap and Patel (1993) reported that in fruits of Barwani Red skin accounted 10.88 per cent, seed 0.39 per cent and edible pulp 88.7 per cent of the total weight.

2.2 Storage behaviour of papaya under ambient and low temperature conditions

Trials on Honey Dew papaya grown in certain regions of India have shown that hard unripe fruits free from latex can be stored at 9±1°C and 85 to 90 per cent relative humidity for 12 days (CFTRI, 1963).

Thompson and Lee (1971) found that fruits of the papaya cultivar Solo 63/2 were damaged when stored at or below 45°F (7°C). They found that the optimum stage of maturity for satisfactory storage and subsequent ripening was when the yellow colour was just beginning to develop in the funicles.

El-Tomi *et al.* (1974) reported that symptoms of chilling injury occurred in papaya fruits stored at temperature below 10°C and increased with duration of storage. At higher storage temperature of 15°C and 20°C the rate of percentage decay was greater.

Peleg and Brito (1974) found that papaya fruits having higher initial Hunter `b' values ripened in a shorter time. Most fruits with Hunter units more than 20 and between 18 to 20 ripened when kept at room temperature (22 to 24°C) for five to seven and eight to ten days respectively.

Fully green papaya fruits harvested 105 to 119 days after fruitset ripened unevenly and were of low quality (Rodriguez *et al.*, 1974).

Studies were carried out by Arriola *et al.* (1975) with the papaya cultivar Criolla picked at two stages of ripeness (green and yellow to greenish) and stored at seven, ten, twelve or twenty three degree celsius (control). Optimum qualities were maintained upto twleve days of storage at 12°C compared with seven to eight days in the control.

Aziz *et al.* (1975) conducted an experiment to study the effect of different temperature (10, 15 and 20°C), on the storage of papaya fruits and observed that percentage weight loss of fruits increased as the storage period progressed and was greater at 15°C than at 10°C.

Basuki *et al.* (1975) stored local papaya fruits at ambient and low temperature conditions and found that storage at 10 to 15°C resulted in the longest shelf life with reasonably good quality.

Arriola *et al.* (1976) reported a storage period of two to three weeks at 12°C and a ripening period of one week at 23°C proved satisfactory.

Broughton *et al.* (1977) found that a temperature of about 20°C was optimal both for inducing postharvest ripening of papaya and for satisfactory fruit storage. Temperature above this made the fruit susceptible to fungal attack, while at lower temperature the onset of the climacteric was delayed and chilling injuries were manifested.

The optimum storage and ripening temperature for Bentong and Taiping papayas as reported by Nazeeb and Broughton (1978) was approximately 20°C. They further observed that chilling injuries occurred at temperature below 15°C when the papayas were stored for more than seven days and the nutritive value of ripe fruit decreased rapidly with prolonged storage.

Veerannah and Selvaraj (1984) observed that CO-1 papaya fruits can be stored for four days without affecting quality when they were harvested 130 days after fruitset.

°Chan *et al.* (1985) stored papaya fruits at five or ten degree celsius for one, four, seven, fourteen or twenty one days. Chilling injury was detectable as visible skin discolouration after four days at five degree celsius.

Chen and Paull (1986) reported that mature green fruits of papaya were most sensitive to chilling and began showing injury after ten days of storage at two degree celsius.

An and Paull (1990) studied the influence of storage temperature on ripening of papaya fruit and found that temperature at or higher than 30°C adversely affected the quality of ripe papaya. Papaya held at 32.5°C for ten days failed to ripen normally. Within the temperature range of 22.5 to 27.5°C the fruits exhibited a quadratic response to ripening time.

Lam (1990) reported that papaya fruits stored at 10°C for 14 days subsequently transferred to 25°C ripened normally after four days and kept at 25°C for 11 days also ripened normally.

Wills (1990) observed that onset of papaya fruit ripening can be delayed by storing at a low temperature, however, chilling injury occurs in many cultivars after one week at 15°C. Satisfactory colour and flavour developed in fruits ripened at 25°C but not at 20°C.

Zhang and Paull (1990) studied the variation in the ripening characteristics in papaya and found that all the cultivars and lines studied showed similar pattern of respiration and ethylene production. Lines RL-13 and RL-1-22 were slow to ripen taking 15-16 days compared with seven days for Sunrise and Kapoho.

Storage life of papaya can be extended by storing at low temperature or by use of ripening retardants. Papaya fruits at full colour can be stored at seven degree celsius and will have normal ripening. But the fruits at colour breaking stage will not ripen normally if stored at seven degree celsius and need the temperature of 12 to 13°C for storage to attain ripening after storage (Chadha, 1992).

Chilling injuries were reported in papaya fruits at 10 to 15°C by Ali *et al.* (1993). They also reported that transferring fruits to ambient temperature following storage at ten degree celsius resulted in rapid increase in fruit colour development and softening. Storage at ten degree celsius for 20 days totally inhibited the development of peel colour and suppressed the rate of decrease in firmness.

2.3 Changes in chemical composition under different conditions of ripening

Investigations by Agnihotri *et al.* (1963) revealed that the papaya fruits after harvest showed three different stages, ripening ranging between four to six days,

indicated by a fall in acidity, accumulation of sugars, development of colour and flavour and softening of the texture, senescence extending over a week when the chemical and physical characters showed the least changes and decay when the fruits gradually deteriorate and develop anthracnose and mould.

Akamine and Goo (1971) reported that to meet the minimum soluble solids percentage of 11.5 for marketable papaya the fruit should have atleast six per cent surface yellow colouration for freshly harvested fruit.

On comparing the performance of Solo papayas with CO-1, Selvaraj *et al.* (1975) reported that there was no much difference in the percentage of pulp but the TSS content of Solo papayas were higher than CO-1. The sugar content did not vary much between CO-1 and Solo papayas but the acidity was found to be little high in Sunrise and Kapoho Solo.

Shah and Shanmugavelu (1975) found that the hybrid Coorg Honey Dew x CO-1 had the highest ascorbic acid, pectin and carotenoid contents as well as the highest brix:acid ratio. Sugar content was highest in CO-1.

Pal *et al.* (1980a) studied the changes in physico chemical composition of different cultivars of papaya ripened on and off the plant. They found that at same stage

of maturity papaya fruits on tree took more days to reach eating ripe stage than off the plant under room temperature.

Pal *et al.* (1980b) examined 12 papaya varieties for their physical characters like size, pulp colour, texture and density, fruit and seed cavity dimensions and chemical composition viz., TSS, acidity, drymatter, alcohol insoluble solids, starch, sucrose, glucose, fructose, minerals and vitamins and observed wide variation in these constituents.

Barria *et al.* (1983) evaluated mountain papayas at four stages of maturity (25, 50, 75 and 100% yellow skin colour) for their chemical constituents. The pH, acidity, TSS, texture, colour, syrup translucence and organoleptic properties were best in fruits harvested at full maturity.

A positive correlation between total sugar, sucrose and TSS while a strong negative relationship existed between sucrose and reducing sugar (Singh *et al.*, 1985).

In CO-5 papaya, Veerannah *et al.* (1985) reported a TSS of 12 to 13 per cent.

Ghanta *et al.* (1992) observed significant variation among papaya cultivars for chemical constituents and the cultivar CO-2 contained highest amount of TSS, total sugar, reducing sugar and ascorbic acid.

2.4 Storage stability of fruit pulp and product

Ghosh *et al.* (1981) observed that pasteurized mango pulp in polypropylene pack had a shelf life of three months at five degree celsius and two months at 37°C while both mango pulp and syrup preserved with SO_2 retained a better quality and had a shelf life of atleast five months under ambient temperature.

Kalra and Revathi (1981) conducted storage studies on guava pulp and found that there was significant variation in most of the chemical characteristics like acidity, vitamin C, TSS, reducing and non-reducing sugars, protein, pH and SO_2 level during 45 days storage period.

Kalra (1982) preserved mango pulp with 1000 ppm SO_2 and stored under room and cold temperature. It was found that titrable acidity decreased under room condition but not under cold condition. Reducing sugars exhibited steep rise at room condition but less at cold temperature and there was not much change in total soluble carbohydrates or TSS.

The chemical composition of mango pulp during storage was studied by Murthy *et al.* (1982) and found that pulp stored in glass bottles had the minimum change in chemical composition.

Kapur *et al.* (1985) found that on processing of mango pulp there was an increase in TSS, reducing and non-reducing sugars in canned pulp while slices and juice showed slight and insignificant variation.

Kulwal *et al.* (1985) canned three products namely slices, sweetened juice and nectar prepared from Coorg Honey papaya fruits in plain cans. Undesirable chemical changes like increase in acidity, inversion of sugar, increase in hydrooxymethyl furfural and furfural tin pick in these products were very rapid at higher storage temperature (37°C) compared to products stored at room temperature.

Chakraborthy *et al.* (1991) conducted studies on canned mango pulp samples for six months at ambient conditions (20-42°C) and found that there was no significant change in the physico-chemical constituents especially, brix, acidity, pH of the pulp samples during storage period except for slight changes in reducing and total sugar content.

Sheeja and Prema (1995) studied the effects of pre-treatments on the shelf life of papaya squash and found that there was an increase in acidity during storage but pre-treatment with sulphur fumes could decrease the rate of increase in acidity. Refrigerated samples were found better in quality aspects than the samples kept at ambient condition because the deteriorative or chemical changes were more at room temperature.

Tiwari *et al.* (1995) found that guava RTS beverage can be stored at room temperature upto six months without major quality deterioration.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The study on `Screening of papaya (*Carica papaya* L.) varieties with special reference to postharvest attributes' was carried out in the Department of Processing Technology, College of Horticulture, Vellanikkara, Thrissur, Kerala during September 1995 to April 1997. Vellanikkara lies between 10° 32' N latitude and 76° 17' E longitude at an altitude of 23 m above MSL, enjoys a warm humid climate.

The study was carried out in four different experiments.

1. Collection and evaluation of papaya varieties
2. Storage behaviour of papaya under ambient and low temperature conditions
3. Chemical changes during ripening under different conditions
4. Storage stability of papaya pulp and its suitability for product development

3.1 Collection and evaluation of papaya varieties

Twelve varieties of papaya including nine released varieties from different centres and three promising local types were used for the study. The details of varieties are presented in Table 1.

Table 1. Sources of papaya varieties

Sl. No.	Variety	Name of variety	Source of seed
1.	V_1	CP-14	Kozhikode, Kerala
2	V_2	CP-15	,,
3	V_3	CO-2	TNAU, Coimbatore
4	V_4	CO-3	,,
5	V_5	9-1-D	,,
6	V_6	MS	Mukund Foundation for Agricultural Research, Coimbatore
7	V_7	CO-4	TNAU, Coimbatore
8	V_8	CO-5	,,
9	V_9	CO-6	,,
10	V_{10}	Solo	,,
11	V_{11}	CP-16	Kozhikode, Kerala
12	V_{12}	Honey Dew	IIHR, Bangalore

Layout

The layout of the experiment was RBD with four replications having 2 plants per plot with a spacing of 2 x 2 m. Two additional replications were maintained for harvesting fruit samples for chemical analysis at regular intervals. To ensure pollination and fruitset, sufficient male plants were maintained as border plants at the same spacing.

Soil

Soil samples were collected before planting and after harvest of crop at a depth of 0-15 cm from basins prepared for plants under each replication and composited to give a sample representing a single plant. The samples were analysed for pH organic carbon, available phosphorus and available potassium using standard analytical proceedures (Jackson, 1973). In general the soil of the experimental field was acid laterite (pH 5) and a well drained one. The fertility status for organic carbon was medium, high for available phosphorus and available potassium.

Planting and aftercare

Seeds were sown in polythene bags of 20 cm x 15 cm size and 150 guage thickness. It was filled with a mixture of FYM, soil and sand in equal proportions. Forty five days old seedlings were transplanted to the mainfield during June, 1995 at a spacing of 2 x 2 m. Pits of size 50 cm^3 were taken and filled with top soil. Two plants were planted in each pit. Male plants were removed as soon as the plants flowered and the female and hermaphrodite plants were retained. One male plant was retained for every ten female or hermaphrodite plants in the border row. FYM was applied as a basal dose @ 10 kg per pit. Factomphos and MOP were used as inorganic source according to Package of Practices Recommendation (KAU, 1993). The plants were irrigated during summer months and the field was kept weed free.

3.1.1 Observations

3.1.1.1 Biometric characters

Observations on biometric characters were recorded at bimonthly intervals from planting till ten months age.

3.1.1.1.1 Plant height

Plant height was measured from the ground level upto the growing point using a graduated pole and expressed in cm.

3.1.1.1.2 Collar girth

Collar girth at 10 cm above the ground level was taken using a measuring tape and expressed in cm.

3.1.1.1.3 Canopy spread

Canopy spread along the east-west and north-south directions were taken using a measuring tape and expressed in cm.

3.1.1.1.4 Leaf area

Leaf area was calculated using the method described by Karikari (1973).

$$Y = 106\ x - 2028$$

where 'x' represents the length of the median mid rib of fifth leaf in cm. Y represents the leaf area of the plant in cm^2.

3.1.1.1.5 Length of petiole

Length of the petiole of fifth leaf from the top was measured and expressed in cm.

3.1.1.1.6 Number of fully developed leaves

The number of fully opened functional leaves were counted at bimonthly intervals. Total number of leaves at the time of first flowering was also noted.

3.1.1.2 Days to first flowering

Number of days from germination to opening of first flower was computed.

3.1.1.3 Days to first harvest

Number of days from germination to first harvest was noted.

3.1.1.4 Monthvar cumulative yield

Fruits were harvested at colour break stage and its weight recorded. Monthvar production of papaya varieties were studied by recording the monthvar cumulative yield and number of fruits for a period of one year commencing from first month of harvest and expressed in kg.

3.1.1.5 Pest and disease incidence

Incidence of major pests and diseases were observed and recorded.

3.1.2 Growth analysis of papaya fruit

For studying fruit development, flowers were tagged on the day of their opening and observations on the following fruit characters were taken at 15 days interval till its full maturity. Two fruits in each variety were used for the study.

3.1.2.1 Days to harvest maturity

Fruits were harvested when yellow colour appeared along the furrows of fruit and number of days taken from anthesis to this stage was calculated.

3.1.2.2 Weight of fruit

Individual fruit weight was recorded and expressed in gram.

3.1.2.3 Length of fruit

The distance between the pedicel and apex was measured and expressed in cm.

3.1.2.4 Circumference of fruit

Circumference of fruit was measured by running a measuring tape around the midpoint of the fruit, recorded its length and expressed in cm.

3.1.2.5 Volume of fruit

The volume of the fruit was estimated by water displacement method and expressed in ml.

3.1.2.6 Polar diameter

Polar diameter of the fruit was noted by cutting the fruit longitudinally into two equal halves through the centre and the length measured using a twine and read on a metre scale and expressed in cm.

3.1.2.7 Equatorial diameter

Equatorial diameter of the fruit was measured from the longitudinally cut fruit at the region having maximum diameter and expressed in cm.

3.1.2.8 Flesh thickness

The thickness of the flesh was measured using twine and expressed in cm.

3.1.2.9 Cavity volume

Cavity volume was measured by estimating the volume of water that the fruit cavity can hold and expressed in ml.

3.1.2.10 Cavity index

Cavity index was calculated using the formula

$$\frac{\text{Cavity volume}}{\text{Fruit volume}} \times 100$$

and expressed as per cent.

3.1.2.11 Physical composition of fruit

Weight of fruit was recorded first, fruit was separated into different components by cutting and peeling

with a peeler. Weight of pulp, peel and seed were recorded separately and relative proportion of each of these to total weight worked out. Physical composition of fruits at fully mature and ripened stages were also studied.

3.1.2.12 Maturity indices of papaya varieties

Physical parameters at optimum maturity stage in each of the 12 varieties of papaya were studied. These were used as indices of harvest maturity in each of the above varieties.

3.2 Storage behaviour of papaya under ambient and low temperature conditions

When yellow colour appeared along the distal end of the furrows, fruits were harvested and stored under ambient (24°C to 30°C with RH 70 to 80%) and low temperature (8±1°C with RH 85 to 90%) conditions.

3.2.1 Observations

3.2.1.1 Physiological loss in weight (PLW)

Weight of fresh fruits were recorded immediately after harvest and subsequent reduction in weight was recorded at 24 hours interval as long as the fruits remained in the marketable stage. Fruits were declared unmarketable when it bore symptoms of decay or mould growth or shrivelling to the tune of 25 per cent or more.

3.2.1.2 Days to ripening

After harvesting mature fruit, they were allowed to ripen under ambient conditions. Fruits stored under low temperature conditions were also subsequently ripened under ambient conditions. When the skin of the fruits turned yellow it was considered fully ripe. The time taken for this in days was computed.

3.2.1.3 Keeping quality/shelf life

The shelf life was calculated as number of days till the fruit remained marketable as described in 3.2.1.1.

3.2.1.4 Tolerance to low temperature

Tolerance to low temperature (8±1°C) was assessed by computing the number of days upto which the fruits could be stored without chilling injury symptoms.

3.2.1.5 Organoleptic evaluation of fruits ripened under ambient and low temperature conditions

A score chart was prepared based on a ten point scale ranging from zero to ten, zero denotes `poor' and ten `excellent' quality. The organoleptic evaluation was done by a panel of 15 semitrained persons. The parameters considered were colour, flavour, sweetness, taste, firmness and overall acceptability.

3.2.1.5 Incidence of postharvest diseases

The organisms present at the site of spoilage were identified by microscopic examination and recorded.

3.3 Chemical changes during ripening of papaya fruits under different conditions

Tree ripe fruits, fruits ripened under ambient conditions and those ripened after low temperature storage were analysed for the following quality parameters.

3.3.1 TSS

TSS was estimated directly using a Erma hand refractometer (range 0-32° brix) and expressed in degree brix.

3.3.2 Acidity

Titrable acidity was estimated as per the procedure described by Ranganna (1986).

3.3.3 pH

pH was determined using the digital pH metre (Digital pH meter PH 5652 A of Electronics corportations of India).

3.3.4 Total, reducing and non reducing sugars

Total sugars and reducing sugars were determined as per the procedure described by Ranganna (1986). The non-reducing sugars were obtained by subtracting the per cent of reducing sugars from the total sugars.

3.4 Storage stability of papaya pulp and its suitability for product development

The experiment was laid out in CRD with three replications with pulps of twelve accessions.

3.4.1 Physico-chemical changes during storage of papaya pulp

Pulp was extracted from fully ripened fruits from twelve accessions and preserved separately by adjusting the acidity to one per cent by adding citric acid and KMS @ 2.5 g per kg and filled in sterilized glass bottles, sealed air tight and stored for a period of four months under ambient conditions.

3.4.1.1 Observations

3.4.1.1.1 TSS

TSS was estimated as in 3.3.1.

3.4.1.1.2 Acidity

Acidity was estimated as in 3.3.2.

3.4.1.1.3 pH

pH was estimated as in 3.3.3.

3.4.1.1.4 Total, reducing and non-reducing sugars

Estimated as in 3.3.4.

3.4.1.1.5 Total and free SO_2

Total and free SO_2 was determined by iodometric titration as described by Ranganna (1986).

3.4.1.1.6 Off flavour development

Product was sensory evaluated for off flavour development.

3.4.1.1.7 Colour degradation

Product was evaluated visually for colour degradation.

3.4.2 Suitability of stored pulp for product development

3.4.2.1 Materials

Solo and CO-3 were found to be more promising in terms of storage stability and pulp quality based on the results of experiment 3.4.1. These two varieties were selected for this experiment. Stored pulp of these varieties were used for preparing ready to serve (RTS) beverage which was compared with RTS prepared from the fresh pulp of the above varieties and evaluated organoleptically.

The experiment was laid out in CRD with four treatments and five replications.

3.4.2.2 Recipe for RTS beverage as per FPO specification (Lal *et al.*, 1960)

Papaya pulp	: 15%
TSS	: 15°brix
Acidity	: 1%
Free SO_2	: 60-70 ppm

The RTS beverage was filled in crown cork bottles @ 200 ml per bottle sealed with crown corks and pasteurised at 95°C in an autoclave for 30 minutes and subsequently cooled to room temperature. These bottles were further stored under refrigerator.

3.4.2.3 Observations

RTS beverage was evaluated organoleptically on the 15th and 30th days of storage on a ten point scale ranging from zero to ten. The parameters evaluated were colour, flavour, taste and overall acceptability by a panel of 15 semitrained persons with the help of score charts.

Statistical analysis

The observations recorded were analysed statistically according to the procedure described by Panse and Sukhatme (1985). The data on organoleptic evaluation for fruit samples were subjected to Freedman two way analysis and RTS beverage by Kruskall Wallis one way analysis (Siegel, 1956).

RESULTS

4. RESULTS

Data recorded in the present study on "Screening of papaya (*Carica papaya* L.) varieties with special reference to postharvest attributes" were analysed and results are presented under the following heads.

1. Collection and evaluation of papaya varieties
2. Storage behaviour of papaya under ambient and refrigerated environment
3. Changes in chemical constituents under different conditions of ripening
4. Storage stability of papaya pulp and its suitability for product development

4.1 Collection and evaluation of papaya varieties

Twelve varieties of papaya comprising nine released varieties and three promising local types were evaluated for biometric and yield parameters (Plate 12 to 24).

4.1.1 Biometric characters

Biometric characters like plant height, collar girth, canopy spread, leaf area, length of petiole and total number of leaves were recorded at the end of 2nd, 4th, 6th, 8th and 10th month of planting and mean values presented in Table 2. General analysis of variance revealed significant differences between growth phases for biometric characters.

Table 2. Biometric characters of papaya varieties at different phases of growth

Variety	Collar girth (cm)					Height (cm)				
	2 MAP	4 MAP	6 MAP	8 MAP	10 MAP	2 MAP	4 MAP	6 MAP	8 MAP	10 MAP
V1	5.85	9.15	17.06	22.19	28.43	63.38	95.38	128.88	158.00	217.63
V2	2.74	7.78	14.38	21.63	27.13	25.88	69.50	117.25	176.50	244.24
V3	7.11	18.00	21.50	25.25	27.13	68.50	133.63	165.63	181.50	200.38
V4	7.94	18.13	23.88	29.31	32.13	75.63	132.63	177.00	198.38	231.38
V5	7.31	16.18	21.25	25.25	28.69	77.06	141.38	180.75	204.50	220.75
V6	7.08	16.06	20.88	26.13	30.31	64.75	115.00	139.38	160.38	188.50
V7	7.59	16.56	23.38	29.25	31.10	71.38	128.50	167.38	199.225	228.50
V8	6.29	12.41	17.31	23.31	26.96	58.63	100.50	135.00	156.38	203.38
V9	6.90	15.50	24.75	30.56	30.19	63.38	123.88	171.75	197.25	220.00
V10	5.15	15.70	21.25	28.13	30.81	57.63	130.50	171.75	199.00	228.38
V11	4.56	8.50	14.75	21.19	27.71	38.38	63.38	110.00	167.75	228.50
V12	6.23	16.00	21.75	29.63	31.56	54.13	115.63	169.75	189.25	220.00
CD(0.05)	2.80	4.95	6.21	6.66	NS	23.78	34.33	36.96	NS	NS

Contd.

MAP - Months after planting

Table 2. Continued

Variety	Canopy spread NS (cm)					Canopy spread EW (cm)				
	2 MAP	4 MAP	6 MAP	8 MAP	10 MAP	2 MAP	4 MAP	6 MAP	8 MAP	10 MAP
V1	94.13	100.00	114.13	183.75	219.00	85.63	93.38	107.50	181.25	217.50
V2	34.75	73.75	129.88	204.25	230.00	30.38	68.00	144.13	192.00	214.13
V3	86.88	128.38	137.88	161.50	195.13	80.13	115.88	124.88	148.75	182.13
V4	89.38	166.00	199.63	175.88	242.75	82.75	151.13	181.88	161.63	223.13
V5	81.38	183.38	197.13	160.63	217.63	74.00	167.50	179.75	149.00	195.75
V6	81.25	173.50	204.38	178.63	213.38	74.63	155.25	187.38	169.38	195.63
V7	81.63	171.00	206.00	191.88	240.50	73.25	155.63	185.75	179.75	225.88
V8	74.63	147.00	181.63	163.88	221.63	63.13	134.88	159.75	148.63	205.00
V9	81.25	177.50	201.63	200.00	224.63	72.00	157.00	186.63	162.13	211.88
V10	61.13	163.75	176.88	147.88	227.63	54.75	149.00	162.00	139.00	195.38
V11	55.75	67.50	169.00	214.25	236.50	49.13	61.38	137.75	194.13	199.38
V12	74.88	165.00	205.00	171.63	245.75	69.63	153.00	194.63	155.50	226.00
CD(0.05)	NS	54.09	46.73	NS	NS	30.81	51.47	40.93	NS	NS

Contd.

Table 2. Continued

Variety	Leaf area (cm^2)				
	2 MAP	4 MAP	6 MAP	8 MAP	10 MAP
V1	887.00	675.00	562.00	2675.75	2609.50
V2	317.25	781.00	1297.75	2728.75	2516.75
V3	979.75	1337.50	1748.25	1576.00	2344.50
V4	920.13	1986.75	2265.00	1960.25	3099.75
V5	1012.88	2689.00	1986.75	1523.00	2967.25
V6	847.25	2397.50	2251.75	1801.25	2596.25
V7	1032.75	2490.25	2291.50	1960.25	3192.50
V8	416.63	1483.25	1629.00	1364.00	2728.75
V9	993.00	2636.00	2397.50	1827.75	3152.75
V10	98.63	1483.25	1244.75	860.50	2106.00
V11	343.75	317.25	2013.25	2834.75	2808.25
V12	953.25	2304.75	2410.75	1695.25	3404.50
CD(0.05)	NS	1172.7	1066.6	847.5	NS

Contd...

Table 2. Continued

Variety	Petiole length (cm)					No. of leaves				
	2 MAP	4 MAP	6 MAP	8 MAP	10 MAP	2 MAP	4 MAP	6 MAP	8 MAP	10 MAP
V1	30.88	32.25	33.63	63.13	57.13	9.25	10.50	14.75	25.13	21.13
V2	10.75	23.25	40.63	59.13	63.13	7.75	10.63	18.50	25.83	20.13
V3	26.00	37.25	44.63	48.75	57.38	8.75	19.25	13.25	14.88	19.13
V4	27.63	49.00	51.88	57.25	65.00	10.75	15.25	19.13	22.50	27.50
V5	24.88	51.25	45.25	40.63	63.13	11.00	15.75	17.25	20.00	47.25
V6	24.00	49.63	48.38	46.63	55.75	11.00	15.88	18.88	18.38	21.63
V7	25.38	54.88	51.00	49.63	64.75	11.50	18.00	18.75	21.25	28.75
V8	20.69	44.25	51.00	43.75	61.75	9.63	14.00	16.88	18.63	23.13
V9	23.63	44.00	48.38	52.50	62.88	9.50	17.13	18.88	21.38	31.25
V10	18.06	51.00	42.38	46.25	63.25	11.13	16.13	19.00	25.63	32.63
V11	16.13	21.25	48.75	57.25	65.25	7.25	11.00	19.88	18.50	21.75
V12	20.69	41.25	47.88	49.00	67.63	10.75	17.13	21.13	24.13	35.13
CD(0.05)	9.26	13.65	NS	9.94	NS	NS	5.25	NS	NS	10.03

Concluded

4.1.1.1 Plant height

Plant height varied significantly with stages of growth. Significant differences were observed between varieties for plant height at 2, 4 and 6 MAP. Maximum height at 2 MAP was in 9-1-D (77.06 cm) and minimum in the local type CP-16 (38.38 cm). The increase in plant height was greatest in the first phase (0 to 2 MAP) and lowest in the fourth phase (6 to 8 MAP). The increase in plant height was the maximum at the first phase of 9-1-D (77.06 cm) closely followed by CO-3 (75.63 cm).

When observed at 10 MAP the local type CP-15 was the tallest (244.24 cm) and MS the shortest (188.5 cm) among the varieties evaluated. The other varieties with comparatively short stature were CO-2 (200.38 cm) and CO-5 (203.38 cm).

4.1.1.2 Collar girth

The difference in collar girth between varieties was significant at all growth phases except 10 MAP.

Among the cultivars studied collar girth at 2 MAP was lowest in the local type CP-15 (2.74 cm) and highest in the variety CO-3 (7.94 cm). Increase in collar girth with advancement of growth was noticed. The increase was highest in second phase (2 to 4 MAP) and lowest in the fifth phase (8 to 10 MAP). At 10 MAP collar girth was highest in Honey Dew (31.56 cm) and lowest in CO-5 (26.96 cm).

Plate 1 Bearing plants of cv. CP-14

Plate 2 Bearing plants of cv. CP-15

Plate 3 Bearing plants of cv. CO-2

Plate 4 Bearing plants of cv. CO-3

Plate 5 Bearing plants of cv. 9-1-D

Plate 6 Bearing plants of cv. MS


R_1V_3


R_4V_4


R_1V_6


R1V8


R1V9


R1 V10

4.1.1.3 Canopy spread

An increase in canopy spread in both direction from first phase to third phase of growth was observed in all the varieties. At the fourth phase a reduction in canopy spread was evident except in CO-2 and local types. Thereafter irrespective of varieties an increase in canopy spread was observed.

Canopy spread in both direction was maximum for Honey Dew at the last phase (NS - 226.0 cm and EW - 245.8 cm) and minimum for CO-2 (NS - 195.13 cm and EW - 182.13 cm).

4.1.1.4 Leaf area

Significant variation in leaf area was noticed between varieties at 4, 6 and 8 MAP. Leaf area was maximum in the fifth phase of growth and minimum in the first phase. At 10 MAP Honey Dew ranked top (3405 cm^2) and Solo the least (2106 cm^2) with respect to leaf area.

4.1.1.5 Length of petiole

Petiole length of the fifth leaf showed significant difference at 2, 4 and 8 MAP. Petiole was longest in Honey Dew (67.63 cm) followed by CP-16 and CO-3 (65.0 cm) and shortest in MS (55.75 cm) at 10 MAP.

4.1.1.6 Number of fully developed leaves

Number of fully developed leaves differed significantly at 4 and 10 MAP. At 10 MAP 9-1-D recorded the maximum number of leaves (47.25) and CO-2 the minimum (19.13).

Plate 13 Fruits of cv. CP-14

Plate 14 Fruits of cv. CP-15

Plate 15 Fruits of cv. CO-2

Plate 16 Fruits of cv. CO-3

Plate 17 Fruits of cv. 9-1-D

Plate 18 Fruits of cv. IS


CP-14


CP-15


Co -2


Co -3


9-1-D


MS


Co - 4


Co - 5


Co - 6


Solo


CP- 16


Honey Dew

4.1.1.7 Number of leaves at the time of first flowering

It is clear from the data presented in Table 3 that there is no significant difference between varieties for number of leaves at first flowering. However, it ranged from 13.25 in CO-5 to 20.75 cm in CP-15 with an overall mean of 16.5.

4.1.1.8 Days to first flowering

The cultivars differed significantly for days to first flowering. It ranged from 146.83 to 242.63 days with an average of 178.43 days. CO-6 was the earliest to flower (146.88 days), followed by CO-3 (150.0 days) and Honey Dew (150.25 days). The local type CP-15 was found to blossom last (242.63 days).

4.1.1.9 Days to first harvest

Studies conducted revealed that there was signiif-cantly difference between varieties for number of days taken for first harvest. CO-3 was the earliest to bear fruits (291 days) followed by MS (301.5 days) and CP-16 the last (410.70 days).

4.1.1.10 Yield

Yield of papaya varieties were recorded for a period of one year from first harvest. Varieties varied significantly for yield per plant both in terms of weight and number of fruits (Table 3 and Fig.1).

Table 3 Yield and biometric characters of papaya varieties

Variety	Leaves at Ist flowering	Days for flowering	Days for Ist harvest	Yield (kg)	Fruit number
V1	19.75	236.63	360.25	27.28	31.50
V2	20.75	242.63	375.25	18.06	43.13
V3	16.50	178.88	322.00	29.30	29.00
V4	14.88	150.00	291.00	38.22	55.63
V5	16.13	157.63	315.00	46.85	46.25
V6	13.88	153.13	301.50	30.99	37.25
V7	17.25	166.00	316.50	44.26	39.45
V8	13.25	171.50	339.88	41.23	34.88
V9	16.63	146.88	315.00	52.50	42.63
V10	16.13	161.13	325.50	19.43	73.38
V11	15.63	226.50	410.75	15.24	40.25
V12	18.38	150.25	315.63	37.47	43.75
CD(0.05)	NS	28.24*	27.9*	20.4*	22.59*

* Significant at 5% level

CO-6 was found to be the highest yielding variety (52.5 kg) in terms of fruit weight. This was on par with 9-1-D (46.85 kg), CO-4 (44.26 kg), CO-5 (41.23 kg), CO-3 (38.22 kg) and Honey Dew (37.47 kg). The lowest yield was recorded in CP-16) (15.24 kg).

Solo ranked first with respect to number of fruits (73.38) followed by CO-3 (55.63). Lowest number of fruits was recorded in CO-2 (29.00).

4.1.1.11 Production pattern of papaya varieties

Study of production pattern of varieties revealed significant difference between varieties and months of harvest (Table 4a and 4b). Data on monthvar yield of fruits showed that varieties CO-2, CO-3, 9-1-D, Co-6 and Honey Dew had the maximum yield in the seventh month of harvest with 5.71, 7.30, 10.76, 8.64 and 6.65 kg respectively.

However, in cultivars CP-15, CO-5 and Solo the maximum yield was obtained in the eighth month of harvest with yields of 4.78, 10.26 and 4.51 kg per plant respectively. The production was lean in the fourth month of harvest in CO-3, 9-1-D, CO-6, Solo and Honey Dew and eleventh month in MS and CP-16 and twelfth month in CP-14, CP-15 and CO-2.

Maximum number of fruits was recorded during the seventh month of harvest for the cultivars CP-14, CO-3,

Table 4a Production pattern of papaya varieties

Variety	Month-var yield (kg)											
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th
V1	0.993	1.975	1.250	2.593	4.510	1.464	4.453	2.658	3.238	2.624	1.190	0.333
	(1.194)	(1.405)	(1.260)	(1.618)	(1.880)	(1.279)	(2.110)	(1.614)	(1.795)	(1.671)	(1.245)	(0.891)
V2	0.673	0.666	1.570	0.999	1.577	2.708	1.853	4.783	2.450	0.713	0.075	0.000
	(1.069)	(1.053)	(1.330)	(1.131)	(1.436)	(1.746)	(1.464)	(2.256)	(1.622)	(0.988)	(0.754)	(0.707)
V3	2.275	2.115	1.600	1.068	2.900	0.681	5.771	2.568	2.771	4.420	2.300	0.890
	(1.577)	(1.494)	(1.363)	(1.225)	(1.608)	(1.050)	(2.178)	(1.540)	(1.704)	(1.981)	(1.579)	(1.075)
V4	0.885	1.338	1.759	0.000	3.703	5.663	7.298	4.781	5.430	3.665	2.240	1.458
	(1.164)	(1.330)	(1.387)	(0.707)	(1.862)	(2.449)	(2.677)	(2.278)	(2.408)	(2.028)	(1.501)	(1.315)
V5	1.325	2.115	0.668	0.225	4.894	3.421	10.761	5.941	5.928	5.239	3.288	3.045
	(1.340)	(1.433)	(1.031)	(0.826)	(2.200)	(1.921)	(3.235)	(2.516)	(2.450)	(2.176)	(1.828)	(1.636)
V6	3.980	3.650	4.606	4.511	2.726	3.500	4.338	1.631	0.806	0.636	0.230	0.370
	(2.049)	(1.994)	(2.128)	(2.108)	(1.743)	(1.866)	(2.106)	(1.417)	(1.048)	(0.967)	(0.828)	(0.882)
V7	2.803	2.805	3.156	2.758	3.370	7.946	5.643	5.976	3.903	1.184	1.876	2.845
	(1.780)	(1.763)	(1.884)	(1.700)	(1.841)	(2.892)	(2.402)	(2.368)	(1.929)	(1.177)	(1.349)	(1.551)
V8	1.673	0.050	1.263	1.808	4.700	4.391	4.374	10.263	4.108	3.591	2.766	2.248
	(1.409)	(0.739)	(1.222)	(1.225)	(1.909)	(1.951)	(2.141)	(3.210)	(2.080)	(1.881)	(1.690)	(1.468)
V9	1.328	3.110	3.013	0.475	4.283	6.819	8.643	7.341	6.180	2.350	5.770	3.186
	(1.344)	(1.886)	(1.871)	(0.953)	(1.844)	(2.463)	(2.950)	(2.779)	(2.418)	(1.621)	(2.236)	(1.836)
V10	0.513	1.094	0.298	0.000	0.255	3.245	3.413	4.510	2.839	1.815	1.210	0.235
	(0.992)	(1.239)	(0.875)	(0.707)	(0.864)	(1.844)	(1.941)	(2.176)	(1.809)	(1.504)	(1.260)	(0.843)
V11	1.696	1.325	2.650	0.550	2.566	2.651	1.800	1.310	0.290	0.230	0.125	0.045
	(1.467)	(1.241)	(1.749)	(0.996)	(1.610)	(1.681)	(1.444)	(1.272)	(0.886)	(0.845)	(0.784)	(0.736)
V12	1.410	2.628	0.535	0.515	1.528	3.579	6.650	5.798	5.400	4.236	3.470	1.720
	(1.373)	(1.727)	(0.980)	(0.971)	(1.369)	(1.961)	(2.623)	(2.327)	(2.255)	(2.031)	(1.770)	(1.476)
CD(0.05)	1.76*	NS	2.34*	2.67*	NS	NS	NS	4.82*	NS	3.90*	NS	NS
	(0.499)		(0.721)	(0.759)				(1.04)	(0.956)*			

Figures in parenthesis indicates transformed values; NS - Non significant; * Significant at 5% level

Table 4b Production pattern of papaya varieties

Variety	Number of fruits											
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th
V1	1.50	2.00	1.50	3.25	3.00	1.88	5.13	3.50	3.88	3.25	2.13	0.50
	(1.40)	(1.43)	(1.36)	(1.74)	(1.70)	(1.38)	(2.30)	(1.85)	(1.89)	(1.77)	(1.49)	(.097)
V2	1.25	1.63	2.00	1.38	3.25	6.63	6.50	10.50	6.13	3.25	0.63	0.00
	(1.31)	(1.43)	(1.47)	(1.24)	(1.83)	(2.47)	(2.35)	(3.16)	(2.35)	(1.45)	(1.00)	(0.71)
V3	2.50	2.63	2.25	1.50	3.50	1.00	3.63	2.13	2.00	4.13	2.75	1.00
	(1.70)	(1.65)	(1.52)	(1.39)	(1.72)	(1.18)	(1.83)	(1.44)	(1.51)	(1.96)	(1.68)	(1.13)
V4	1.88	2.38	3.25	0.00	5.75	8.00	10.00	6.63	7.25	5.00	3.50	2.00
	(1.50)	(1.57)	(1.74)	(0.71)	(2.21)	(2.89)	(3.06)	(2.63)	(2.73)	(2.28)	(1.85)	(1.47)
V5	2.50	2.25	0.75	0.25	4.63	3.75	9.88	5.38	5.00	4.75	4.38	2.75
	(1.67)	(1.47)	(1.06)	(0.84)	(2.12)	(2.00)	(3.15)	(2.40)	(.233)	(2.15)	(2.06)	(1.58)
V6	4.38	4.75	4.88	4.63	2.63	5.25	4.88	2.38	1.25	1.00	0.50	0.73
	(2.14)	(2.18)	(2.22)	(2.14)	(1.71)	(2.26)	(2.22)	(1.67)	(1.191)	(1.06)	(0.93)	(1.00)
V7	2.75	3.75	3.00	2.63	3.00	6.50	5.63	5.25	2.50	0.33	1.88	2.25
	(1.77)	(2.01)	(1.85)	(1.66)	(1.76)	(2.64)	(2.41)	(2.30)	(1.61)	(0.88)	(1.40)	(1.39)
V8	2.25	0.25	1.38	1.75	4.75	3.88	2.75	5.38	3.88	3.38	2.75	2.50
	(1.56)	(0.84)	(1.25)	(1.22)	(1.92)	(1.87)	(1.78)	(2.39)	(2.03)	(1.84)	(1.69)	(1.52)
V9	1.00	3.00	2.25	0.50	2.75	5.50	7.50	6.25	6.25	1.75	3.25	2.63
	(1.23)	(1.84)	(1.66)	(0.97)	(1.57)	(2.26)	(2.74)	(2.58)	(2.43)	(1.48)	(1.80)	(1.72)
V10	3.00	5.25	1.13	0.00	1.25	10.38	14.00	15.63	9.86	6.88	5.00	1.00
	(1.81)	(2.31)	(1.18)	(0.71)	(1.27)	(3.22)	(3.69)	(3.99)	(3.21)	(2.68)	(2.25)	(1.13)
V11	4.88	4.50	6.25	1.25	5.50	5.63	4.38	3.88	1.75	1.50	0.50	0.25
	(2.26)	(1.96)	(2.49)	(1.26)	(2.22)	(2.30)	(2.04)	(1.94)	(1.48)	(1.35)	(0.97)	(0.84)
V12	2.50	4.13	0.88	0.50	2.00	5.13	8.38	5.75	4.50	4.50	3.00	2.50
	(1.70)	(2.13)	(1.10)	(0.97)	(1.51)	(2.32)	(2.94)	(2.40)	(2.19)	(2.16)	(1.76)	(1.70)
CD(0.05)	NS	NS	NS	NS	NS	NS	NS	5.52*	4.42*	NS	NS	NS
			(1.881)*	(0.83)*				(1.07)*	(1.00)*			

Figures in parenthesis indicates transformed values; NS - Non significant; * Significant at 5% level

9-1-D, CO-6 and Honey Dew with 5.13, 10.0, 9.88, 7.50 and 8.38 fruits per tree respectively. In CP-15, CO-5 and Solo maximum yield in terms of number of fruits was obtained during their eighth month of harvest (10.50, 5.38 and 15.63 fruits per tree). CO-3, 9-1-D, CO-6, Solo and Honey Dew recorded the minimum number of fruits during their fourth month of harvest. The peak period of production both in terms of fruit weight and number of fruits was either the seventh or eighth month of harvest in most of the varieties.

4.1.1.12 Pest and disease incidence

No major pests were observed throughout the period of plant growth. Incidence of diseases like mosaic was observed in MS and 9-1-D and collar rot and leaf spot in cultivars CP-14, CP-15 and CO-4.

4.1.2 Growth and development of papaya fruit

Growth and development of fruits of twelve varieties of papaya were studied in detail at periodic intervals from anthesis to maturity. Changes in respect of physical parameters like weight, length, circumference, volume, polar and equatorial diameter, flesh thickness, cavity volume and index and fruit composition were studied at ten phases of fruit growth and mean values are presented in Tables 5a to 5m and Plates 25 and 26. General analysis of variance revealed significant differences in physical characters between varieties and stages of growth.

25 Stages of growth and development of cv. 9-1-D

26 Stages of growth and development of cv. CP-16


135
120
105
90
75
60
45
30
15


150
135
120
105
90
75
60
45
30
15

4.1.2.1 Days to harvest maturity

The days to attain harvest maturity varied from 120 to 150 days after anthesis in the different varieties. In most of the varieties fruits matured 135 days after anthesis except CP-15, CP-16, CO-2 and MS. Cultivars CP-15, CO-2 and MS took only 120 days whereas cultivar CP-16 took 150 days to reach harvest maturity.

4.1.2.2 Weight of fruit

Fruit weight increased with advent of time, with maximum value at harvest maturity (Table 5a). The variety CO-6 recorded the highest increase in weight at maturity, 85 times greater than recorded at the initial stage. The increase in weight was the least in CO-3, only 8 times more that value in the first stage.

Three varieties of papaya Solo, 9-1-D, and CO-5 were selected to represent light, medium and heavy types respectively and growth pattern studied by plotting growth curve. Cultivar Solo representing light fruit types exhibited a simple sigmoid growth pattern whereas 9-1-D and CO-5 exhibited double sigmoid growth pattern in respect of fruit weight. Growth increment in Solo was almost constant upto 60 days. The peak period of growth in Solo was between 60 and 75 days, thereafter the rate of growth was low. Growth increment rates in cultivars in 9-1-D and CO-5 was clearly manifested at three distinct stages. In the case of 9-1-D, in the initial phase was at the first fortnight, the second at 30th to 60th day and 3rd at 75th to 90th day of fruit growth. In cultivar CO-5 the initial phase of growth increment was observed in the first month

Table 5(a). Physical changes in papaya fruits during development - Fruit weight (g)

Variety	Stages in days after flowering									
	15 DAF	30 DAF	45 DAF	60 DAF	75 DAF	90 DAF	105 DAF	120 DAF	135 DAF*	150 DAF*
V1	150.00	290.00	320.00	415.00	620.00	755.00	1010.00	1280.00	1410.00	-
V2	17.50	200.00	390.00	500.00	690.00	950.00	1090.00	1190.00	-	-
V3	17.50	150.00	420.0	670.00	760.00	960.00	1060.00	1110.00	-	-
V4	11.10	90.00	140.00	167.50	210.00	230.00	245.00	305.00	325.00	-
V5	130.00	250.00	475.00	750.00	805.00	1010.00	1075.00	1160.00	1245.00	-
V6	41.15	160.00	205.00	355.00	525.00	760.00	950.00	1110.00	-	-
V7	20.00	95.00	305.00	440.00	620.00	760.00	1110.00	1210.00	1390.00	-
V8	60.00	140.00	205.00	515.00	820.00	1155.00	1290.00	1670.00	1955.00	-
V9	16 50	85.00	300.00	525.00	700.00	950.00	1210.00	1360.00	1420.00	-
V10	18.50	37.50	65.00	90.00	190.00	242.50	290.00	310.00	330.00	-
V11	32.50	77.50	180.00	260.00	475.00	525.00	640.00	685.00	710.00	730.00
V12	30.00	110.00	155.00	180.00	545.00	750.00	850.00	940.00	1090.00	-
CD (0.05)	35.81	120.71	141.63	293.40	266.12	320.48	352.07	303.57		

*Not considered for statistical analysis

of fruit growth. The second and third phases were at 45th to 90th day and 105th to 120th day of growth of fruit.

Among the varieties tested the heaviest fruit were produced by CO-5 whereas varieties CO-3 and Solo had smaller fruits. CO-3 had a mean fruit weight of 325 g whereas CO-5 produced fruits with mean weight of 1955 g.

4.1.2.3 Length of fruit

The length of fruits showed a continuous increase from anthesis to maturity (Table 5b). The increase at different growth stages was not uniform in all varieties. The fruit length at harvest maturity ranged from 14.25 cm in Solo to 34.3 cm in local type CP-15. The increase in fruit length at maturity over the initial fruit length ranged from 1.31 times in 9-1-D to 15.73 times in CP-15.

4.1.2.4 Circumference of fruit

Fruit circumference showed an increasing trend upto maturity. There was significant increase in fruit circumference during all stages. It is evident from the data presented on fruit circumference that increase in fruit circumference was maximum in CO-6 which was 4.22 times higher than initial circumference. The maximum fruit circumference was noticed in CO-6 (47.5 cm) and minimum in Solo (27 cm) at maturity.

4.1.2.5 Volume of fruit

A progressive increase in volume of fruit during growth and development was observed (Table 5d). Maximum fruit volume was noticed at 120th, 135th or 150th day of

Table 5(b). Physical changes in papaya fruits during development - Fruit length (cm)

Variety	Stages in days after flowering									
	15 DAF	30 DAF	45 DAF	60 DAF	75 DAF	90 DAF	105 DAF	120 DAF	135 DAF*	150 DAF*
V1	11.30	13.95	15.90	18.30	24.75	26.10	29.05	31.90	32.90	-
V2	2.05	19.10	25.20	26.90	28.10	29.80	32.00	34.30	-	-
V3	5.30	12.55	20.10	22.85	24.30	26.35	26.75	27.25	-	-
V4	6.20	10.45	11.00	12.50	15.70	16.50	17.10	17.80	18.20	-
V5	12.05	15.60	19.85	22.05	22.50	24.55	25.95	27.10	27.85	-
V6	8.35	12.00	13.30	15.60	18.20	21.40	24.00	26.15	-	-
V7	6.55	10.85	16.00	17.55	19.75	22.35	23.75	24.80	25.90	-
V8	7.55	12.05	14.65	19.00	22.40	24.55	27.75	29.10	30.60	-
V9	7.45	10.55	14.65	17.65	19.00	22 50	24.00	24.75	25.50	-
V10	6.10	7.85	9.85	9.10	12.35	13.35	13 90	14 10	14.25	-
V11	6.90	8.50	12.70	14.90	19.05	19.80	20.70	21.00	21.30	22.60
V12	7.30	9.40	12.35	13.50	17.35	19.55	21 60	22.00	24.05	-
CD(0.05)	2.34	3.42	3.73	4.78	3.45	3.27	4.22	4.37		

*Not considered for statistical analysis

Table 5(c). Physical changes in papaya fruits during development - Fruit circumference (cm)

Variety	Stages in days after flowering									
	15 DAF	30 DAF	45 DAF	60 DAF	75 DAF	90 DAF	105 DAF	120 DAF	135DAF*	150 DAF*
V1	17.10	21.65	24.65	27.35	27.25	29.55	35.50	37.35	39.25	-
V2	7.55	16.40	21.80	24.00	29.00	32.00	34.85	35.55	-	-
V3	7.40	17.70	25.15	27.00	31.00	34.10	35.00	35.50	-	-
V4	9.25	14.35	16.30	18.50	22.95	23.60	24.90	26.50	27.30	-
V5	16.10	21.90	29.20	32.70	33.80	37.45	38.35	38.90	39.75	-
V6	12.80	19.50	24.45	25.75	32.95	36.20	41.40	42.50	-	-
V7	10.75	18.00	25.50	29.10	32.20	34.25	39.30	41.10	43.10	-
V8	11.45	19.00	21.65	27.40	34.10	38.75	39.65	43.60	45.90	-
V9	9.10	18.00	27.15	29.75	34.5	40.25	41.30	45.75	47.50	-
V10	8.60	11.25	14.50	16.45	22.95	25.30	26.45	26.90	27.00	-
V11	12.10	14.60	21.60	25.50	30.65	31.95	33.80	35.05	35.80	36.45
V12	10.80	16.50	18.65	20.25	27.50	34.40	35.70	37.95	41.20	-
CD(0.05)	3.54	4.13	4.71	3.82	5.27	6.35	5.42	6.56		

*Not considered for statistical analysis

Table 5d Physical changes in papaya fruits during development - Fruit volume (ml)

Variety	Stages in days after flowering									
	15 DAF	30 DAF	45 DAF	60 DAF	75 DAF	90 DAF	105 DAF	120 DAF	135 DAF*	150 DAF*
V1	205.00	345.00	377.50	510.00	770.00	290.00	1177.50	1510.00	1615.00	-
V2	40.00	195.00	475.00	700.00	890.00	1150.00	1540.00	1620.00	-	-
V3	25.00	145.00	475.00	810.00	960.00	1310.00	1390.00	1455.00	-	-
V4	38.00	135.00	200.00	225.00	285.00	305.00	330.00	420.00	450.00	-
V5	139.00	265.00	650.00	1070.00	1160.00	1295.00	1470.00	1555.00	1725.00	-
V6	46.50	180.00	245.00	410.00	697.50	1130.00	1360.00	1680.00	-	-
V7	45 00	75.00	420.00	590.00	855.00	1087.50	1480.00	1670.00	1765.00	-
V8	71.00	200.00	292.50	635.00	1010.00	1596.00	1775 00	2265 00	2760.00	-
V9	25.00	160.00	445.00	725.00	875.00	1280.00	1580.00	1835 00	2050.00	-
V10	50.00	67.50	110.00	150.00	247.50	310.00	350.00	380 00	402.50	-
V11	49.50	92.50	190.00	355.00	555.00	640.00	730.00	780 00	830 00	867 50
V12	46.00	125.00	210.00	260.00	650.00	830.00	965 00	1170.00	1430.00	-
CD(0 05)	47 92	129.95	193.28	409.88	416.80	454.80	502.30	447 90		

*Not considered for statistical analysis

fruit development in the different cultivars. The variety CO-5 had the maximum fruit volume (2760 ml) and Solo the minimum (402.5 ml) on the 135th day of development. There was 37 fold increase in fruit volume in CO-5 compared to the volume on the fifteenth day of fruit development.

4,1.2.6 Polar diameter

Increase in polar diameter with march of time was noted in all the varieties (Table 5e). Polar diameter was the maximum in CP-15 (31.0 cm) and minimum in Solo (10.3 cm) at maturity. The rate of increase in polar diameter at different stages of development did not display any uniform pattern. However, the greatest increase in polar diameter was observed in CO-2 where 3.9 times increase over the initial value was observed.

4.1.2.7 Equatorial diameter

A gradual increase in equatorial diameter was seen in all varieties during growth and development (Table 5f). The equatorial diameter in the initial stage i.e., 15 DAP ranged from 1.75 cm in CO-2 to 4.65 cm in CP-14 and 9-1-D. At the final stage of development it ranged from 9.15 cm in Solo to 14.05 cm in CO-5.

4.1.2.8 Flesh thickness

Irrespective of varieties there was an increase in flesh thickness with fruit growth and development. The thickness of pulp after 15 days of anthesis ranged from 0.3 cm to 1.1 cm and at maturity from 1.65 cm to 3.45 cm. Maximum thickness of flesh was noticed in CO-5 (3.55 cm) at maturity registering 492 per cent increase over the initial value (0.60 cm).

Table 5(e). Physical changes in papaya fruits during development - Polar diameter (cm)

Variety	Stages in days after flowering									
	15 DAF	30 DAF	45 DAF	60 DAF	75 DAF	90 DAF	105 DAF	120 DAF	135 DAF*	150 DAF*
V1	9.25	12.15	14.50	16.45	20.05	23.00	23.80	28.60	29.50	-
V2	8.00	16.00	21.25	22.80	25.85	26.90	29.95	31.00	-	-
V3	4.75	11.10	17.85	19.60	21.10	22.20	22.70	23.25	-	-
V4	5.00	8.70	9.60	10.30	12.95	14.40	14.80	15.05	15.90	-
V5	10.75	12.36	16.15	17.00	19.35	20.45	20.90	22.40	24.25	-
V6	6.95	9.35	10.25	12.55	13.80	16.45	18 40	19.55	-	-
V7	5.35	8.65	11.75	14.25	14.55	16.40	18.75	19.40	19.65	-
V8	6.35	9.55	11.25	15.15	18.50	20.45	21.25	22.75	23.95	-
V9	6.45	8.65	12.25	12.90	13.80	16.15	19.35	20.00	20.55	-
V10	4.95	5.80	7.50	8.10	9.30	9.80	9.95	10.15	10.30	-
V11	6.00	6.95	10.40	11.70	14.90	15.90	16.25	16.65	17.15	17.55
V12	6.00	7.25	10.10	10.60	12.80	14.80	16.70	17.25	17.70	-
CD(0.05)	1.69	2.93	2.90	3.30	2.40	2.30	2.70	2.40		

*Not considered for statistical analysis

Table 5(f). Physical changes in papaya fruits during development - Equatorial diameter (cm)

Variety	Stages in days after flowering									
	15 DAF	30 DAF	45 DAF	60 DAF	75 DAF	90 DAF	105 DAF	120 DAF	135 DAF*	150 DAF*
V1	4.65	6.25	7.50	8.35	8.75	9.45	10.20	10.90	11.80	-
V2	2.10	4.30	6.75	7.50	8.30	10.00	10.55	11.10	-	-
V3	1.75	5.50	7.55	8.80	9.55	10.85	11.05	11.35	-	-
V4	2.35	4.40	5.10	5.60	7.00	7.40	7.70	8.00	8.55	-
V5	4.65	6.75	8.05	10.15	10.45	10.70	12.15	12.50	12.85	-
V6	4.00	5.95	7.50	8.85	10.10	11.05	12.40	13.05	-	-
V7	2.95	5.35	8.15	9.20	10.35	11.25	12.65	13.15	13.20	-
V8	3.20	5.75	6.55	8.60	10.05	11.85	12.40	13.45	14.05	-
V9	3.55	5.75	8.35	10.25	10.90	11.90	13.10	13.50	14.00	-
V10	2.00	3.00	4.15	5.20	7.95	8.35	8.65	8.85	9.15	-
V11	3.75	4.35	6.20	7.70	9.35	9.70	10.25	10.85	11.30	11.60
V12	3.25	5.20	6.05	6.60	8.70	10.75	11.15	11.95	13.00	-
CD(0.05)	1.30	1.50	1.30	1.60	1.50	1.60	1.80	1.60		

*Not considered for statistical analysis

Table 5(g). Physical changes in papaya fruits during development - Flesh thickness (cm)

Variety	Stages in days after flowering									
	15 DAF	30 DAF	45 DAF	60 DAF	75 DAF	90 DAF	105 DAF	120 DAF	135 DAF*	150 DAF*
V1	1.00	1.35	1.65	1.90	2.05	2.15	2.25	2.30	2.40	-
V2	0.50	1.05	1.25	2.00	2.05	2.10	2.30	2.40	-	-
V3	0.40	1.20	1.60	2.15	2.30	2.30	2.45	2.35	-	-
V4	0.30	0.70	1.00	1.00	1.40	1.55	1.80	2.00	2.00	-
V5	1.10	1.30	1.75	2.00	2.15	2.30	2.60	2.65	2.80	-
V6	0.65	1.15	1.35	1.35	2.10	2.15	2.25	2.40	-	-
V7	0.55	0.90	1.35	1.65	1.90	2.05	2.30	2.40	2.80	-
V8	0.60	1.00	1.40	1.75	2.25	2.60	2.85	2.95	3.55	-
V9	0.65	1.15	1.80	2.00	2.15	2.25	2.75	3.35	3.45	-
V10	0.45	0.70	1.00	1.25	1.35	1.45	1.45	1.65	1.65	-
V11	0.80	1.20	14.5	1.70	1.95	2.05	2.10	2.15	2.25	2.40
V12	0.60	1.15	1.20	1.70	1.95	21.0	2.50	2.85	3.10	-
CD(0.05)	0.31	0.40	0.52	0.34	0.28	0.46	0.31			

* Not considered for statistical analysis

4.1.2.9 Cavity volume and index

Fruit growth in respect of cavity volume expressed an increasing trend upto maturity (Table 5h). Volume of fruit cavity at maturity was the maximum in CO-5 i.e., 80 times more than that at initial stage (15 DAF) and least in Solo where only a 13 fold increase was recorded. Cavity index was maximum in Solo (38.30%) and minimum in CP-14 (17.65%) at maturity (Table 5i).

4.1.2.10 Physical composition of fruit

The physical components of fruits like the peel, pulp, seed and pulp/peel ratio displayed significant variation between varieties and at different stages of maturity. The mean values of fruit components at different stages of maturity are presented in Table 5j to 5m. A comparison of physical composition of mature and ripe fruits revealed significant differences in per cent of pulp and placenta between the two stages. However the differences between mature and ripe fruit in peel per cent and pulp:peel ratio was not significant (Table 6).

4.1.2.10.1 Peel

The proportion of peel at harvest maturity was found to be maximum in CO-3 (11.82%) and minimum in CO-6 (4.61%). In CO-3 the peel per cent showed 46 per cent decrease whereas CO-6 exhibited 85 per cent decrease at 135 days when compared to 15 DAF. But in ripe fruits a slight increase in peel per cent was observed (Table 6).

Table 5(h). Physical changes in papaya fruits during development - Cavity volume (ml)

Variety	Stages in days after flowering									
	15 DAF	30 DAF	45 DAF	60 DAF	75 DAF	90 DAF	105 DAF	120 DAF	135 DAF*	150 DAF*
V1	52.00	110.00	150.00	185.00	220.00	236.00	275.00	285.00	285.00	-
V2	20.00	58.00	70.00	120.00	170.00	280.00	320.00	340.00	-	-
V3	10.00	27.00	120.00	210.00	260.00	330.00	390.00	400.00	-	-
V4	5.50	18.00	52.00	75.00	110.00	130.00	145.00	160.00	170.00	-
V5	32.00	98.00	175.00	260.00	330.00	410.00	440.00	465.00	475.00	-
V6	16.00	60.00	85.00	150.00	240.00	345.00	430.00	480.00	-	-
V7	15.00	40.00	135.00	170.00	280.00	320.00	360.00	390.00	420.00	-
V8	8.00	22.00	40.00	120.00	250.00	430.00	500.00	600.00	650.00	-
V9	12.00	50.00	130.00	200.00	240.00	435.00	455.00	490.00	550.00	-
V10	10.70	15.20	20.0	35.00	75.00	105.00	115.00	130.00	155.00	-
V11	10.00	13.40	80.00	170.00	210.00	240 00	260.00	280.00	295.00	310.00
V12	12.00	30.00	47.00	65.00	160.00	185.00	210.00	250.00	405.00	-
CD(0.05)	12.00	39.90	68.30	115.00	124.90	133.00	142.30	142.20		

*Not considered for statistical analysis

Table 5(i). Physical changes in papaya fruits during development - Cavity index (%)

Variety	Stages in days after flowering									
	15 DAF	30 DAF	45 DAF	60 DAF	75 DAF	90 DAF	105 DAF	120 DAF	135 DAF*	150 DAF*
V1	22.266	33.624	39.865	35.965	28.822	26.540	23.991	18.999	17.650	-
V2	66.667	37.692	14.048	16.670	18.933	24.242	20.779	21.006	-	-
V3	41.667	19.559	25.333	25.007	27.073	25.333	27.948	27.339	-	-
V4	14.444	13.333	25.859	33.333	38.586	42.565	43.939	38.291	37.780	-
V5	24.902	37.157	26.548	23.528	28.403	31.839	29.925	29.889	27.540	-
V6	34.785	33.000	35.573	37.308	35.604	31.712	31.092	28.864	-	-
V7	35.000	53.571	31.971	28.706	32.759	29.835	24.379	23.659	23.800	-
V8	11.098	11.667	13.757	20.140	25.159	27.069	28.361	26.596	23.550	-
V9	48.333	30.952	29.101	28.586	27.667	33.605	29.520	26.640	26.830	-
V10	22.000	22.600	18.803	23.333	30.327	33.908	32.843	34.167	38.310	-
V11	24.843	14.727	44.886	51.993	38.529	37.500	35.586	35.897	35.540	35.740
V12	22.917	26.494	22.565	25.279	24.727	22.444	21.699	21.701	28.320	-
CD(0.05)	36.76	23.94	17.16	19.04	10.94	7.43	6.78	8.84		

* Not considered for statistical analysis

Table 5(j). Physical changes in papaya fruits during development - Peel (%)

Variety	Stages in days after flowering									
	15 DAF	30 DAF	45 DAF	60 DAF	75 DAF	90 DAF	105 DAF	120 DAF	135 DAF*	150 DAF*
V1	8.015	7.055	9.760	9.370	9.440	11.120	9.650	8.770	6.560	-
V2	19.335	13.745	12.130	12.200	8.960	7.110	9.115	9.600	-	-
V3	18.335	12.180	9.920	8.165	8.120	8.550	7.210	7.470	-	-
V4	21.955	15.490	10.980	8.240	6.245	7.010	7.900	9.255	11.820	-
V5	17.515	14.590	10.740	8.685	9.960	9.950	10.415	10.110	7.230	-
V6	20.880	9.780	9.775	8.510	6.875	6.540	8.350	9.135	-	-
V7	18.000	14.920	12.170	11.540	8.565	10.080	7.445	7.715	6.950	-
V8	15.230	11.455	11.110	7.150	9.265	7.245	7.445	7.150	5.550	-
V9	27.890	16.200	11.780	7.495	6.285	8.710	7.500	7.715	4.610	-
V10	20.000	15.215	15.285	12.250	9.720	10.240	9.160	10.420	8.640	-
V11	15.050	13.135	9.375	9.320	8.255	9.635	10.150	10.285	9.430	9.600
V12	17.500	10.630	11.715	11.870	8.030	7.860	8.130	9.110	10.000	-
CD (0.05)	8.07	3.85	4.78	3.85	3.67	2.90	3.54	3.14		

* Not considered for statistical analysis

4.1.2.10.2 Pulp

Pulp proportion showed an increasing trend till harvest maturity only in CO-5 whereas in CO-4 and Solo at harvest maturity a slight decrease in pulp content was noted. The percentage of pulp continued to increase upto 75th day in seven varieties, upto 90th in two varieties and upto 120th day in one variety. Pulp per cent at harvest maturity was maximum in variety CO-5 (92.46%) and minimum in CP-16 (81.25%). A high recovery of pulp (more than 90%) was also obtained from CO-6 (90.72%) and CP-15 (90.21%). A slight decrease in pulp per cent with ripening of fruits was observed in all varieties (Table 6).

4.1.2.10.3 Seed

The proportion of seed to total weight showed an erratic pattern in different varieties throughout the growth period of fruit (Table 51). However, the per cent of seed at the final stage was more compared to the initial stage in most of the varieties except CP-14, CP-15, CO-4 and Honey Dew.

4.1.2.10.4 Pulp/peel ratio

Irrespective of varieties there was an increase in pulp : peel ratio upto 75 days after anthesis. At harvest maturity maximum pulp/peel ratio was for CO-6 (19.68) and minimum for CO-4 (7.09). Pulp/peel ratio was low in ripe compared to mature fruits.

4.1.2.10.5 Placenta

Comparison of proportion of placenta in ripe and mature fruits indicated a higher per cent of placenta in

Table 5(k). Physical changes in papaya fruits during development - Pulp (%)

Variety	Stages in days after flowering									
	15 DAF	30 DAF	45 DAF	60 DAF	75 DAF	90 DAF	105 DAF	120 DAF	135 DAF*	150 DAF*
V1	82.820	83.905	83.605	84.045	87.770	85.985	86.865	88.400	89.270	-
V2	76.000	82.835	86.265	84.605	87.840	92.180	87.195	90.210	-	-
V3	79.250	84.380	82.740	90.580	90.135	86.315	88.760	87.085	-	-
V4	74.150	81.360	85.120	88.875	88.930	87.570	87.340	84.415	83.830	-
V5	81.320	81.960	88.225	89.880	89.575	86.830	86.970	89.445	89.320	-
V6	77.850	83.105	86.105	88.585	89.795	87.420	88.760	88.520	-	-
V7	76.000	76.710	79.205	79.320	85.420	86.405	89.030	90.475	88.860	-
V8	82.855	83.335	82.670	89.225	89.810	91.125	92.055	92.250	92.460	-
V9	70.335	74.715	81.670	87.395	88.695	86.640	88.975	90.955	90.720	-
V10	75.050	79.590	77.070	81.650	80.935	81.470	84.880	86.490	86.020	-
V11	75.900	77.900	84.450	82.730	83.975	81.215	80.950	87.675	80.370	81.250
V12	73.000	84.515	83.875	83.630	86.215	86.540	85.430	83.700	83.020	-
CD(0.05)	8.00	4.00	6.30	5.60	6.20	4.80	3.90	6.80		

*Not considered for statistical analysis

Table 5(l). Physical changes in papaya fruits during development - Seed (%)

Variety	Stages in days after flowering									
	15 DAF	30 DAF	45 DAF	60 DAF	75 DAF	90 DAF	105 DAF	120 DAF	135 DAF*	150 DAF*
V1	9.165	9.040	6.635	6.585	2.790	2.895	3.485	2.830	4.170	-
V2	4.665	3.420	1.605	3.195	3.200	0.710	3.690	0.190	-	-
V3	2.415	3.440	7.340	1.255	1.745	5.135	4.030	5.445	-	-
V4	3.895	3.150	3.900	2.885	4.825	5.420	4.760	6.330	4.350	-
V5	1.165	3.450	1.035	1.435	0.465	3.220	2.615	0.445	3.450	-
V6	1.270	7.115	4.120	2.905	3.330	6.04	2.890	2.345	-	-
V7	6.000	8.370	8.625	9.140	6.015	3.515	3.525	1.810	4.190	-
V8	1.915	5.210	6.220	3.625	0.925	1.630	0.500	0.600	1.990	-
V9	1.775	9.085	6.550	5.110	5.020	4.650	3.525	1.330	4.670	-
V10	4.950	5.195	7.645	6.100	9.885	8.290	5.960	3.090	5.340	-
V11	9.050	8.965	6.175	7.950	7.770	9.150	8.900	2.040	10.200	9.150
V12	9.500	4.855	4.410	4.500	5.755	5.600	6.440	7.190	6.980	-
CD(0.05)	2.20	4.90	3.10	2.70	3.50	4.50	3.70	4.30		

*Not considered for statistical analysis

Table 5(m). Physical changes in papaya fruits during development - Pulp/Peel ratio

Variety	Stages in days after flowering									
	15 DAF	30 DAF	45 DAF	60 DAF	75 DAF	90 DAF	105 DAF	120 DAF	135 DAF*	150 DAF*
V1	10.33	11.97	9.30	9.82	10.08	7.87	9.27	10.08	13.61	-
V2	3.94	6.03	7.16	7.00	9.94	12.98	9.59	9.44	-	-
V3	4.32	7.15	8.42	11.10	11.22	10.12	12.65	12.31	-	-
V4	3.39	5.25	7.76	10.89	14.30	12.52	11.12	9.14	7.09	-
V5	4.66	5.79	8.27	10.39	9.27	8.88	8.48	8.88	12.35	-
V6	4.43	8.53	8.81	10.65	13.19	14.00	11.05	9.93	-	-
V7	4.29	5.20	6.51	6.96	9.99	8.65	12.80	12.11	12.79	-
V8	5.61	7.32	7.63	12.68	9.72	12.61	12.51	12.93	16.66	-
V9	2.52	4.68	6.94	11.96	14.12	10.00	12.45	11.83	19.68	-
V10	3.75	5.23	5.05	6.69	8.63	7.96	9.27	8.38	9.96	-
V11	5.10	5.93	11.16	9.19	10.44	8.78	8.02	8.65	8.52	8.46
V12	4.33	7.97	7.23	7.17	10.95	11.04	10.53	9.67	8.30	-

* Not considered for statistical analysis

Table 6. Physical composition of mature and ripe papaya fruits

Variety	Pulp (%)		Peel (%)		Seed (%)		Placenta (%)		Pulp/peel ratio	
	Mature	Ripe	Mature	Ripe	Mature	Ripe	Mature	Ripe	Mature	Ripe
V1	89.27	88.96	6.56	6.36	3.17	2.65	1.00	2.02	14.06	14.18
V2	91.00	90.88	5.77	5.91	2.17	1.17	1.07	2.03	15.91	15.38
V3	88.72	87.14	4.97	5.52	5.31	5.41	1.00	1.92	18.22	16.20
V4	83.22	80.80	10.21	12.62	4.73	6.58	1.83	3.91	8.21	6.01
V5	88.55	83.08	7.23	7.83	3.06	5.40	1.17	3.62	12.29	11.59
V6	87.52	81.27	8.78	10.13	2.67	4.96	1.03	3.63	10.15	9.08
V7	88.19	83.72	6.95	9.32	3.79	5.02	1.07	1.94	13.18	9.01
V8	92.13	90.95	5.55	5.62	1.25	1.65	1.07	1.78	16.83	16.20
V9	90.72	90.52	4.41	4.73	3.94	3.06	0.93	1.69	20.71	19.53
V10	86.02	81.52	8.64	8.97	4.07	5.18	1.27	4.34	9.98	9.20
V11	81.25	79.62	9.60	8.77	7.75	9.00	1.40	4.54	8.49	9.08
V12	83.02	82.42	9.73	9.65	6.21	4.96	1.04	2.97	8.55	8.54
CD(0.05)	3.53*	6.71*	1.58*	4.29*	3.36*	3.94*	0.38*	2.04*	3.53*	8.61*

* Significant at 5% level

Table 7. Physical indices of harvest of papaya varieties

Varieties	Days to maturity	Weight (g)	Length (cm)	Circum-ference (cm)	Volume (ml)	Polar diameter (cm)	Equiat-orial diameter (cm)	Flesh thickness (cm)	Cavity volume (ml)	Cavity index (%)	Peel (%)	Pulp (%)	Pulp/peel ratio
V1	135	1410	32.90	39.25	1615.00	29.50	11.80	2.40	285	17.65	6.56	89.27	13.61
V2	120	1190	34.30	35.55	1620.00	31.00	11.10	2.40	340	21.01	9.60	90.21	9.44
V3	120	1110	27.25	35.50	1455.00	23.25	11.35	2.35	400	27.34	7.47	87.09	12.31
V4	135	325	18.20	27.30	450.00	15.90	8.55	2.00	170	37.78	11.82	83.83	7.09
V5	135	1245	27.85	39.75	1725.00	24.25	12.85	2.80	475	27.54	7.23	89.32	12.35
V6	120	1110	26.15	42.50	1680.00	19.55	13.05	2.40	480	28.86	9.14	88.52	9.93
V7	135	1390	25.90	43.10	1765.00	19.65	13.20	2.80	420	23.80	6.95	88.86	12.79
V8	131	1955	30.60	45.90	2760.00	23.95	14.05	3.55	650	23.55	5.55	92.45	16.66
V9	134	1420	25.50	47.50	2050.00	20.55	14.00	3.45	550	26.83	4.61	90.72	19.68
V10	134	330	14.25	27.00	402.50	10.30	9.15	1.65	155	38.31	8.64	86.02	9.96
V11	150	730	22.60	36.45	867.50	17.55	11.60	2.40	310	35.74	9.60	81.25	8.46
V12	133	1090	24.05	41.20	1430.00	17.70	13.00	3.10	405	28.32	10.00	83.02	8.30

ripe, than mature fruits. The per cent of placenta ranged from 0.93 to 1.83 in mature as against 1.69 to 4.54 in ripe fruits (Table 6).

4.1.2.11 Maturity indices of papaya varieties

Physical parameters at colour break stage in each of the 12 varieties of papaya were estimated and mean values presented in Table 7. Harvest maturity in papaya varieties can be determined based on these physical characters.

4.2 Storage behaviour of papaya under ambient and refrigerated conditions

Variation in varietal response to storage under ambient and refrigerated conditions (8±1°C) were studied and results are presented here.

4.2.1 Physiological loss in weight

The average values for PLW under ambient conditions were significantly higher than that of refrigerated storage (Table 8). Under ambient condition the loss in weight was highest in CP-16 (2.07% per day) and lowest in Solo (0.75% per day). In refrigerated storage the variation in PLW was insignificant between the varieties. However, maximum loss was recorded in CP-16 (0.653% per day) and minimum in CO-3 (0.321% per day).

Table 8. Effect of storage on postharvest characteristics of papaya

Variety	PLW % (mean per day)		Days for full ripening		Shelf life (days)		Safe storage period in LT**
	AM	LT	AM	LT	AM	LT	
V1	0.960	0.43	4.33	4.00	6.67	17.00	11.00
V2	1.670	0.59	3.67	3.00	6.33	13.00	8.33
V3	1.060	0.45	6.33	3.67	8.33	17.00	11.33
V4	0.910	0.32	7.33	2.67	9.67	15.67	11.33
V5	0.860	0.47	5.67	2.67	8.33	14.67	11.33
V6	0.800	0.55	9.33	2.67	12.33	14.00	10.00
V7	0.140	0.43	6.33	3.00	9.67	15.00	10.00
V8	0.920	0.51	6.67	3.00	9.00	14.00	9.33
V9	0.870	0.48	5.00	3.67	7.67	15.67	10.67
V10	0.750	0.39	7.67	2.33	11.00	14.67	10.33
V11	2.070	0.65	3.33	1.67	5.00	12.33	9.00
V12	0.850	0.41	5.33	2.33	9.33	15.00	9.67
CD(0.05)	0.583*	NS	2.92*	NS	3.04*	NS	1.87*

* Significant at 5% level; AM - Stored under ambient conditon; LT - Stored under low temperature

** Free from chilling injury

4.2.2 Days to ripening

Studies revealed that there was significant difference between the varieties for number of days taken for full ripening when stored under room conditions. Maximum number of days was taken by MS (9.3 days) and minimum by CP-16 (3.3 days).

4.2.3 Keeping quality/shelf life

Shelf life is the period upto which the commodity remain marketable. Data on shelf life of papaya cultivars is given in Table 8. Shelf life showed significant difference between the varieties under ambient conditions of storage. Maximum shelf life was found in MS (12.3 days) followed by Solo and minimum in CP-15 (5.0 days).

Shelf life of papaya cultivars was not significantly affected by low temperature storage. CP-14 and CO-2 had longer shelf life (17.0 days) compared to other varieties under low temperature storage conditions of 8±1°C.

4.2.4 Tolerance to low temperature

The varieties displayed significant variation for tolerance to low temperature (8±1°C) conditions. Varieties CO-2, CO-3 and 9-1-D were relatively more tolerant (11.33 days) and CP-15 was found to be chilling sensitive (8.33 days) beyond which they exhibited chilling injury symptoms of pitting of the fruit skin. In general the different varieties had a storage life of 10.2 days under low temperature.

Refrigerated storage prior to keeping for ripening did not have a significant influence on days taken for full ripening (Table 8).

4.2.5 Organoleptic evaluation of fruits ripened under ambient and low temperature conditions

Organoleptic evaluation of fruits ripened under different conditions viz., plant ripe, ripened under ambient and low temperature conditions revealed that conditions of ripening did not have a significant effect on organoleptic qualities like colour, flavour, sweetness, taste, firmness and overall acceptability (Table 9).

4.2.6 Incidence of postharvest diseases

Microscopic examination of the spoiled fruits revealed the presence of the following pathogens:

Colletotrichum gloeosporioides

Cercospora sp.

Fusarium sp.

Rhizopus sp.

4.3 Chemical changes during ripening of papaya under different conditions

General analysis of variance for chemical constituents under different conditions of ripening viz., plant ripe, ripened under ambient conditions and after refrigerated storage showed significant difference for constituents like TSS, pH, total, reducing and non-reducing sugar contents (Table 10).

Table 9 Organoleptic qualities of fruits ripened under different conditions

Variety	Sensory score values																	
	Colour			Flavour			Sweetness			Taste			Firmness			Overall acceptability		
	PR	AM	LT	PR	AM	LT	PR	AM	LT	PR	AM	LT	PR	AM	LT	PR	AM	LT
V1	6.8	5.4	5.0	5.3	5.1	4.1	6.3	5.3	4.5	6.4	5.2	4.5	4.1	5.0	5.3	5.2	5.2	4.8
V2	6.3	6.2	4.9	6.0	5.7	4.4	6.0	6.7	4.8	6.1	5.9	4.8	6.4	8.3	6.7	6.3	5.9	4.9
V3	6.2	6.4	5.5	3.7	3.7	4.9	6.0	3.7	6.1	5.1	3.8	5.5	4.7	5.1	5.2	4.7	4.1	5.6
V4	8.9	8.4	7.0	6.8	7.4	6.0	8.2	7.7	6.4	7.0	7.7	6.4	6.3	6.2	6.3	8.2	7.6	6.6
V5	7.2	7.4	6.5	7.3	7.1	6.1	7.6	7.7	7.4	6.6	6.8	7.3	5.3	6.4	5.6	6.9	7.4	7.2
V6	6.3	6.2	6.8	5.6	5.0	5.1	5.9	6.4	5.9	6.7	5.2	6.6	4.9	5.9	5.6	6.0	5.7	6.1
V7	5.0	5.3	6.3	4.7	4.6	5.5	4.6	5.7	6.1	4.1	5.9	6.3	4.5	5.1	6.4	4.6	5.7	6.8
V8	7.3	5.8	5.6	5.4	4.2	5.3	6.3	4.6	4.5	6.5	4.8	4.8	4.9	5.4	4.6	6.2	4.7	5.2
V9	6.0	7.2	7.0	5.1	4.4	5.3	6.9	5.3	5.0	5.8	5.2	5.0	6.2	5.6	5.9	6.0	5.5	5.7
V10	7.9	7.6	6.6	7.0	8.1	5.3	8.2	8.8	5.7	6.8	8.9	6.6	7.3	7.5	6.8	8.9	8.3	6.8
V11	3.5	5.6	4.9	3.1	6.5	4.4	2.6	5.9	4.1	2.3	5.1	4.3	4.9	4.7	4.2	2.4	4.9	4.8
V12	5.0	6.5	4.6	4.8	5.3	4.4	6.7	6.1	6.0	6.9	6.1	5.8	5.8	5.7	3.4	6.4	6.5	5.4
Freedman's X^2 (5%)		4.072^{NS}			1.21^{NS}			5.02^{NS}			1.21^{NS}			0.711^{NS}			0.296^{NS}	

NS - Non significant PR - Ripened on the plant AM - Ripened under ambient condition
LT - Ripened after low temperature storage

4.3.1 TSS

Significant difference in TSS was seen among the varieties and conditions during ripening. But the interaction effect between varieties and conditions was not found to be significant (Table 10).

Among the varieties Solo recorded the maximum TSS of 14.6° brix which was on par with Honey Dew 13.86° brix whereas CO-5 recorded the minimum (11.2° brix).

Of the three conditions, fruits ripened on the plant recorded highest TSS (13.41° brix) whereas lowest was registered in fruits ripened after refrigerated storage.

Eventhough interaction effect was not significant, highest TSS was for Solo ripened on the plant (15.5° brix) closely followed by the same variety ripened under ambient conditions (15.3° brix).

4.3.2 Acidity

Difference in acidity was not significant among the varieties, different conditions and their interaction effect.

However, among the varieties CP-14 registered maximum (0.199%) and Solo the minimum (0.087%) acidity.

Table 10 Chemical constituents of papaya fruit under different conditions of ripening

Variety	TSS (° Brix)			Acidity (%)			pH		
	PR	AM	LT	PR	AM	LT	PR	AM	LT
V1	13.67	11.83	11.87	0.119	0.095	0.383	4.407	5.113	4.657
V2	14.00	13.50	11.17	0.081	0.165	0.145	5.473	5.127	5.337
V3	12.40	11.67	12.17	0.106	0.094	0.092	4.423	4.990	5.430
V4	14.33	13.57	12.97	0.102	0.085	0.099	4.803	5.563	4.687
V5	13.00	11.90	11.87	0.102	0.105	0.115	5.097	5.810	5.560
V6	13.00	13.00	12.87	0.105	0.107	0.111	4.470	5.733	5.047
V7	13.87	12.53	11.97	0.110	0.102	0.125	5.137	5.837	5.593
V8	11.67	10.93	11.00	0.104	0.098	0.113	4.740	5.813	5.493
V9	13.50	12.87	12.93	0.078	0.101	0.128	5.823	5.663	4.760
V10	15.50	15.33	13.97	0.098	0.077	0.085	5.520	5.680	5.450
V11	12.67	12.33	12.33	0.094	0.090	0.117	5.250	5.440	5.307
V12	14.27	14.00	13.30	0.111	0.105	0.126	5.583	5.540	5.480
CD(0.05)	1.49	1.81	NS	NS	NS	NS	0.525	0.379	0.555

PR - Plant ripe
AM - Ambient
LT - Low temperature
NS - Non significant

Table 10 Continued

Variety	Total sugar (%)			Reducing sugar (%)			Non reducing sugar (%)		
	PR	AM	LT	PR	AM	LT	PR	AM	LT
V1	7.14	5.57	5.75	6.46	4.89	5.20	0.68	0.68	0.54
V2	8.00	7.16	6.36	7.46	6.23	5.76	0.53	0.93	0.60
V3	8.63	6.63	7.04	7.44	5.57	6.46	1.19	1.06	0.57
V4	7.88	6.74	6.45	6.83	5.46	5.64	1.31	1.28	0.81
V5	8.06	6.71	7.15	6.59	5.36	5.90	1.47	1.35	1.25
V6	7.32	6.81	6.85	4.83	4.50	5.64	2.49	2.31	1.21
V7	6.46	6.27	6.16	5.34	5.04	5.17	1.12	1.24	0.99
V8	5.46	5.67	5.13	4.33	4.76	4.60	1.13	0.91	0.53
V9	7.11	6.33	6.69	5.19	5.35	5.71	1.92	0.98	0.98
V10	8.94	7.50	6.75	5.58	6.13	5.30	3.36	1.37	1.44
V11	7.58	8.26	5.97	6.69	6.40	5.43	0.89	1.86	1.54
V12	7.56	6.13	7.16	6.68	5.48	5.92	0.88	0.64	1.24
CD (0.05)	1.78	NS	NS	1.87	NS	NS	0.817	NS	NS

PR - Plant ripe
AM - Ambient
LT - Low temperature
NS - Non significant

Concluded

Of the different conditions, fruits ripened after low temperature storage recorded the maximum value for acidity (0.137%) and plant ripe fruits the minimum (0.101%).

4.3.3 pH

Variation in pH was significant among the varieties, conditions and between their interactions (Table 10).

Among the varieties Solo recorded the highest pH (5.55) and CP-14 the least (4.73).

CO-4 ripened under ambient condition registered the maximum value for pH (5.84) and minimum for CP-14 ripened on the plant (4.41).

4.3.4 Total, reducing and non-reducing sugars

Significant variation was noticed between the varieties and conditions of ripening but not for their interaction with respect to total, reducing and non-reducing sugar content (Table 10).

Solo was found to be superior compared to other varieties for total and non reducing sugars (7.73% and 2.06% respectively) content whereas non-reducing sugar was less in CP-14 (0.63%).

Variation in sugar content was found to be prominent under different conditions. Plant ripe fruits registered

the maximum value for total, reducing and non-reducing sugar content (7.51%, 6.12% and 1.41% respectively). The minimum values for total and non-reducing sugars were recorded in fruits after refrigerated storage (6.46% and 1.22% respectively). However, reducing sugar content was least in fruits ripened under ambient conditions (5.43%).

Interaction effect between the varieties and conditions were not found to be significant. However, Solo ripened on plant registered maximum values for total and non-reducing sugars (8.94% and 3.36%) whereas plant ripe fruits of CP-15 recorded highest reducing sugar content (7.46%).

4.4 Storage stability of papaya pulp and its suitability for product development

Storage studies were conducted with pulp of the twelve varieties for a period of four months under ambient condition. Results of analysis of samples at monthly intervals for various physicochemical characters viz., TSS, acidity, pH, total, reducing and non-reducing sugars, total and free SO_2 content, off flavour development and colour degradation are presented here.

4.4.1 Observations

4.4.1.1 TSS

A progressive decline in TSS with storage was observed during the period of study (Table 11). The percentage

decrease in TSS varied from 3.60 to 20.14 in different varieties at the end of 4 months storage period. Decrease was least in CO-3 followed by Solo (3.6 and 4.26%) and maximum in CP-14 (20.14%).

4.4.1.2 Acidity

Significant difference in acidity was observed between and within varieties during the four months storage period. A general reduction in acidity with storage was noticed in all the varieties. There was considerable variation in degree of decline in acidity between varieties. The percentage decrease in acidity at four months compared to that at one MAS varied from 3.95 in Solo to 23.78 in Honey Dew.

4.4.1.3 pH

It was found that pH differed significantly between the varieties during storage. A gradual increase in pH with storage was recorded in all the varieties. The minimum value for pH was recorded by CO-3 (3.06) in the first month and highest for CP-16 (4.17) in the fourth month of storage. The percentage increase in pH at four MAS varied from 0.45 in CP-14 to 26.1 in Honey Dew compared to that at one MAS.

4.4.1.4 Total, reducing and non-reducing sugars

There was significant difference in total, reducing and non-reducing sugar content during the storage period.

Table 11 Changes in chemical constituents of papaya pulp during storage

Variety	TSS (°brix)					Acidity (%)					pH				
	0 MAS	1 MAS	2 MAS	3 MAS	4 MAS	0 MAS	1 MAS	2 MAS	3 MAS	4 MAS	0 MAS	1 MAS	2 MAS	3 MAS	4 MAS
V1	12.46	11.67	11.67	11.47	10.40	1.00	0.990	0.990	0.958	0.930	3.10	3.53	3.59	3.47	3.54
V2	12.89	12.83	12.73	12.53	12.13	1.00	0.996	0.976	0.956	0.926	3.50	3.86	3.71	3.34	3.95
V3	12.40	12.10	12.00	12.00	12.33	1.00	0.988	0.984	0.964	0.939	3.10	3.20	3.45	3.33	3.67
V4	13.62	12.83	12.80	12.73	12.97	1.00	0.980	0.956	0.939	0.912	3.00	3.06	3.07	3.46	3.69
V5	12.26	12.00	11.73	11.47	10.67	1.00	0.980	0.959	0.956	0.896	3.00	3.14	3.18	3.55	3.85
V6	12.96	13.10	13.00	13.07	12.00	1.00	0.987	0.982	0.870	0.863	3.30	3.53	3.54	4.02	4.12
V7	12.46	12.00	12.00	11.80	10.53	1.00	0.985	0.976	0.965	0.930	3.00	3.15	3.19	3.57	3.61
V8	12.00	12.70	12.77	12.33	11.00	1.00	0.974	0.972	0.968	0.930	3.20	3.18	3.21	3.54	3.70
V9	13.10	12.07	11.67	11.73	11.20	1.00	0.977	0.952	0.862	0.857	3.20	3.23	3.23	3.64	3.99
V10	14.10	14.07	14.00	13.67	13.50	1.00	0.988	0.985	0.982	0.949	3.30	3.35	3.43	3.65	3.85
V11	12.44	13.93	13.67	12.47	11.10	1.00	0.966	0.935	0.879	0.839	3.40	3.67	3.84	3.98	4.17
V12	13.86	14.07	14.00	13.33	12.80	1.00	0.963	0.867	0.757	0.734	3.10	3.26	3.52	4.02	4.11
CD (0.05)		0.671	0.613	0.905	0.730		0.029	0.029	0.029	0.029		0.204	0.292	0.263	0.234

MAS - Months after storage

Contd.....

Table 11 contd.....

Variety	Total sugar (%)					Reducing sugar (%)					Non reducing sugar (%)				
	0 MAS	1 MAS	2 MAS	3 MAS	4 MAS	0 MAS	1 MAS	2 MAS	3 MAS	4 MAS	0 MAS	1 MAS	2 MAS	3 MAS	4 MAS
V1	6.15	5.38	5.52	6.22	6.10	5.21	3.97	4.53	5.00	5.20	0.94	1.41	0.99	1.22	1.32
V2	7.17	5.97	6.27	7.54	7.00	6.07	4.87	5.27	6.23	6.26	1.10	1.10	1.00	1.31	2.00
V3	7.13	5.88	6.22	6.56	5.73	6.07	5.42	4.80	4.75	5.75	1.06	0.37	1.42	1.31	0.97
V4	6.77	6.48	6.52	7.47	6.74	5.98	5.87	5.74	6.21	6.41	0.79	0.60	0.78	1.26	0.35
V5	6.72	6.19	6.75	6.80	6.63	5.36	4.77	5.43	5.59	5.70	1.36	1.43	1.31	1.21	0.93
V6	6.99	6.53	6.47	7.27	6.87	4.99	5.94	6.13	6.38	6.00	2.00	0.60	0.42	0.89	0.86
V7	6.30	6.14	6.29	6.39	6.14	5.18	5.43	5.50	5.53	6.11	1.12	0.71	0.80	0.85	0.73
V8	5.42	6.26	6.24	6.42	5.12	4.57	5.94	5.49	5.20	5.80	0.86	0.31	0.75	1.22	0.72
V9	6.71	5.52	5.61	6.58	6.20	5.42	4.89	5.11	5.27	5.79	1.29	0.63	0.50	1.31	0.41
V10	7.73	7.11	6.88	8.48	7.64	5.67	5.70	6.19	7.35	6.70	2.06	1.41	0.70	1.13	0.94
V11	7.27	7.48	8.03	8.10	7.00	6.17	6.34	6.96	7.16	6.81	1.10	1.14	1.07	0.94	0.97
V12	6.95	7.35	7.69	7.29	6.47	5.92	6.31	6.35	6.09	6.34	1.03	1.04	1.34	1.19	1.13
CD (0.05)		0.613	0.584	1.080	1.260		0.876	0.846	1.490	NS		NS	NS	NS	NS

MAS - Months after storage NS - Non significant

Contd.....

Table 11 contd.....

Variety	Total SO_2 (ppm)				Free SO_2 (ppm)			
	1 MAS	2 MAS	3 MAS	4 MAS	1 MAS	2 MAS	3 MAS	4 MAS
V1	1310.33	752.67	472.00	428.62	1060.33	599.00	341.33	273.33
V2	1057.67	887.33	598.67	481.33	1080.00	693.33	406.67	383.33
V3	1279.33	829.33	696.67	554.67	1103.33	714.67	556.67	473.33
V4	1291.00	688.00	626.67	552.00	1032.33	545.33	516.67	449.33
V5	1274.33	808.67	640.00	497.33	1072.00	680.67	573.33	411.33
V6	1271.33	1050.67	1026.67	997.67	1098.00	998.67	956.00	856.67
V7	1202.67	798.00	673.33	536.00	1015.67	792.33	537.33	470.67
V8	1303.00	881.67	768.33	493.33	1073.67	774.67	674.33	409.33
V9	1061.33	990.33	972.00	866.00	958.67	890.00	822.67	752.00
V10	1053.33	972.00	946.67	826.67	922.00	853.33	810.67	637.00
V11	1060.00	884.00	664.00	580.33	913.33	713.33	553.33	494.33
V12	1304.33	1034.67	917.33	785.33	1159.33	945.33	796.00	626.67
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Concluded

MAS - Months after storage NS - Non significant

Total sugar content showed a decreasing trend at the end of storage period. Percentage decrease was minimum in Solo and CO-3 compared to the initial values. Reducing sugar content was found to increase during the storage period. Non-reducing sugar content decreased at the end of storage period.

4.4.1.5 Total and free SO_2 content

Studies indicated that total and free SO_2 content varied significantly during the storage period. The values showed a decreasing trend with storage. The average content of total and free SO_2 in different varieties at the end of four month storage period was 730.20 and 516.80 ppm from 1400 ppm and 1100 ppm respectively.

4.4.1.6 Off flavour development

Papaya pulp from different varieties did not exhibit a tendency to develop off flavour during the storage period.

4.4.1.7 Colour degradation

There was no marked degradation in pulp colour of different varieties during storage.

4.4.2 Suitability of papaya pulp for product development

RTS beverage prepared from fresh and preserved papaya pulp was organoleptically evaluated for colour, flavour, taste and overall acceptability at 15 and 30 days after

Table 12. Organoleptic qualities of RTS beverage

Variety	Sensory score values							
	15 days after storage				30 days after storage			
	Colour	Flavour	Taste	Overall acceptability	Colour	Flavour	Taste	Overall acceptability
CO-3 F	7.6	7.0	6.6	7.0	7.0	5.8	6.0	6.2
CO-3 S	5.6	5.6	6.0	5.4	5.4	6.6	6.4	6.0
Solo F	7.4	6.6	6.6	6.6	6.7	5.6	5.8	6.0
Solo S	6.0	4.9	5.6	4.9	5.2	6.8	6.4	6.2
Kruskall Wallis H (5%)	10.5*	8.67*	1.02^{NS}	7.92*	8.3*	2.54^{NS}	0.579^{NS}	0.202^{NS}

* - Significant at 5% level
NS - Non significant
F - RTS prepared from fresh pulp
S - RTS prepared from stored pulp

preparation and mean values of scores are presented in Table 12. Evaluation of RTS beverage prepared from fresh and preserved pulp of CO-3 and Solo indicated that there was significant difference for colour, flavour and overall acceptability between the samples 15 DAS whereas for taste the difference was not significant. RTS prepared from fresh pulp of CO-3 was found to be superior in colour, flavour and overall acceptability followed by those prepared from the fresh pulp of Solo. The score obtained for the RTS prepared from preserved pulp was found to be lower than that for the RTS prepared from fresh pulp in the two varieties.

After 30 days of storage, RTS beverage prepared from fresh and preserved pulp of both the varieties did not exhibit significant difference for flavour, taste and overall acceptability. But colour differences were significant, highest score registered for RTS beverage prepared from fresh fruits of variety CO-3 (7.0) followed by Solo (6.7). Minimum score for colour was obtained for RTS beverage prepared from preserved pulp of Solo.

However, all the RTS samples prepared from fresh and preserved pulp was acceptable after 30 days of storage.

DISCUSSION

5. DISCUSSION

Papaya, an important fruit of the tropics and subtropics, deserves greater attention due to its high nutritive value and production potential. It is easily cultivable, has a short pre-bearing period, gives quick returns and adapts itself to diverse soil and climatic conditions. Papaya fruits have tremendous potential in the processing sector. Year round fruiting behaviour, high nutritive value, low cost and suitability for preparation of a wide range of processed products renders it the ideal fruit for processing industry.

Rarely planted on an orchard scale in Kerala papaya is commonly seen in homeyards where it thrives as a neglected plant. Though there are a large number of superior varieties of papaya released elsewhere little attempts have been made to study their performance under the soil and climatic conditions of Kerala.

The performance of papaya varieties were found to vary under different localities (Ghanta *et al.*, 1992). Papaya fruits are highly perishable and after harvest cannot be stored for more than one or two days (Muthukrishnan and Irulappan, 1990). Little attempts have been made to study the postharvest behaviour of papaya. Hence a study was undertaken for evaluating the performance

of some released cultivars of papaya and postharvest behaviour of the crop under Vellanikkara conditions. The results obtained under the study are discussed in this chapter.

5.1 Collection and evaluation of papaya varieties

A study on growth and development of papaya revealed significant differences in biometric characters at different growth phases. However, between varieties rate of this change was not significant, indicating a more or less uniform pattern of growth in different papaya varieties.

It is reported that within the limits set by a plant's inherent capacity for growth, its overall performance is a direct consequence of its ability to exploit the local environment such as light, temperature, water supply and mineral nutrients (Leopold and Kriedemann, 1975).

In papaya, short stature is desirable as it facilitates easy harvesting and papain extraction. Among the different cultivars studied the local type CP-15 was found to be the tallest accession. Cultivars MS, CO-2 and CO-5 were comparatively short in stature. The cultivar Honey Dew was found to be the most vigorous, registering high values for collar girth, canopy spread, petiole length and leaf area. A comparatively short stature and a compact canopy covering fruits, as observed in CO-2, would be ideal plant habit for high density planting.

It was found that the increase in plant height and collar girth was maximum in the early period of vegetative growth and towards the later period the increment was less. During the early period higher growth rate was noticed, but with the advance of age of the plant growth rate showed a decline. Wareing (1970) has pointed out that trees often show a decline in height and girth increments with ageing as most plant tissues show a slow decline in vigour with ageing.

Canopy spread showed an increasing trend upto six months in almost all varieties and afterwards it decreased and again after eight months registered an increase in canopy spread. The reduction in vegetative growth that occurs during the reproductive phase has been attributed to a shift in distribution of growth limiting nutrients within the plant (Thimman, 1980).

In the present study number of leaves and leaf area did not show a steady increase. Leaf production rate and increase in leaf area during various growth periods were different among the varieties. The decrease may be attributed to high temperature, moisture stress and heavy wind experienced during the growth period of the plant. Shah and Loomis (1965) also stated that moisture stress may affect the health of roots and also cause foliar senescence.

The number of leaves at first flowering was highest in the local type CP-15 and lowest in CO-5. Ghanta *et al.* (1992) reported 25.4 leaves for CO-2 and 25.3 leaves for CO-6 as against 16.5 in CO-2 and 16.63 in CO-6 at the time of flowering in the present study, indicating the varying performance of varieties under different soil and climatic conditions.

Cultivars CO-6, CO-3, 9-1-D, MS and Honey Dew were earlier in flowering, compared to other varieties and these varieties were the earliest to bear fruits also. Local types took more days for flowering and harvesting, compared to other cultivars. Selvaraj *et al.* (1975) observed a prebearing period of 314 to 326 days in different Solo papayas, which was in corroboration with the present study, whereas the results obtained by Ram and Majumder (1984) indicated that the various cultivars evaluated were late in flowering compared to the present results. Singh *et al.* (1984) observed that the days to first flowering and days to first harvesting in the various cultivars studied differed from 212 to 229 and 344 to 364 days, respectively which was in general agreement with the present results.

CO-6 recorded the maximum yield of 52.5 kg with 42.63 fruits in one year harvesting period, compared to other cultivars. Earliness combined with high yield in CO-6 indicates its overall superiority in performance. The high yielding cultivars were vigorous as evidenced from high

values for biometric characters like number of leaves, leaf area, canopy spread, etc.

The superiority of cultivars 9-1-D, CO-4, CO-5, CO-3 and Honey Dew with respect to yield has been supported by findings of Veerannah *et al.* (1982, 1985) and Suma (1995). These varieties recorded high pulp recovery with heavier fruits indicating their suitability for processing. The number of fruits was more in Solo than the other cultivars. The yield of Solo in terms of weight and number in the present study is supported by the findings of Sulladmath *et al.* (1981). Though the yield of Solo in terms of weight was comparatively less, the other superior attributes as the handy size, thick pulp and superior quality are in their favour. The big sized fruits pose a problem in handling and in consumption, as a single fruit cannot be consumed by a single person. Under such situation, the Solo papayas meet the needs admirably because of the small sized fruit and superior quality (Selvaraj *et al.*, 1975). According to Leopold (1964) the decrease in fruitsize with increasing number of fruits developing on the plant is due to the fact that as increasing number of fruits draw upon the nutrient supplies of the plant, competitive limitations on the growth rates of the fruits begin to set in.

It was also noticed that as the size of the fruit increases the number of fruits per plant decreases (Fig.1). Yield was the highest in cultivar CO-6 which also

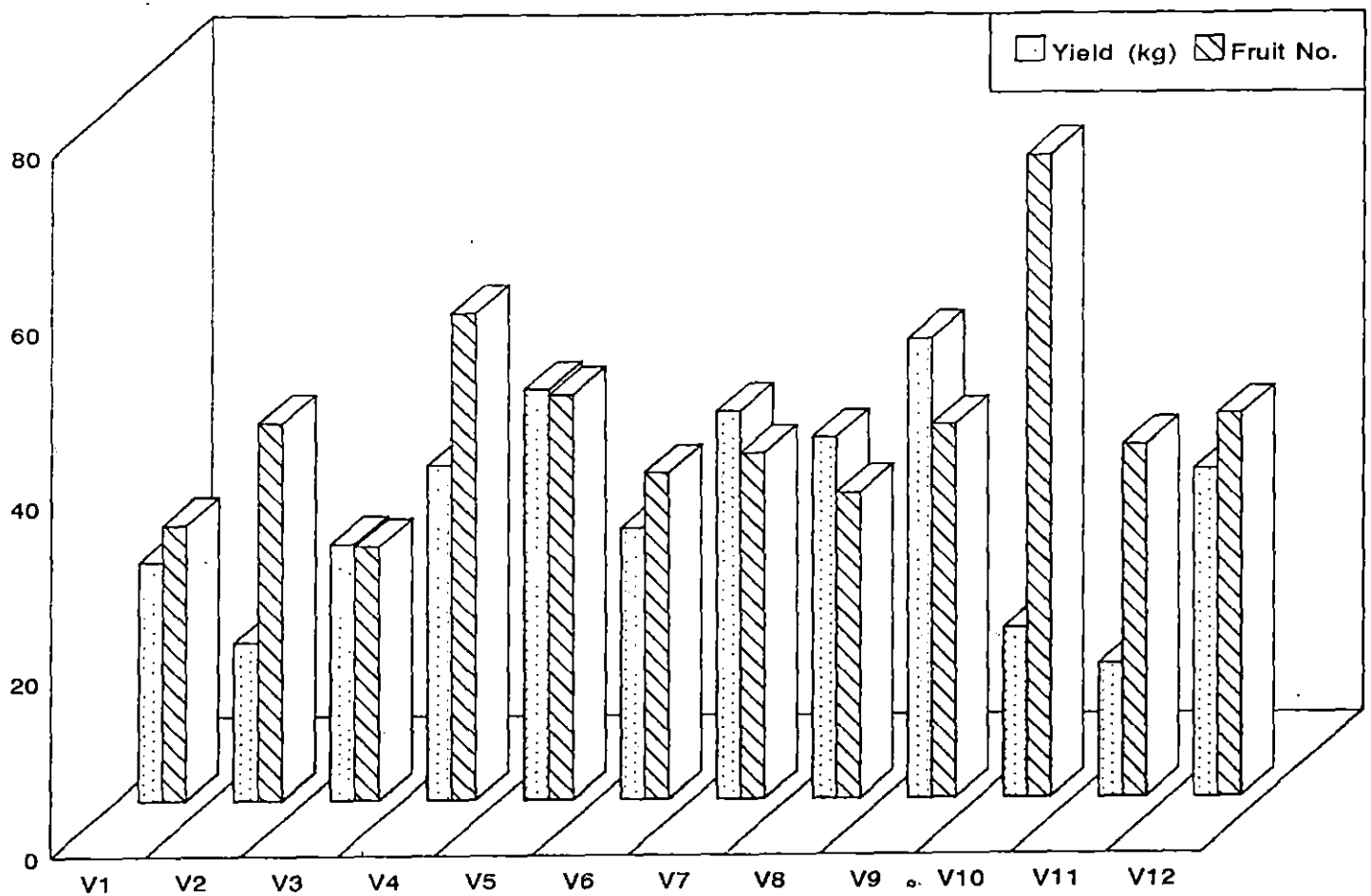


Fig. 1. Yield of papaya varieties

registered maximum fruit weight. Suma (1995) also reported that fruit yield displayed the highest association with the fruit weight. The heavier fruits borne on the tree drains the nutrients resulting in flower skip as observed by Auxcilia (1995).

A study on the production pattern of papaya varieties showed that maximum yield was obtained during October-November in most of the varieties where flowering might have occurred during. May-June which resulted in high fruit set. The fruit growth and yield was favoured by the south west monsoon. Minimum yield was recorded during June-July where the flowering might have occurred during January-February. This period corresponds to summer with low soil moisture regime and frequent dry wind. Dry period adversely affected flowering and fruitset in all the varieties which led to poor yield in June-July.

5.1.1 Analysis of fruit growth

Correct stage of maturity of fruit is very important at harvesting time to reduce postharvest losses. This maturity is indicated by several parameters based on visual, physical and chemical indices. These not only help in deciding a harvest date but also to sort out the harvested fruits into lots of varying maturity for their optimum use. Although attempts have been made to fix maturity standards based on physico-chemical characters of fruits at maturity. Colour break at blossom end of fruit is

the main criteria for ascertaining fruit maturity. Fruits harvested before maturity do not ripen properly. On the other hand fruits harvested late soften quickly resulting in spoilage during handling and transport (Chadha, 1992).

The results of the present study shows that varieties vary considerably in days to maturity from 120 to 150 days. This was in confirmation with the results reported by Selvaraj *et al.* (1982b), Balakrishnan *et al.* (1986) and Chadha (1992).

A precise information on optimum stage of harvest of fruit based on the physiological maturity will enable the producers to harvest the fruit in time. To find out the correct stage of harvest, it is essential to know the changes that occur during the development and maturation of fruits (Balakrishnan *et al.*, 1986).

It was observed that the characters fruit weight, length, circumference, volume, polar diameter, equatorial diameter, flesh thickness and cavity volume increased as the age of the fruit advanced. Hulme (1970) reported that, the enlargement of fruit in terms of length and breadth was due to both cell expansion and cell division. During the initial stages of fruit growth, cell division continued to take place and at later stages only cell expansion occurred.

Increase in volume was at a faster rate compared to fruit weight. Chittiraichelvan (1975) also found a similar trend in CO-2 papaya which he attributed to the increase in moisture content rather than any possible accumulation of dry matter.

It is evident from Fig.2a and 2b that light fruited varieties exhibited a simple sigmoid growth pattern whereas in heavy and medium fruited types a double sigmoid growth pattern was observed. Growth increment in the light fruited variety Solo was confined to a single peak. Three distinct phases of growth increment were observed in medium and heavy fruited types. In 9-1-D which had medium size fruits, the first phase from 30 to 60 days and second from 75 to 90 days whereas in the heavy fruited type, CO-5 it was from 45 to 60 days and 105 to 120 days. Chittraichelvam (1975) and Veerannah and Selvaraj, (1984) observed a simple sigmoid growth pattern with respect to fruit weight in CO-2 and CO-1 papayas.

Qualitatively the difference between the medium and the heaviest could be observed at the third phase of growth. The third phase was less pronounced in medium whereas it was pronounced as the peak growth stage in the heavy fruit types.

Fig.2a Changes in fruit weight during development

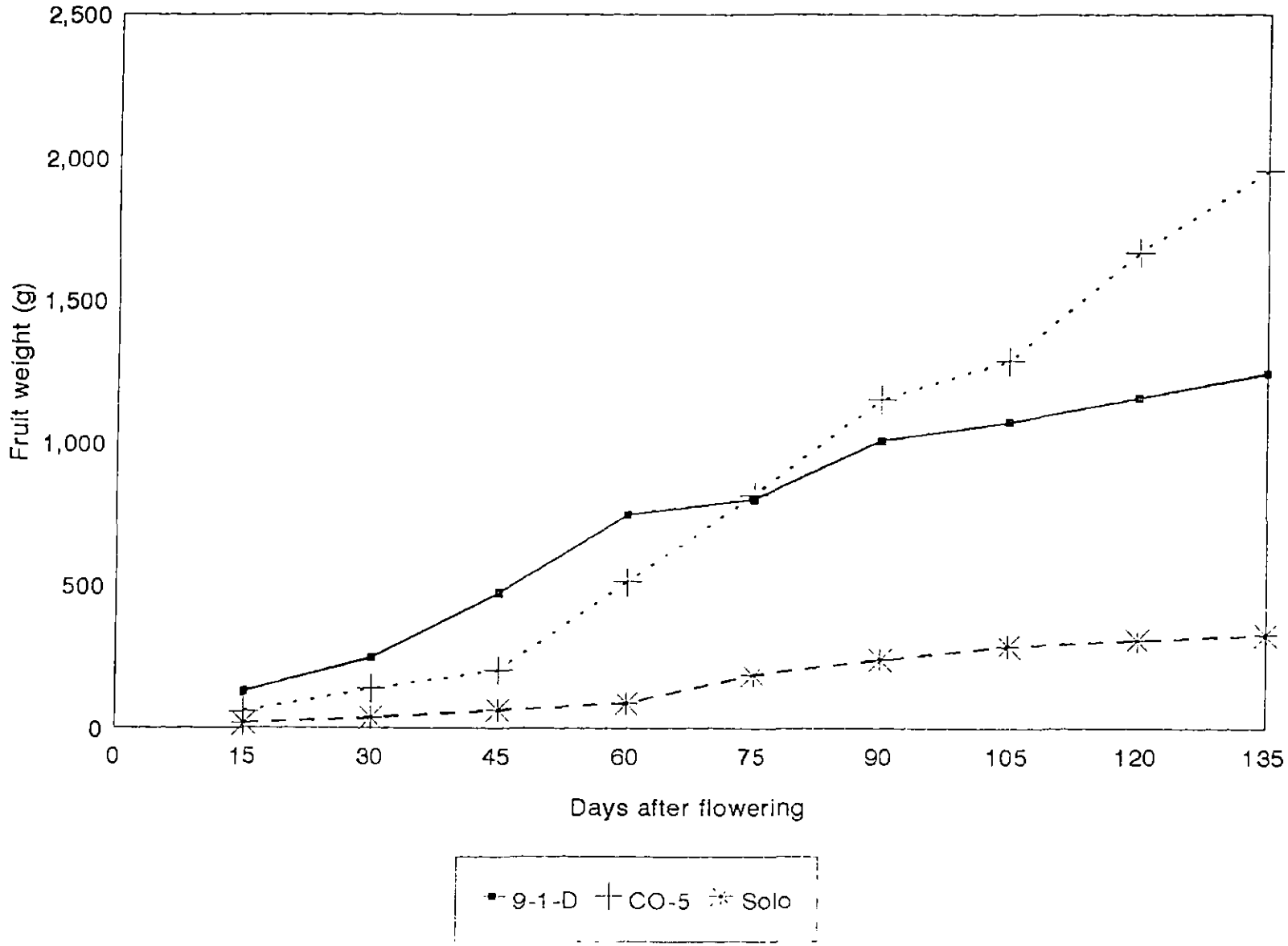
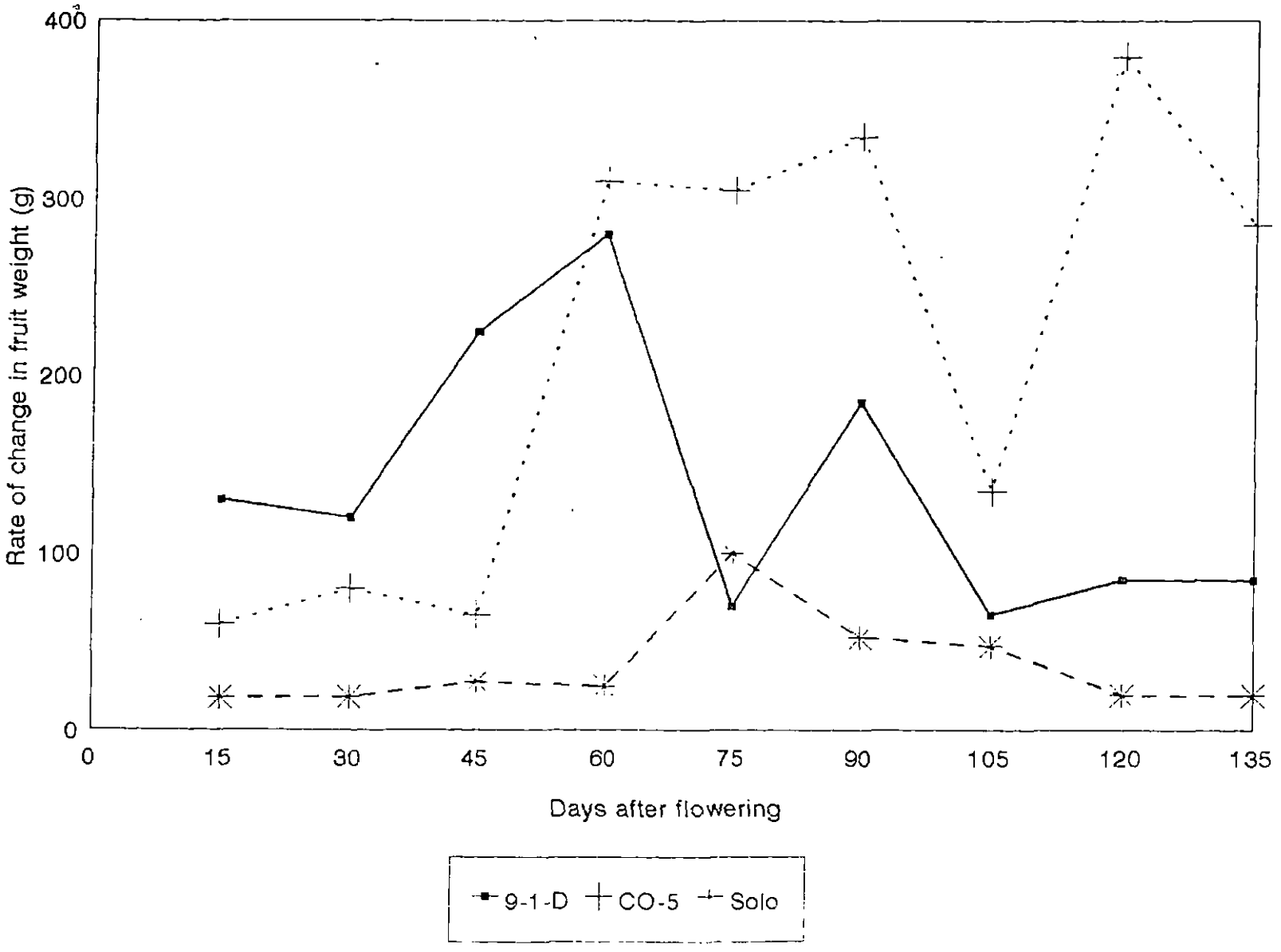


Fig.2b Rate of change in fruit weight during development



The increase in fruit weight at maturity is due to the fact that the developing fruit acts as a strong physiological sink, attracting nutrients to its tissue. Therefore, there will be an enhanced deposition of metabolites inside the cells (Joseph, 1985). Bollard (1970) reported that the major increase in fruit weight towards maturity could be attributed to an increase in both cell size and amount of intercellular space in the flesh, which enables the maximum possible accumulation of food substances.

In papaya minimum values for cavity volume and cavity index are desirable on account of high pulp recovery. Star shaped or ridged seed cavities are preferred as it is more compact and fruit can be transported to larger distances (Suma, 1995).

In the present study cavity volume was lowest for CO-3 and Solo but in these cavity index was high. Small fruit size can be accounted for this. Cavity index was lowest for the cultivars CP-14, CP-15, CO-4 and CO-5. These are characterised by long fruits with narrow cavity. Long fruits with narrow cavity had been reported to travel well, on the other hand fruits with large and wide cavity were considered delicate and got bruised in transit (Hayes, 1970).

In the present study it was found that the proportion of peel decreased with maturity whereas the pulp proportion tend to increase in the earlier stages but it decreased slightly in the later stage. The decrease may be due to the presence of cellulose and hemicellulose in the peel which at maturity are converted to starch as observed in banana by Simmonds, 1966. In most of the varieties evaluated in the present study the pulp/peel ratio increased in early stages whereas it decreased lightly towards maturity. Pantastico (1975) reported that in banana as a result of sugar increase in the pulp, osmotic pressure is developed and water is withdrawn from the skin by the pulp, causing a change in the pulp/peel ratio. Lodh *et al.* (1970) also observed a sudden decrease in peel weight and a corresponding increase in pulp weight at maturity in mango. A comparison of physical composition of mature and ripe fruits indicated a slight decrease in proportion of pulp and increase in peel and placenta with onset of ripening in most of the varieties of papaya. Ghanta (1994) also observed a similar result with cultivar Ranchi.

The proportion of seed followed an erratic pattern. This may be due to poor pollination or abortion of seeds during development (Chittraichelvan, 1975, Singh, 1990).

Harvest indices formulated in the present study based on days to maturity and physical parameters at maturity of different papaya cultivars have enormous significance in ensuring quality and reducing postharvest losses in papaya.

5.2 Storage behaviour of papaya under ambient and refrigerated conditions

Papaya is highly perishable and ripe fruits cannot be stored for more than two or three days under ambient conditions. The estimated post-harvest loss in papaya fruits is 10-25 per cent in ripe fruits and 5-10 per cent in green fruits (Mandal and Dasgupta, 1981). Hence preservation of papaya in fresh condition with out loss of quality for extended period is important.

Significant variation was observed between varieties for physiological loss in weight and was highest in the local type CP-16 and lowest in Solo followed by MS. Difference between cultivars in PLW was also reported in other fruit crops like mango by Kaushik and Kumar (1992). Data on loss in weight during storage reveal that there was an increase in weight loss with the increased period of storage. Moreover, the weight loss was comparatively higher in the early period than at later period of storage. Results obtained by Sen *et al.* (1982) corroborates with this result. The increase in weight loss with increased period of storage may be due to evapotranspiration of moisture.

The average physiological loss in weight was high under ambient than refrigerated conditions (Fig.3). Similar results have been reported by Ramana *et al.* (1984) in mango. The check in PLW under low temperature conditions may be due to retardation of the process of transpiration and respiration. Rangavalli *et al.* (1993) also reported a close relationship between loss of fruit weight and respiration rate.

Water loss is loss of saleable weight and thus is a direct loss in marketing. A loss in weight of five per cent will cause perishable commodities to appear shrivelled or wilted (Wills *et al.*, 1989). In the present study average loss in weight was 2.07 per cent per day in CP-16 as against 0.75 per cent per day in Solo which indicate that CP-16 is liable to lose its marketability within a shorter time compared to Solo.

Variety MS took maximum number of days for ripening followed by Solo under ambient conditions. The ripening process is related to production of ethylene. The varieties did not ripen in the refrigerated environment. The papaya fruits show a characteristic respiration climacteric during ripening (Salunkhe and Desai, 1984). In climacteric fruits low temperature can also be used to delay the onset of ripening. Lowering of temperature decreases not only production of ethylene, but also the rate of response of tissues to ethylene (Wills *et al.*, 1989). Storage at low

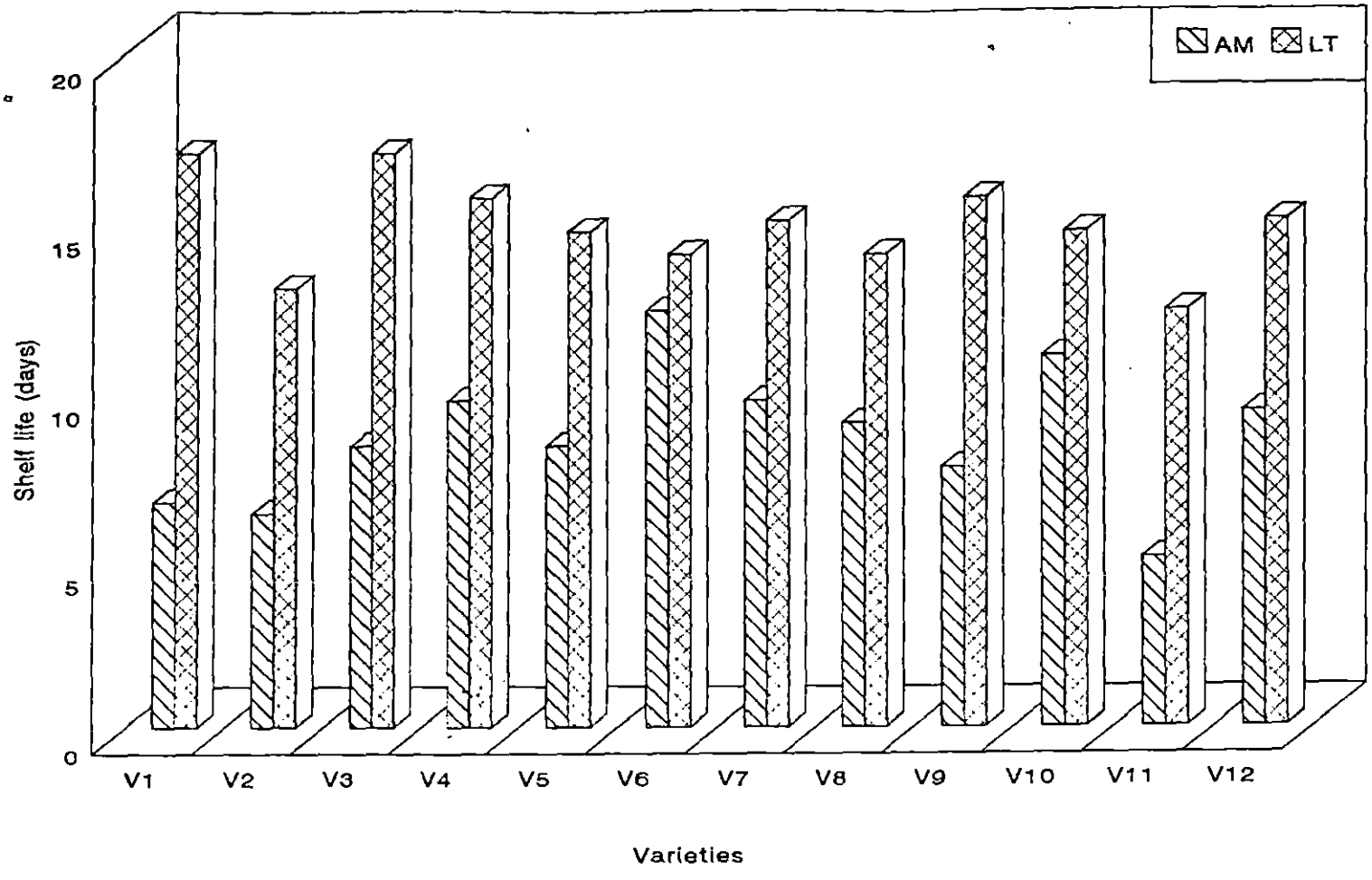


Fig.3. Shelf life of papaya varieties

temperature did not impair the subsequent ripening as is evidenced from the present study. Medlicott *et al.* (1990) reported impaired ripening in mango after storage at 8 and 10°C. The varieties did not differ significantly for days to ripening after low temperature storage. Longer shelf life was found in MS, followed by Solo and minimum in local type CP-16 under ambient conditions. However, in a refrigerated environment there was no significant difference between varieties in shelf life. A high rate of respiration is usually associated with a short storage life (Pantastico, 1975). Shelf life was significantly higher in refrigerated than ambient environment. Similar resutls were reported by Ramana *et al.* (1984) in mango and CFTRI (1963) in papaya. The mean shelf life was 14.83 days in refrigerated condition as against 8.61 days in ambient conditions which clearly indicates that an extended shelf life of 6.22 days was obtained by low temperature storage. In Honew Dew papaya a storage life of 9.67 days was obtained in the present study where as a shelf life of 12 days was reported at 9±1°C and 85 to 90 per cent RH (CFTRI, 1963). This may be due to the increased sensitivity to chilling injury at 8±1° C.

In papaya it was reported that chilling injury occurs at a temperature of 43°F characterized by impaired ripening, pitting and water soaking of skin (Jones and Kubota, 1940, Pantastico *et al.*, 1971). In the present study different cultivars responded differently to low

temperature storage 8±1°C cultivars CO-2, CO-3, 9-1-D, Solo, CO-6 and CP-14 were more tolerant to low temperature as indicated by longer safe storage period in low temperature (Table 8). Storage beyond this period was found to induce chilling injury symptoms in all the varieties. Jones (1942) and Thompson and Lee (1971) reported chilling injury in Solo variety stored at 7°C. Changes in membrane permeability have been suggested as possible causes of chilling injury (Pantastico, 1975).

Organoleptic evaluation of fruits ripened under different conditions indicated that there was no significant difference between varieties for colour, flavour, sweetness, firmness, taste and overall acceptability. However, Lakshminarayana *et al.* (1970), Kapse *et al.* (1985) and Medlicott *et al.* (1990) observed loss in colour texture and flavour in low temperature storage of some tropical fruits.

Incidence of fruit rot caused by *Colletotrichum gloeosporioides, Cercospora* sp., *Rhizopus* sp and *Fusarium* sp was observed during storage of papaya. Pantastico, 1975 and Singh, 1990 has also reported postharvest spoilage caused by the same microorganisms in papaya. *Colletotrichum* sp was reported to be the most important cause of fungal rots in papaya by Wardlaw *et al.* (1939). Thompson and Lee (1971) observed the incidence of fruit rot by fungi *Colletotrichum* and *Rhizopus* in cold storage of papaya.

Post harvest spoilage due to micro organisms was comparatively low in fruits stored in refrigerated low in fruits stored in refrigerated environment in the present experiment. Low temperature storage is ideal for reduction in PLW and incidence of postharvest diseases as well as enhancement of shelf life as evidenced from the result of the study conducted.

5.3 Chemical changes during ripening of papaya under different conditions

Fruits undergo changes in chemical composition during ripening indicated by development of colour, flavour and texture. Hence attainment of maximum eating quality necessitates completion of such chemical changes for maximum eating quality. Changes in chemical composition of papaya fruits with conditions of ripening have been reported by Pal *et al.* (1980a).

Maximum values for TSS was obtained in fruits ripened on the plant and minimum for fruits ripened after LT storage. Akamine and Goo (1971) observed that TSS of papaya pulp increased with increase in surface yellow colouration upto 80 per cent colour level. The developing fruit acts as a physiological sink drawing nutrients from other parts (Pantastico, 1975) accounting for high TSS and sugars in tree ripe fruits. Pal *et al.* (1980a) had also recorded a higher TSS content in tree ripe than room ripened fruits. Acidity was highest for fruits ripened after LT storage and lowest for tree ripe fruits whereas pH was highest in

fruits ripened under ambient conditions in the present study. However, Pal *et al.* (1980a) reported higher acidity content in the ripe fruits. Mattoo and Modi (1969) and Chattpar *et al.* (1971) also reported that there was a significant decrease in the TSS content and less starch breakdown during chilling. TSS content was high in fruits stored at room temperature than in low temperature stored ones which was probably due to the slow conversion of starch into sugar, slow digestion of pectic acid, fats and proteins under low temperature as reported by Singh *et al.* (1985) in certain varieties of mango. The acidity was low in fruits stored at room temperature whereas it was high in fruits stored at low temperature as the respiration rate was arrested to the minimum at this temperature (Kapse *et al.*, 1977).

Tree ripe fruits recorded the maximum values for total, reducing and non-reducing sugars whereas these values were minimum for fruits ripened after LT storage. The findings of Pal *et al.* (1980a) is in confirmation with the present results. Thimman (1980) reported that in fruits ripened on the plant the sugar content increased due to transport of the reserve carbohydrate, to the fruits from leaves.

Kapse *et al.* (1977) reported that the sugars increased rapidly in fruits stored at room temperature and then decreased. Salunkhe and Desai (1984) also observed a

similar trend in acidity in papayas stored under room condition. This was because starch was converted to sugar during ripening. After that sugar decreased because senescence stage had started and sugar formed from starch was utilised for further respiration. Under low temperature condition sugar content increased slowly and then decreased slowly because there is a suppression in rate of respiration and enzyme activity. The results of the study clearly indicates that tree ripe fruits are superior in quality attributes. However, if the fruits are allowed to ripe on the plant, there is every likelihood of damage by birds and squirrels. Moreover harvesting without damage to fruits is difficult and these fruits have shorter shelf life.

Association of different chemical constituents decide the taste and quality of papaya. In papayas, the sugar content is greater than the acidity and therefore the sweetness predominates (Salunkhe and Desai, 1984). Of the different varieties evaluated Solo recorded maximum TSS. Higher TSS in Solo was also recorded by Selvaraj *et al.* (1975) and Veerannah *et al.* (1982). The results of TSS obtained for CO-2 and CO-3 in the present study are supported by the findings of Veerannah *et al.* (1982) whereas the TSS obtained for CO-4 and CO-5 was slightly lower than reported by them. Ghanta *et al.* (1992) reported a lower TSS for CO-2 and CO-6 than that obtained in the present study.

The acidity in ripe papaya is comparatively low and is reported to range from 0.062 to 0.116 per cent (CFTRI, 1963) which is in general agreement with the results of the present study. The acidity obtained for CO-4, CO-6 and Solo by Veerannah *et al.* (1982), Kulasekharan *et al.* (1986) and Selvaraj *et al.* (1975) was slightly higher than the present findings whereas results obtained for CO-2 and CO-6 are in consonance with the findings of Ghanta *et al.* (1992). According to Pantastico (1975) cultural and environmental condition to which a variety is exposed can bring about variation in chemical composition.

Higher values for total and non-reducing sugar was obtained for Solo whereas reducing sugar was higher in CO-2. Higher total sugar was also reported for Solo by Selvaraj *et al.* (1975) and Veerannah *et al.* (1982). The total reducing and non-reducing sugar content for the various varieties obtained by Pal *et al.* (1980a) was in general agreement with the present study.

5.4 Storage stability of papaya pulp and its suitability for product development

Ripe papaya fruits are highly perishable and cannot be stored in the fresh form for more than a few days. In the semiprocessed form it can be preserved for a period of one year for subsequent utilization for product preparation. However, physico-chemical changes are likely to occur in pulp during storage, the degree of change often depending

upon varieties and storage conditions. Hence a detailed study of changes in chemical constituents of papaya pulp during storage is important.

A progressive decline in TSS, acidity, total sugar and SO_2 was observed during the storage period whereas, pH and reducing sugar was found to increase in the various varieties studied.

According to Pantastico (1975) the non-volatile organic acids are among the major cellular constituents undergoing changes. Reduction in acid content and increase in pH could be due to the breakdown of acid during respiration (Agnihotri *et al.*, 1963 and Kaushik and Kumar, 1992). Contrary to this a rise in acidity in storage of mango pulp was reported by Kalra (1982) and Murthy *et al.* (1982). In the present study the pulp was preserved by adjusting acidity to one per cent by adding citric acid granules, accounting for comparatively low change in acidity.

The reduction in total sugar content may be attributed to its consumption during respiration. Increase in reducing sugars may be due to sugar hydrolysis during storage as reported by Luh and Kamber (1963), Brekke *et al.* (1976); Adsule and Anand (1977) and Kulwal (1985).

Kalra (1982) reported an increase in reducing sugar during pulp storage studies but in the present study there was only slight increase. The changes observed in TSS, acidity and reducing sugars in storage was in confirmation to those obtained by Kalra and Tandon (1985). A reduction in content of total and free SO_2 used as preservative for storage of pulp was observed at the end of study. Decrease in SO_2 content with storage of pulp was also reported by Kalra and Revathi (1981), Ghosh *et al.* (1981) and Tandon and Kalra (1984). SO_2 being a gas is more liable to loss during storage.

It is evident from Table 11 that changes in storage was comparatively low in varieties CO-3 and Solo. This indicates the stability of stored pulp of these varieties and their suitability for preservation in semiprocessed form.

Ready to Serve Beverages (RTS) have a big potential in domestic market in India and most of the drinks available are synthetic containing very little nutrients. Papaya RTS beverage has good potential and can be easily manufactured and marketed with good profitability. From the stored pulp of CO-3 and Solo which was found to be best, RTS was prepared and compared with those prepared from fresh fruits. Results indicated that RTS prepared from fresh fruits was better compared to stored pulp. But all the RTS were acceptable after 15 and 30 days of storage as

evidenced from organoleptic score values for overall acceptability. Thirumaran *et al.* (1992) also found that among the varieties evaluated for RTS beverage CO-3 scored higher grade than the other varieties which is attributed to its superior red colour.

High yielding varieties CO-6, CO-5, 9-1-D and CO-4 recorded higher recovery of pulp and heavier fruits indicating their suitability for processing units. When storage is concerned varieties like MS, Solo, CO-3 and CO-4 is preferred due to their comparatively longer shelf life.

Varieties Solo and CO-3 were superior in quality registering high values for TSS, total sugars and comparatively low acidity. Moreover these varieties have the distinct advantage of hermaphroditism. Further red colour of flesh of these varieties renders them ideal for processing. Varieties with red colour of pulp are preferred for preparation of products like sauce, jam, fruitbar and beverages (KAU, 1995).

SUMMARY

SUMMARY

The investigation on `Screening of papaya (*Carica papaya* L.) varieties with special reference to postharvest attributes' was conducted at the Department of Processing Technology, College of Horticulture, Vellanikkara, during 1995-1997. The objectives of the study were to evaluate the performance of twelve varieties of papaya under Vellanikkara conditions, to study the storage behaviour of papaya under ambient and low temperature environment, to understand the chemical changes under different conditions of ripening of fruit and storage of pulp and to assess the suitability of preserved pulp for preparation of RTS beverage.

Twelve varieties of papaya were planted in an RBD with four replications. Biometric characters were recorded at five phases of growth, viz., 2, 4, 6, 8 and 10 MAP. Physical changes during growth and development of papaya fruit was studied at fortnightly intervals from 15 days after flowering till harvest maturity. The results of the present investigation are summarised as below:

1. Among the varieties evaluated Honey Dew was found to be the most vigorous in respect of collar girth, canopy spread, petiole length and leaf area. The cultivars MS, CO-2 and CO-5 were comparatively short statured.

2. The number of leaves at first flowering varied from 13.25 in CO-5 to 20.75 in CP-15.

3. The cultivars CO-6, CO-3, 9-1-D, MS and Honey Dew were the earliest to flower and bear fruits and the local types were late bearing in nature.

4. The high yielding cultivars were CO-6, 9-1-D, CO-4, CO-5, CO-3 and Honey Dew and the local varieties were comparatively low in productivity.

5. Among the varieties studied, Solo had the maximum number of fruits (73.38). However, it had the least fruit weight (265 g).

6. A study on the production pattern of papaya varieties revealed that highest yield was obtained in the 7th and 8th month of harvest in most of the varieties corresponding to the month of October-November whereas the yield was least during June-July.

7. The varieties differed significantly for days to maturity, which varied from 120 to 150 days. Cultivars CO-2, MS and CP-15 were the earliest to mature whereas the local type CP-16 was the last.

8. With the advance of age of fruit characters like fruit weight, length, circumference, volume, polar diameter, equatorial diameter, pulp thickness and cavity volume were found to increase.

9. The pulp per cent increased with maturity with a corresponding decrease in peel percent. Maximum pulp contents were obtained in the cultivars CO-5, CO-6 and CP-15.

10. Physical parameters like fruit weight, length, circumference, volume, flesh thickness, cavity volume, proportion of pulp, peel and pulp/peel ratio were worked out at full maturity in each of the 12 varieties. These can serve as useful guides of maturity indices in the respective varieties under Vellanikkara conditions.

11. The growth pattern in respect of fruit weight exhibited a single sigmoid curve in light fruited type Solo and a double sigmoid curve in medium fruited 9-1-D and heavy fruited CO-5. Growth increment in Solo was confined to a single peak wehreas three distinct phases of growth increment were observed in 9-1-D and CO-5.

12. Average physiological loss in weight was the lowest in Solo (0.75% per day) under ambient conditions.

13. The number of days taken for full ripening varied from 3.3 days in CP-16 to 9.3 days in MS under ambient conditions.

14. Shelf life was maximum in the cultivar MS (12.3 days) followed by Solo (11.0 days) and minimum in CP-16

(5.0 days) under ambient conditions. The shelf life could be prolonged to 14.83 days by low temperature storage.

15. Low temperature storage (8±1°C) was found to reduce PLW, prolong shelf life and reduce incidence of postharvest spoilage in papaya.

16. The varieties differed significantly for tolerance to low temperature conditions. CO-2, CO-3 and 9-1-D were relatively more tolerant.

17. Conditions of ripening did not have a significant effect on organoleptic qualities of fruits, viz., colour, flavour, sweetness, firmness and overall acceptability.

18. The pathogens found to cause post harvest spoilage during storage of papaya were *Colletotrichum gloeosporioides*, *Cercospora* sp, *Fusarium* sp and *Rhizopus* sp.

19. Chemical evaluation of fruits ripened under different conditions showed that maximum TSS, total, reducing and non-reducing sugars and minimum acidity was in plant ripe fruits. TSS, total and non-reducing sugars were comparatively low in fruits ripened after low temperature storage.

20. Among the varieties evaluated the highest TSS (14.6°brix), total sugar (7.73%) and non-reducing sugar (2.06%) were recorded by Solo. Significant

variation was not observed among varieties for acidity.

21. TSS, acidity, total sugar and SO_2 in pulp declined during storage whereas a slight increase in reducing sugar content was noticed.

22. Of the twelve varieties, fruit pulp of CO-3 and Solo were found to be more stable compared to other varieties registering minimum variation in chemical constituents at the end of storage compared to the initial values.

23. Evaluation of RTS prepared from the stored and fresh pulp of CO-3 and Solo revealed the superiority of fresh pulp over processed pulp. However, the RTS prepared from all samples were acceptable at 15 and 30 days after storage.

24. The present investigation revealed the overall superiority of the cultivar Solo and CO-3 in respect of number of fruits, red colour and flesh, high TSS, total and reducing sugars, low PLW in storage and more shelf life of fruits and storage stability of pulp.

25. High yielding cultivars like CO-6, CO-5, 9-1-D and CO-4 recorded higher recovery of pulp and heavier fruits indicating their suitability for processing units and these cultivars can be recommended for large scale cultivation for processing.

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*Originals not seen

APPENDIX I

WEATHER DATA OF VELLANIKKARA

	1995							1996				
Elements	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
Max. Temp.	31.6	29.9	30.6	30.1	32.2	31.3	32.5	33.1	34.7	36.4	34.6	32.8
Min. Temp.	23.1	23.2	23.7	23.5	23.2	22.5	21.3	22.4	23.4	24.3	25.0	25.2
Rain	500.4	884.7	448.7	282.5	110.4	88.4	0.0	0.0	0.0	0.0	152.0	95.4
Rainy days	19.0	26.0	22.0	13.0	8.0	5.0	0.0	0.0	0.0	0.0	7.0	4.0
RH 1%	94.0	96.0	94.0	94.0	91.0	91.0	71.0	71.0	72.0	32.0	87.0	91.0
RH 2%	77.0	81.0	78.0	70.0	65.0	69.0	43.0	35.0	34.0	37.0	59.0	63.0
Sun shine (h)	3.7	2.1	3.7	6.1	8.3	6.5	10.3	9.4	9.9	9.3	8.3	7.7
W.speed km/h	10.1	1.7	2.0	2.0	1.8	1.1	6.7	7.1	5.9	3.6	3.0	2.4

	1996							1997				
Elements	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
Max. Temp.	30.5	28.8	29.1	29.2	30.1	31.5	30.5	32.0	33.9	35.7	35.2	34.4
Min. Temp.	23.8	23.1	23.6	23.7	22.9	23.6	21.8	22.9	21.8	24.0	24.5	24.5
Rain	400.3	588.7	310.0	391.6	219.3	22.1	60.4	0.0	0.0	0.0	8.2	63.0
Rainy days	16.0	25.0	20.0	17.0	12.0	2.0	2.0	0.0	0.0	0.0	1.0	4.0
RH 1%	94.0	96.0	95.0	94.0	93.0	84.0	80.0	78.0	82.0	82.0	83.0	87.0
RH 2%	75.0	83.0	78.0	74.0	70.0	59.0	55.0	45.0	39.0	37.0	50.0	57.0
Sun shine (h)	4.7	2.7	3.7	4.3	6.0	7.1	6.8	9.6	9.3	9.6	9.6	6.7
W.speed km/h	3.0	2.7	3.0	2.7	2.0	3.7	6.4	6.9	3.9	4.0	3.3	3.3

APPENDIX II

SOIL DATA OF THE EXPERIMENTAL FIELD

Before planting				After planting			
pH	Organic carbon (%)	Available phosphorus (kg ha^{-1})	Available potassium (kg ha^{-1})	pH	Organic carbon (%)	Available phosphorus (kg ha^{-1})	Available potassium (kg ha^{-1})
5.0	0.35	40.32	191	5.3	0.53	40.32	268
4.8	0.53	40.32	268	5.4	0.70	40.32	218
4.7	1.23	40.32	300	5.0	0.35	40.32	218
5.0	0.35	40.32	191	4.9	0.35	40.32	191

SCREENING OF PAPAYA *(Carica papaya* L.*)* VARIETIES WITH SPECIAL REFERENCE TO POSTHARVEST ATTRIBUTES

By

M. RENI

ABSTRACT OF A THESIS

Submitted in partial fulfilment of the
requirements for the degree of

Master of Science in Horticulture

Faculty of Agriculture
Kerala Agricultural University

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1997

ABSTRACT

The study on `Screening of papaya (*Carica papaya* L.) varieties with special reference to postharvest attributes' was conducted at the Department of Processing Technology, College of Horticulture, Vellanikkara during 1995-1997. Twelve varieties were evaluated for their performance under Vellanikkara conditions. The storage behaviour of fruits under ambient and low temperature conditions were compared. The changes in chemical constituents of fruits under different conditions of ripening and in pulp during storage were studied.

Variety Honey Dew was found to be superior in respect of collar girth, canopy spread, petiole length and leaf area. Varieties CO-6, CO-5, 9-1-D and CO-4 were high yielding with heavier fruits and higher recovery of pulp whereas maximum number of fruits was in Solo (73.38). Though Solo had the smallest fruits (265 g), in respect of quality Solo ranked top registering high TSS (14.6° brix), total and non-reducing sugars (7.73% and 2.06%, respectively).

The local types were comparatively late and low in productivity. The number of days taken to attain harvest maturity ranged from 120 to 150 days in the various cultivars. The physical characters of fruits like fruit weight, length, circumference were found to increase with maturity of fruits.

The growth pattern in respect of fruit weight was simple sigmoid in Solo which had light fruits whereas in 9-1-D and CO-5 which had respectively medium and heavy fruits it was double sigmoid.

Maximum shelf life was recorded in cultivar MS (12.3 days) followed by Solo (11.0 days) under ambient conditions. Low temperature storage was found effective in reducing PLW, enhancing shelf life and reducing incidence of postharvest spoilage of fruits.

TSS and sugars were found to be highest in tree ripe fruits and least in fruits after LT storage. The chemical constituents viz., TSS, acidity, pH and sugars were found to vary during storage of pulp. But the variation was minimum in cultivars CO-3 and Solo.

RTS beverage prepared from fresh and preserved pulp of CO-3 and Solo were acceptable after 30 days of storage.

The present investigation revealed the overall superiority of the cultivar Solo and CO-3 in respect of number of fruits, colour of flesh, TSS, total and reducing sugars, PLW in storage and shelf life of fruits and stability of pulp. Cultivars CO-6, CO-5, 9-1-D and CO-4 can be recommended for commercial cultivation for processing purposes.