EFFECT OF STAGE OF MATURITY ON STORAGE LIFE AND QUALITY OF PAPAYA (*Carica papaya* L.)

By

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Thesis Submitted in partial fulfillment of
the requirements for the degree of

Bachelor of science

In

Food Science and Technology

of the Faculty of Applied Sciences
Sabaragamuwa University of SriLanka.
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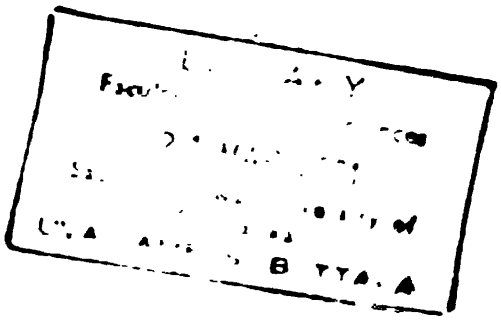
December 2000



DECLARATION

The work described in this thesis was carried out by me at the Food Research Unit, Department of Agriculture, Gannoruwa, Peradeniya and Faculty of Applied Sciences under the supervision of Dr.K.H.Sarananda and Mr.M.A.J.Wansapala.
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AFFECTIONATELY DEDICATED

TO

MY EVER LOVING PARENTS,

BROTHERS ,SISTER

AND

TEACHERS

ABSTRACT

Papaya fruits (*Carica papaya*) harvested at five stages of maturity ranging from dark green to fully coloured (75% colour) fruit were tested for quality during storage.

Dark green fruit developed yellow skin colour during ripening at the same rate as pale green (breaker) fruit, but they did not have the same extent of skin-colour development at eating ripe stage. More mature fruits, which had reached or closely approached full maturity on the tree, had better eating quality when ripened than immature fruits. Therefore papaya fruit should not be harvested before reaching fully maturity (25%-50% yellow colour development).

Harvested fruits of this maturity can be kept at ambient temperature (25^0-28^0C) for 6days When fruits stored at 15^0C, storage life can be extended for up to 15 days. Low temperature minimized the rate of ripening process.

Fruits harvested at 25%-50% were able to reach the peel colour, ^{0}Brix, Titratable acidity and less diseases as an acceptable level. Fruits harvested earlier than 25% colour stage were inferior in quality.

This study showed that, maturity stages have significant effect on ripe fruit quality of papaya stored both at ambient and 15^0C. It was further observed that the quality of this variety did not depend on ripening temperature.

ACKNOWLEDGEMENT

This study was undertaken at Food Research Unit Gannoruwa, under the supervision of Dr.K.H.Sarananda, Research Officer, first and foremost, I express my gratitude and sincere thanks to him, for giving me an opportunity to undertake the study in the Postharvest Technology, and for his invaluable guidance, constructive suggestions, and kind support throughout the study period. His valuable criticism in the preparation of the research report is well appreciated.

I wish to express my sincere appreciation to Mr.M.A.J.Wansapala, programme co-ordinator Dept. of Natural Resources Faculty of Applied Sc. Sabaragamuwa University, Buttala, for his guidance and invaluable help rendered throughout my study period.

I wish to express my deep sense of gratitude to Mr.N.Nadarajah, The former Department Head, Department of Natural Resources, for providing me an opportunity to carry out the study at Gannoruwa, for his previous guidance and encourangements.

I acknowledge with my deep sense of gratitude to Dr.K.K.D.S.Ranaweera, Deen, Faculty of Applied sciences Sabaragamuwa University, Buttala, for giving me the facilities to carry out this project successfully.

I also wish to extend my sincere appreciation to Mr.T.D.W.Siriwardena, Head, Food Research Unit Gannoruwa, for giving me an opportunity to undertake this study, and making necessary arrangements throughout this study.

I would like to thank to all staff of Food Research Unit, Gannoruwa, for giving kind support for my experiment work

A special word of thanks goes to Mrs Indira Wickramasinghe, lecturer, for the assistance given me in different ways, and Mrs Chamila Rathnaweera, for giving support in statistical analysis

At last, but not least I offer my thanks to my colleagues, for their voluntary help me in various ways during the research period

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CHAPTER-1

INTRODUCTION

Papaya (*Carica papaya*) belongs to the family Caricacea, which produce whole some fruits in many uses It is one of the most important fruit crops grown in SriLanka. It is widely distributed in tropical areas and eaten as a fresh fruit. The fruit can also cooked immature and acceptable products have been prepared through processing.

The papaya fruit is prominence in nutrition, Medicines and Industry. Because it contain about 85-90% water. 10-13% sugar and 0.6% protein, as well as vitaminA, B1, B2 and C. They are low enough in sodium to be used in special diets. The world demand for papaya increases annually Though the demand for papaya fruit is increase in the market, there is a limited supply due to lack of established technologies on harvesting, handling, transport, storage and ripening As a result poor quality fruits are often available, particularly in the producing countries and there is a considerable loss. In SriLanka the post harvest loss reported for papaya is about 40% As such, reducing post harvest loss is of vital important.

One of the major problems in papaya industry is identification of optimum harvest maturity to ensure adequate fruit ripening to good eating quality. Due to that careful control is necessary, since green immature fruit will not ripen to give normal ripe fruit quality. Papaya is a climacteric fruit with typical respiratory and ethylene production patterns during ripening. Therefore, for long-distance transport fruit must be harvested at optimum stage of maturity using maturity indices is extremely important

The fruit quality and self-life not only depend on stage of maturity at harvest but also on proper harvesting method and storage temperature The goals of harvesting are to pick the fruit at desired stage of maturity, with minimum loss due to damage. Papayas of correct stage of maturity can be hand picked or harvested by use of picking poles.

The papaya fruit has, however, a limited shelf life of less than a week under ambient tropical conditions Modified atmosphere can be used to increase the storage life Fruits did not ripen at 10°C or less temperature and that at 15°C. papaya could be stored successfully to maintain

their characteristics. Temperature between 13°C and 16°C have been found to be adequate for storing papaya(Robert,1997)

The most important post-harvest diseases of papaya are anthracnose (*Colletotrichum gloesporides*). Black rot (*Phoma caricae-papayae*) and Stem end rot (*Botryodiplodia theobromae*) Identification of the causes and the measures to control these diseases is important to reduce post-harvest loss of papaya. Mechanical damage has been reported as one of the major causes for these diseases because it influences the fruit to microbial infection (Snowdon,1990)

Occurrence of 'Green Islands' has been reported in papaya. Due to this abrasion and puncture injury, apparently induced areas of skin that remains green and sunken when fruit was fully ripe Therefore it is required to handle fruits carefully during harvesting, grading and transport (Eloisa *et al.*,1993).

High susceptibility to mechanical damage during transport is one of the major problems for the early harvesting of papaya Currently, papayas are harvested green mature stage of colour break stage resulting poor quality fruits. The major reason for high level of mechanical damage is poor packages used during transport. Tea-chests are widely being used and loose packing is also common among some traders.

Therefore experiments were conducted having following objectives

1. Find out the best stage of maturity that gives better quality of ripe papaya.
2. Study the possibility of storing papaya at 15°C.

CHAPTER-2

Literature Review

2.1 Origin

Papaya is a native to tropical America, but now it has fast spread all over the tropical world. Some of the popular names of this fruit in different countries are,

Papaw or pawpaw	-England	
Mamao	-Brazil	
Lechoso	- Venzuela	
Fruta bomba	-Cuba	
Papayer	-French	
melonenbaum	-Greman	
lechosa	-Spanish	
mamoeiro	-Portuguese	(Tropical fruit)

In SriLanka Tamil name -papaci
Sinhala name -Gas labu

2.2 Botany of papaya

2.2.1 Botanical classification of papaya

Family - Caricaceae
Genus - Carica
Specis - papaya

Papaya (*Carica papaya*), is a small-unbranched soft -wooded tree, "almost an herb" with latex vessels in all parts It has a melon like fruit that varies greatly in shape and size The skin is smooth and thin shading from deep orange or yellow when ripe to green The flesh varies from 2 5 to 5 0 cm in thickness and from light yellow to deep salmon-pink in colour Numerous

round black, wrinkled seeds, each enclosed in a gelatinous membrane (sarcotesta), cling to the inner wall Seedless fruits have also been known to occur.

There is a wide diversity of biological type of cultivated papaya, which may be dioecious (with male and female flowers on the same plant) of hermaphrodite (with male and female parts on the same flowers) (Arriola *et al* ,1980; wills, 1990)

Not all papaya trees bear fruit. The ones that do are female and the male trees only fertilize them The sex of the plant becomes apparent when it flowers, about six months after close to the stem, one on the axil of each leaf. The flower is large, bell shaped and the colour of wax; when ready to be fertilized, it turns white and begins to open. The flowers of male plant hang from very long stalks in clusters (Paull,1993)

2.2.2 Pollination and fruit set

In normal bisexual lines, the anthers extend directly over the stigmatic rays, ensuring automatic self-pollination, even when flowers are bagged to prevent cross pollination. Pollen should be placed upon the stigma before bagging. Self-incompatibility in cultivars is relatively rare, although they are isolated

2.2.3 Fruit

The fruit superficially resembles a melon, being spherical, pyriform, oval or elongated in shape Fruit from female trees are spherical and those from hermaphroditic trees can show diverse shapes depending upon modifying factors affecting flower morphology during ontogeny Fruit size ranges from 255g to 6 8kg, with flesh thickness from 1 5 to 4 cm The fruit is normally composed of five carpels, united to form a central cavity containing the seeds The fruit-seed cavity can be star-shaped to round Placentation is parietal, with the seeds attached by a 0 5-1mm stalk The seeds are dark grey to black when mature and enclosed in a sarcotesta Parthenocarpy in papaya is rare seedless fruit or fruit with very low seeds can be produced on female trees and are generally smaller in size. Fruit colour is white in immature fruit to a pale orange yellow, salmon-pink or red, depending upon cultivar, in ripe fruit Total fruit starch declines from0 4% to les than 0 1% during the first 80 days of fruit development Flesh total soluble solids can be as low as 5% up to 19%(Paull *et al* ,1997)

Green fruit contains and abundance of milky latex, which contains the protease papain. The pericarp consist of a network of lacticifers, which develop close to the vascular bundles and anastomose profusely through out the fruit. Lacticifers collapse as the fruit ripens and there is little or no latex at the fully ripe stage(Arriola *et al* .,1980).

2.3 Harvest maturity stages:-

Fruit should be harvested when skin color changes from dark green to light green and when one yellow streak begins developing from the base of the fruit upward. Picking of fruit at the required maturity ensures good quality for consumption, suitability for storage and transport, normal ripening, and conformity with market specifications(Saluke,1984).

2.3.1 Fruit maturity indices

Common indices used for determining maturity include skin colouration, sweetness (measured as Brix) latex taste and texture(Saluke,1984).

2.3.1.1 Peel colouration

This is the most commonly applied index of maturity In general, fruit should be picked on the appearance of a skin colour change from deep to light green with one yellow streak at the blossom end These firm mature-green fruit under controlled environmental conditions (10-12^{0}C, 85-90% R H) can further extend storage life to 14 days An additional period of 4-5 days at 20^{c}C is required for development of good colouration and flavour

2.3.1.2 Sweetness

The sweetness of the papaya pulp or juice can be measured by sampling a representative number of fruits The test involves the removal of a small portion of the pulp, and measurement

of soluble solids (sugar) content of the juice with a refractometer, which gives the direct sweetness level in Brix (%sugar) The test can be carried out in the field or pack house with a portable refractometer (Maharaj and Sankat,1980).

The desired level of Brix depends on the form in which the fruit is traded(ie.fresh or processed) and on market specifications Most domestic fresh fruit markets in the Caribbean accept fruits having a minimum Brix of 9%, while the majority of extra-regional markets require a minimum of 11% Under normal conditions, the Brix will be higher during the dry season and lower in the wet season

The use of sugar contents as a maturity index is not as easily applied in the field as is surface colouration The measurement of ^{0}Brix during the production cycle is necessary, however, as a quality control check which enables the grower to guarantee minimum sweetness levels, and to monitor and modify the cultural practices accordingly.

2.3.1.3 Texture

The use of texture as a maturity index is not recommended for papaya, since 'feeling' the fruit may cause injury and soft fruit are rejected.

2.4. Harvesting methods

Papaya can be harvested either directly by hand or with the use of various types of harvesting aids and equipment When harvesting without using proper methods, result in losses due to damage of fruits Regarding to farmers level there are some recommended aids in low cost They are hand picking, pole and catching system, papaya harvester

2.4.1 Manual harvesting

Manual methods predominate in the harvesting of papayas Although they tend to be slow and in some countries very costly they do offer the advantages of accurate selection for maturity and low levels of fruit damage Care must be taken not to detach fruit to close to either

of the abscission layers (Point of attachment of peduncle to stem or to the fruit) since this may lead to infection of both the plant and the fruit.

As the papaya tree continues to grow, the use of harvesting aids becomes necessary. Such aids include various types of picking poles, ladders and picking platforms.

2.4.2 Picking poles

These range from sample lengths of wood or bamboo, to pole-and-cup/bag devices. In the case of simple poles, during actual picking, one hand is used to hold the pole and prod the peduncle of the fruit, while the other tries to catch the papaya when it falls.

2.5 Ripening Process

2.5.1 Ethylene production

Ethylene gas is the ripening agent which produces naturally by ripening fruits. It causes fruits to ripen & decay, vegetable & floral to wilt. Controlling ethylene gas after picking will extend the storage life of commodity-allowing them to be held for a much longer period of time. While refrigeration & humidity slow decay, they don't halt the production of harmful ethylene gas

Table 2.1

Ethylene production and sensitivity levels

Fruit	Rate of ethylene Production	Level of ethylene sensitivity	Principal reaction to ethylene gas
Papaya	High	High	Sprouting

Source http //www ethylenecontrol com/about html

Physiologically, the papaya is a climacteric fruit (Jones, 1942; Akamine, 1966; and Selvaraj *et al*.,1982) with typical respiratory and ethylene production pattern during ripening. At the onset of ripening, respiration rises to a maximum (the climacteric peak) and subsequently declines slowly (Paull and Chen ,1983)

The respiratory climacteric is just preceded with a similar pattern of increased ethylene production (Paull and Chen,1983) Ethylene, the simple of the organic compounds affecting the physiological process of plant, is a natural product of plant metabolism and is produced by all tissues of higher plants

Pal and Selvaraj (1987) observed an increasing trend of mitochondrial protein and RNA content until harvest maturity (145days) which declined thereafter, while DNA content decreased from 110 days. They suggested that the increased protein and RNA contents are associated with an increased synthesis of enzymes that catalyse the ripening proceses.

According to Paull,(1983) the amino acid methionine is converted to S-adenosylmethionine (SAM) which is the precursor of 1-aminocyclopropane-1-carboxylic acid (ACC), the immediate precursor of ethylene(Johnson *et al.*,1999). ACC synthase, which converts SAM to ACC, is the main site of control of ethylene biosynthesis. The conversion of ACC into ethylene is mediated by an enzyme (ethylene forming enzyme, EFE or ACC oxidase).

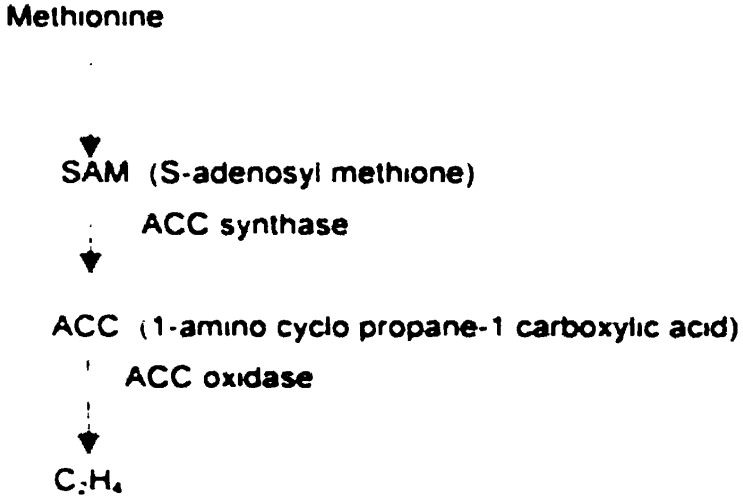

Fig 2 1

Generally C_2H_4 production rates increase with maturity at harvest, physical injuries, disease incidence increased temperature up to 30°C and water stress

It reduced by storage at low temperature, by reduced O_2 (less than 8%) levels, and elevated CO_2 (more than 2%) levels around the commodity.

2.6 Compositional changes

Many changes in pigments take place during development and maturation of the commodity on the plant (Firmin,1997).

1 loss of chlorophyll
2 development of carotenoids
3 break down of pectins and other polysaccharides results in softening of fruits and consequent increase in susceptibility to mechanical injuries.

Changes in organic acids, proteins, aminoacids and lipids can influence flavor quality of commodity Loss in vitamin content, especially ascorbic acid (vit C) is detrimental to nutritional quality

2.6.1 Change in papaya cell walls and fruit softening during ripening

The apparent molecular mass range of different extractable fractions of papaw fruit pectin and hemicellulose during fruit ripening has been determined by analysing fruits of cv Sunset at the 30 50 60 and 100% yellow stages The pectin molecular mass declined and the solubility of pectin in cyclohexane-diamino tetraacetic acid and Na_2CO_3 solutions increased during ripening The molecular mass decreased and the solubility of hemicellulose in KOH increased during ripening as the yield of cell wall material declined The loss of high molecular mass pectins decreased throughout ripening while the demethylation rate was greater early in

ripening Changes in pectin molecular size did not parallel loss of fruit firmness during early ripening. The pectin fractions were mainly composed of rhamnose, glucose, xylose, galactose,mannose and arabinose, in decreasing order of concentration. Non cellulose fraction, followed by mannose and galactose and traces of rhamnose and arabinose. The results suggested that pectin hydrolysis and the modefication of hemicellulose were both involved in papaw fruit softening. Pectin hydrolysis was apparently more important during the late phase of fruit softening (Paull,1999)

2. 7 Factors affecting fruit quality

2.7.1 Maturity

Papaya fruit accumulate sugars in the final phase of development (chan *et al.*,1979); fruit are therefore not harvested until the skin colour shows some yellowing (Akamine and Goo,1971) Less mature fruit ripen poorly, with lower total soluble solids and therefore should be culled

2.7.2 Abrasion/Impact

Papaya fruit are very susceptible to abrasioin injury (Quintana and Paull,1993). Abrasion injury can be caused by a drop of as little as 5cm onto a plywood. Impact injury is a problem for fruit with 40% or more colour(Robert. E,1997)

2.7.3 Storage temperature

Papaya fruit at colour-turning stage can be stored at temperatures as low as 7°C for not more than 14 days, and will ripen normally when transferred to room temperature (Thompson and Lee 1971, Chen and Paull. 1986) Symptoms of chilling injury occur after 14 days at 7°C for mature green fruit (Table 2 3) and 21 days for 60% yellow fruit (Chen and Paull,1986) chilling injury symtoms include skin scald, hard lumps in the pulp around the vascular bundles.

water soaking of flesh and greater susceptibility to decay (Thompson and Lee, 1971; El-Tomi *et al*. 1974 Chen and Paull,1986).

Table 2.2

Requirements for papaya ripening and storage: relative humidity should be in the range 85-95%.

Ripenness	Description	Storage temperature and maximum days in storage	Ripening temperature and days to ripen
Mature green	Entire surface green, tinge of yellow colour on the pulp and black seeds. Fruit will ripen normally.	10°C,<14 days	22.5-27.5°C, 10-16 days.
Colour turning (breaker)	Farely visible yellow streaks emanating from the blossom end.	7°C,<17days	22.5-27.5°C, 7-10 days
Quarter-ripe	One-fourth of the skin surface is yellow	7°C,<21 days	
Half-ripe	Half of the skin surface is yellow	7°C,<21 days	
3/4 -ripe	Three-fourths of the skin surface is yellow	7°C,<21 days	

Source Robert E Paull *et al* (1997)

2.7.4 Ethylene treatment

Ethylene-treated papayas ripened faster and more uniformly as a cohort in terms of skin degreening, softening and flesh color (Ann and Paull,1990). Since papaya ripen from the inside outwards the effect of Ethylene treatment is to accelerate the rate of ripening of the mesocarp tissue nearer the skin that has not started to soften. The already well-softened mesocarp that is near to the seed cavity is not responsive to ethylene.

2.8 Diseases

The major post harvest diseases are anthracnose, Rhizopus rot, stem end rot and black spot (Table 2.3) Post harvest diseases, especially anthracnose, become a problem when fruit have 25% or more skin yellowing (Wardlaw *et al.*,1939; Alvarez and Nishijima, 1987). Papaya diseases greatly increase in severity and incidence following 4 weeks storage at 10^{0}C. The inter-relation ship of mechanical injury and storage disorders (chilling injury) on the development of post harvest disease incidence has not been fully determined (Somner and mitchell,1978;Alvarez and Nishijima,1987; Nishijima *et al.*,1990) cuticle disruption occurs as latex vessels breakdown, when the fruit is 40-60% yellow. (Paull and chen; 1989) Fruit fly punctures can also increase *Rhizopus* rot (Hunter and Buddenhagen,1972) as can mechanical injuries and fruit lesions caused by fungi such as anthracnose and *Cercospora* black spot (Nishijima *et al*.1990) Post harvest diseases are effectively controlled by hot water (20min.49^{0}C) (Akamine and Arisumi 1953; Coaey *et al.*,1984) and thiabendazole (Couey and Fanas, 1979)

Table 2.3

Major postharvest diseases of papaya and control measures.

Disease	Symptom(s)	Control
Anthracnose. Chocolate spot. Grey-depressed lesion. *Colleotrichum gloesporioides*(Penz)Sax	Small, round, depressed areas on ripening portions of the fruit. The spots enlarge rapidly during fruit ripening forming circular, slightly sunken lesions. Green portions of th papaya may become affected and the disease appears as small,water-soaked lesions. These lesions enlarge very slowly and rarely become larger than 12mm in diameter as long as the fruit remain green.	Decay occurring in storage can be reduced by hot water treatment (20min,49^{0}C). Separate infected fruit. To salvage the fruit, cut out the infected area and wrap the fruit with plastic wrap for resale
Rhizopus fruit rot (*Rhizopus stolonifer* (Herex Fr)Lind)	Rhizopus invades injured mature fruit only, and does not usually cause rot in sound uninjured immature fruit	Hot water dip (20 min,49^{0}C) Rotting fruit should be disposed of to prevent spreading the disease.
Stem-end rot various fungi	A dry, film, dark rot extends into the fruit starting at the stem end	Hot water dip(20 mn,49^{0}C)

Black spot (Alternaria alternata (Fr Keisoler))	Tiny, dark raised spots which turn black and enlarge to 0.75-3mm in diameter. The tissue just beneath the epidermis of the fruit becomes corky but the spot does not develop into a fruit rot.	No postharvest control. Cosmetic

Source Robert E.Paull *et al.*, (1997)

2.8 Important of papaya

2.8.1 Nutrition

Rich in sugars, the papaya fruit contains digestive enzymes and vitamins. The ripe fresh papaya is used as table fruit throughout the tropics. Unripe fruits are commonly eaten, cooked as a vegetable The young leaves are also consumed as vegetable.

Table 2.4

Composition and food value of papaya fruit

Composition	Quality (per cent)
Moisture	89.6
Carbohydrates	9.5
Protein	0.5
Fat	0.1
	(per 100g)
Calorific value	40
Calcium	0.01
Phosphorus	0.01
Iron	0.4
Carotene (IU/100g)	2,020
	(mg/100g)
Thiamine (B1)	40
Riboflavin (B)	250
Nicotinic acid	0.2
Ascorbic acid (vitamin C)	46

Source Anonymous, 1941, Health bulletin no:23

2.8.2 In medication

Papaya is one of the rare fruits recommended even for the diabetics The vitamin A abundant papaya also improves the eyesight The fruits are prescribed in piles, dyspepsia liver, spleen and several digestive disorders The roots of papaya possess the qualities of a nerve tonic A slice of papaya fruit rubbed over the skin is said to remove many skin disorders Papain an enzyme extracted from the fruits is used in the treatment of dyspepsia and similar digestive ailments, scorpion- and insect -bites, and displaced disc in the spinal cord It is an essential ingredient in various pharmaceutical preparations like glycine papain liquid papain as indine, digestive mixtures and liver tonics In liquid preparation, has been used for reducing

enlarged tonsils, prevention of post-operative adhesions, treatment of sloughing worms, burns and for dissolving the membrane of diphtheria. The decoction obtained from the dried leaf is considered very good for heart ailment and cancer. The seeds of papaya also have certain medicinal properties (Irulappan, 1992).

2.8.3 Industry

Fruits are used in the preparations of jelly, candy, nectar, slab, toffee, canned papaya, pickle, ready-to-serve beverage, jam, several dehydrated and frozen papaya products and concentrates Papaya fruits are also used for the extraction of pectin, and dried pectin has a jelly grade of about 220.

Papain is used for chill-proofing of beer, meat tenderization, degumming of silks and rayons. Pre-shrinking of wool, curing of leather, fish and in pharmaceuticals

Table 2.5
Export of fresh fruits,

1990		1991		1992		1993		1994	
Kg	Rs	Kg	Rs	Kg	Rs	Kg	Rs	Kg	Rs
1670	41140	6010	181330	6309	387588	2147	307303	1010	11705

Source: Customs returns,(EDB)

CHAPTER-3

Materials and methods

3.1 Experiment 1: Effect of stage of maturity harvest, on quality of papaya

Papaya variety 'Rathna' was purchased from Agricultural Research center at Girandunakotte. Fruits were catagorised into five groups of maturities at mature green stage to 75% yellow colour development. The categories of maturity used were

1-Dark green peel
2-Mature, tinged o f yellow colour
3-25% colour development
4-50% colour development
5-75% colour development

Harvested fruits were packed in ventilated plastic crates vertically stem-end down to minimize compression damage during transport Packed crates were then transported to laboratory at Food Research Unit Gannoruwa Fruits were then cleaned by a piece of cloth to remove dust and other foreign matters Fruits were catagorised into 5 stages of maturity Each fruit was weighed and peel colour was recorded and left at ambient temperature (25^{0}C) to ripe. Percentage weight loss, peel colour development and disease severity were recorded, until fruits become fully ripe Fruits were analysed for physico chemical analysis at full ripe stage The parameters tested were flesh colour, total soluble solids, titratable acidity, sweetness and over all acceptability

3.2 Experiment 2: Effect of storage temperature on quality of papayas.

Rathna variety fruits of different stages of maturity 1-5 were harvested from Girandurukotte Agricultural Research Station. Fruits were carefully transported to the laboratory. Fruits of each maturity stage were weighed and divided into two groups and one group was transferred into a cold room maintained at 50°C The remaining group of fruits were stored at ambient temperature 23°+3°C.

Percentage weight loss, peel colour development, Total soluble solids, severity of disease development, titratable acidity (citric acid), Visual Quality Ranging were recorded periodically similar to the experiment 1. Observations were recorded daily in fruits stored at ambient temperature, and fruits stored at 15°C the duration was 5 days.

Observations were recorded as following Physico-Chemical parameters,

1- Percentage weight loss (moisture loss)
2- Peel colour Index
3- Flesh colour Index
4- VQR (visual quality rating Index)
5- Disease severity Index
6- TSS(total soluble solids)
7- Titratable acidity(Citric acid)
8- Sensory Evaluation

3.3 % of weight loss(moisture loss)

Weight of each replicate was measured daily and 7day intervals, at ambient temperature and 15°C respectively by using digital Electronic balance The reduction in weight was expressed as percentage of weight loss

3.4 Indexes used in this study

All replicates were checked using following indexes during period of storage.

3 4 1 Peel colour index used for colour recording

1-Green

2-Trace of yellow (colour break)

3-More green than yellow

4-More yellow than green

5-Full yellow

6-Over ripe

3 4.2. Flesh colour index

1-Pale

2-Slightly pale

3-Dark

4-Very dark

3 4.3 Disease severity index

0-No disease

1-1-10% disease

2- 11-20% disease

3-21-30% disease

4-More than 30%

3 4 4 VQR (Visual quality rating index)

1-Non. edible. for most discolouration and shriveling (limit of edible)

2-Slight edible up to 10% of surface affected

3-Moderately edible up to 10% of surface affected limit of edible

4-Severe. more than 25% of surface affected

5-Fair. defects moderate defect

6-Little, more fair, slight defects

7-Good, slight defects

8-Better, slight defects

9-Excellent

3 4 5 Green Islands and green patches index

1-Non

2-Slight

3-Moderate

4-Very high (Maria and Quintana, 1993)

Finally for consumer acceptability, sensory evaluation was carried out using 6 member trained taste panel at Food Research Unit.

3.6 Determination of Titratable acidity

Acidity of fruit was expressed in terms of Citric acid content. Amount of Citric acid in the sample was estimated by titrating with Standard NaOH solution(0.01), using phenolphthalein as an indicator

The fruit extract was prepared by, first peeled and seeds were removed by opening the opened fruit Then middle portion of the pulp about 30g was taken and grinding in a motor and pestle, filtered into a container by using muslin cloth and the filtrate was quantitatively transferred into a measuring cylinder

After adjusting the volume, a portion of the extract(5ml) was taken into a 250ml volumetric flask and making the volume up to the mark with distilled water A portion of the above (50ml) extracted was titrated against 0 01N NaOH solution until the end point The titratable acidity was calculated as follows

$$\text{Titrable Acidity} = \frac{V*N*0.06404}{W} * 100$$

Where

V=Volume of 0.01N NaOH solution required to neutralize whole sample(ml)

N=Normality of NaOH

W=Weight of the sample

3.6 Determination of Total soluble solids (Brix value)

Fruit juice was extracted by using a grounded sample of papaya fruit in motor and pestle. Brix value of the extract was measured by using a hand held refracto meter.

3.7 Sensory Evaluation

A consumer preference test was carried out to evaluate the quality of different maturity stage of papaya Sensory properties colour, latex taste, sweetness, over all acceptability were investigated using a descriptive sensory analysis score card Samples were given to a trained taste panel which consisted of 10 members at Gannoruwa Food Research Unit, Kandy were selected for this purpose Panelists were assigned to individual booths for the evaluation. Each booth was facilitated with drinking water to rinse mouth in between tasting.

Each tasting booth was sufficiently illuminated and the panelist were served with a score card for the descriptive analysis with scaling (See appendix 1). The panelists were requested to mark a vertical line across the horizontal line at the point that reflects his perception of the magnitude of the properties assessed

After the panelists had completed their judgements the scores were tabulated by measuring the length from the left end to the vertical line made by the panelists These data

were then analyzed using ANOVA and DMRT5%, to select a satisfactory stage of maturity to give good quality papaya

Chapter –4

Results and Discussion

Table 4.1. Shows the percentage weight loss of papaya stored at ambient temperature was higher at advanced maturity stages. The significant increase in weight loss at 3 and 4 days at ambient temperature was continued to be increased with the stage of maturity. It can also be seen from the table the percentage weight loss of papaya stored at ambient temperature loose very high amount of moisture when fruits were at advance stages of maturity. Fruits of 50% colour development and 75% colour development were ready to eat stage at 4 days. However, fruits of other maturities were not ready to eat at 4days. These fruits continued to be increased the weight loss until they reach ready to eat stage. The percentage weight loss of papaya stored at 15°C for 12 days however, lost moisture in early stages of maturities. Fruits of 75% colour development stage were not ready to eat stage at 12 days at 15°C. However, those fruits ripened within 1-2 days upon transfer to ambient temperature. The higher levels of moisture loss in fruits stored at ambient temperature may be due to completion of the ripening process. Since papaya is a climacteric fruit it can loose more moisture and stored food for completion of ripening (Akamine, 1966, Paull and Chen, 1983). Delayed ripening of fruits at 15°C may have reduced the weight loss However, the very high level of weight loss in less mature fruits stored at 150C has to be studied

Table 4.1. Mean percentage weight loss of papaya stored at ambient and 15°C for 4 and 12 days respectively.

Stage of maturity	% weight loss		
	Storage period at ambient T°		Storage period at 15°C
	3 days	4 days	12 days
Dark green peel	10.4d	16.6d	22.5a
Mature tinged of yellow colour	11.1c	17.7c	18.5b
25% colour development	13.2b	21.2b	15.6c
50% colour development	14.8a	24.9a	14.5d
75% colour development	14.6a	24.5a	11.2e

Treatment means in a column having a common letter(s) are not significantly different by DMRT 5% Each data point represents a mean of at least 5 samples

The percentage peel colour development of papayas stored at ambient temperature was higher with advanced maturity stages (Table 4.2). The significant increase in peel colour development at 3 and 4 days at ambient temperature was continued to be increased with the stage of maturity It can also be seen from the table higher percentage colour development was higher when fruits were at advance stage of maturity. Fruits of 50% colour development and 75%colour development were ready to eat at 4 days. However, fruits of other maturities were not ready to eat at 4 days. These fruits continued to be increased the colour development until they reach ready to eat stage. The percentage colour development of papaya stored at 15^{0}C for 12 days however, colour development is high in advance staged of maturities. Fruits of 75% colour development stage were not ready to eat stage at 12 days at 15^{0}C. However, those fruits ripened within 1-2 days upon transfer to ambient temperature.

The higher levels of colour development in fruits stored at ambient temperature may be due to loss of chlorophyll during ripening. Since papaya is a climacteric fruit, during ripening the colour of the pulp turns reddish. In red-fleshed cultivars, however, the change in colour is associated with increase in lycopene content (Selvaraj *et al.*, 1982). Delayed ripening of fruits at 15^{0}C may have decreased the colour development. However, the lower levels of colour development in less mature fruits stored at 15^{0}C an ambient temperature has to be studied

Table 4.2. Mean percentage peel colour development of papaya stored at ambient and 15°C for 4 and 12 days respectively (–transformation)

Stage of maturity	% colour Development		
	Storage period at ambient T°		Storage period at 15°C
	3 days	4 days	12 days
Dark green peel	1.5b	1.4c	1.6b
Mature tinged of yellow Colour	1.6b	1.7b	1.6b
25% colour development	1.8ab	1.9b	2.1a
50% colour development	2.1a	2.2a	2.2a
75% colour development	1.9a	2.3a	2.2a

Treatment means in a column having a common letter(s) are not significantly different by DMRT5% Each data point represents a mean of at least 5 samples.

Colour index

1-Green

2-Colour break

3-More green than yellow

4-More yellow than green

5-Full yellow

6-Over ripe

There was no significant difference in VQR among different stages of maturities (Table 4 3) Although the VQR of papaya stored at 15°C had low values at early stages and high levels at advance stages, those were not significant

The lower levels of VQR in fruits stored at ambient temperature may be due to Green patches, Green Islands and microbial infection. Since papaya is a climacteric fruit during ripening, fruit become soft, therefore it is susceptible to microbial attack and deteriorates Delayed ripening of fruits at 15°C may have reduced the deterioration. However, the very high levels of VQR in mature fruits stored at 15°C may be due to low temperature arrest of pathogen growth

Table 4.3. Mean percentage visual quality rating of papaya stored at ambient and 15°C ($\sqrt{}$ - transformation)

Stage of maturity	% Visual Quality Rating	
	Storage period at ambient	Storage period at 15°C
Dark green peel	2 8a	1.8a
Mature tinged of yellow colour	2 5a	1.8a
25% colour development	2 6a	2.0a
50% colour development	2 5a	2.7a
75% colour development	2 1a	2.3a

Treatment means in a column having a common letter(s) are not significantly different by DMRT 5% Each data point represents a mean of at least 5 samples

VQR index

1-Non edible

3-Moderately edible

5-Fair

7-Good

9-Excellent

Table 4.4 Shows the percentage Total Soluble Solids of papaya stored at ambient temperature was not significantly difference among maturity stages The percentage Total Soluble Solids of papaya stored at 15°C had significant different however, having high values at 50% to 75% colour development stages of maturities. Fruits of this stage were not ready to eat stage at 12 days at 15°C However, those fruits ripened within 1-2 days upon transfer to ambient temperature

The similar levels of TSS in fruits stored at ambient temperature may be due to completion of the ripening process Since papaya is a climacteric fruit (Akamine, 1966; Paull and chen, 1983) when fruits were harvested at the colour break stage, the climacteric respiration peak is observed about 6 days after harvest (Paull and Chen,1983) and also papaya fruit with at least 3% skin yellowing meet the state requirement of 11 5% soluble solids (Akamine and Goo, 1971) Delayed ripening of fruits at 15°C may have low TSS in early stages of maturity. These values could be increased with the completion of ripening process upon transfer to ambient temperature

Table 4.4. Mean percentage Total Soluble Solids of ripened papaya stored at ambient and 15°C.

Stage of maturity	% TSS content (°Brix)	
	Storage period at ambient T°	Storage period at 15°C
Dark green peel	9.4a	8.3c
Mature, tinged of yellow colour	11.1a	9.4b
25% colour development	10.3a	9.2b
50% colour development	10.8a	10.7a
75% colour development	10 4a	10.4a

Treatment means in a column having a common letter(s) are not significantly different by DMRT 5% Each data point represents a mean of at least 5 samples.

Table 4.5 Shows the percentage severity of disease of papaya stored at ambient temperature and at 15°C was not significantly different among stages of maturities It was observed that presence of anthracnose rot the main problem in all the maturity stages. However, wound infection of other diseases especially in less matured fruits causes relatively high disease incidence when they ripe to table ripe stage. It was also noted that relatively higher incidence of disease incidence in fruits stored at 15°C.

Maximum flesh colour, sweetness and overall acceptability and minimum latex taste observed in 75% colour development maturity shows the best quality ripened fruits can be obtained if fruits are harvested at that stage (Table 4.6). However, high susceptibility to mechanical damage during transport does not permit to harvest fruits at that stage of maturity and therefore fruits can be harvested at 25% to 50% colour development stages. Latex taste in the major problem in sensory properties of ripened papaya. The highest latex taste was recorded when fruits were harvested at tinged of yellow colour stage. Overall acceptability of fruits is the main parameter determine the consumer acceptability. Table 4.6 shows the highest acceptability was recorded at 50% to 75% colour development stages.

Table 4.5. Mean percentage Disease severity Index of papaya stored at ambient and 15°C ($\sqrt{}$ - transformation)

Stage of maturity	% Disease severity Index	
	Storage period at ambient T°	Storage period at 15°C
Dark green peel	0.7a	1.0a
Mature. tinged of yellow	0 9a	1.0a
Colour		
25% colour development	1.1a	0.9a
50% colour development	0.8a	1 1a
75% colour development	1.0a	1 1a

Treatment means in a column having a common letter(s) are not significantly different by DMRT5% Each data point represents a mean of at least 5 samples

Disease index

0-No disease

1-1-10% disease

2-11-20% disease

3- 21-30% disease

4- more than 30% disease

Table 4.6. Percentage flesh colour, Latex taste, Sweetness and Over all acceptability of ripened papaya stored at ambient temperature.

Storage of maturity	% Results of Sensory Evaluation			
	Storage period at ambient temperature			
	Flesh colour	Latex taste	Sweetness	Over all accep.
Mature tinged of yellow colour	70.9d	32.8a	64.2c	63.3c
25% colour development	76.2c	18.0c	63.3c	69.5b
50% colour development	79 7b	17.0c	71 4b	74.9a
75% colour development	85.2a	23.0b	76.7a	73.2a

Treatment means in a column having a common letter(s) are not significantly by DMRT 5% Each data point represents a mean of at least 10 samples.

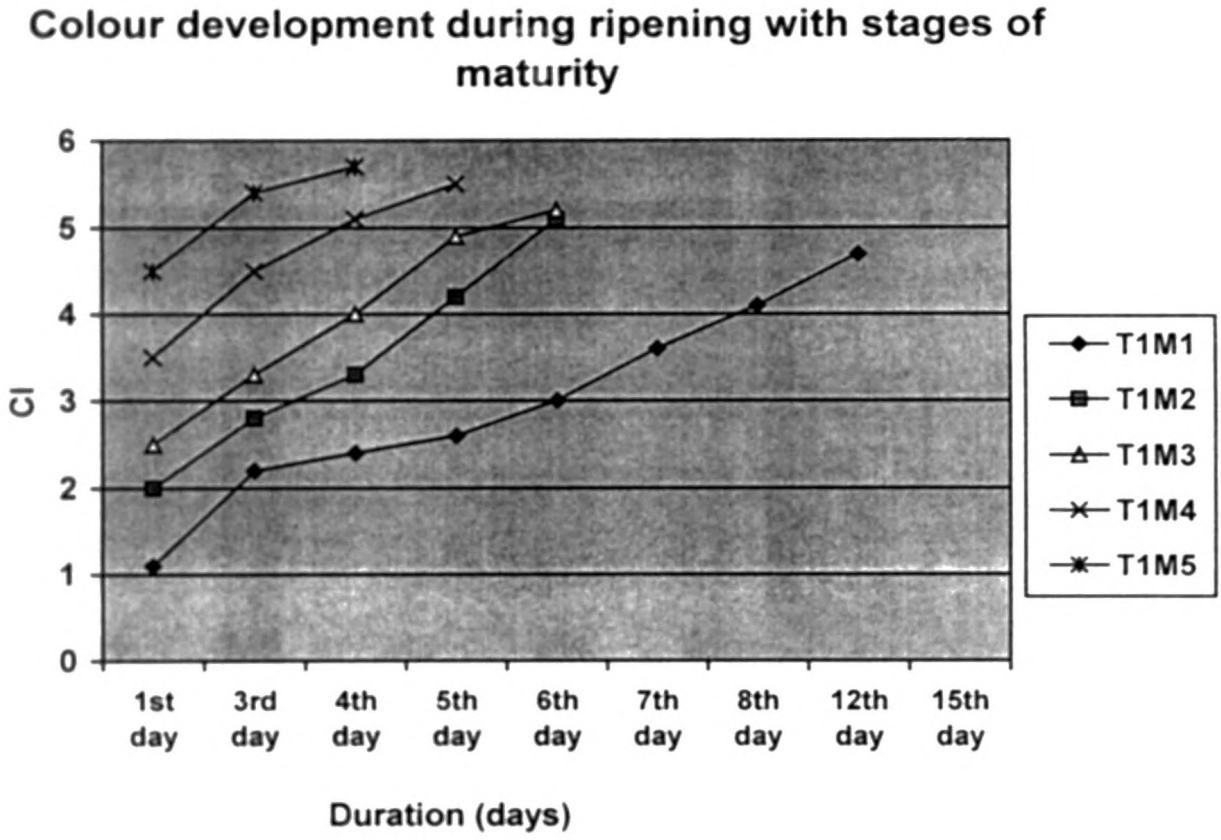

Figure 4.1 Colour development with ripening of papaya.

T1- Stored at an ambient temperature

M1- Dark green peel

M2-Mature tinged of yellow colour

M3-25% colour development

M4- 50% colour development

M5- 75% colour development

The highest peel colour development was recorded in fruits harvested at 50% -75% peel colour development (Fig 4.1). Although fruits harvested at colour break stage develop peel colour it was less with compared to those in 50%-75% peel colour developed fruits.

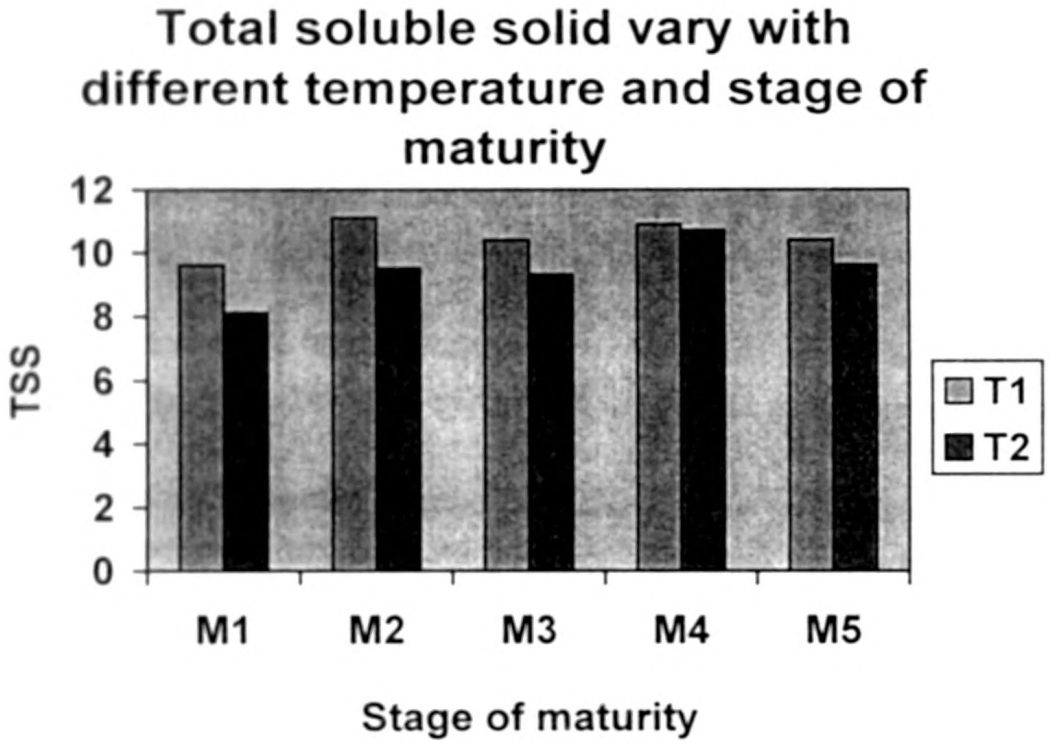

Figure 4.2 Total soluble solid at ripened papaya.

T1- stored at an ambient temperature

T2- stored at 15°C

M1-dark green peel

M2- mature tinged of yellow colour

M3- 25% colour development

M4- 50% colour development

M5- 75% colour development

Fig 4.2 shows the Brix value of ripened fruits of all maturity stages reached a reasonable level indicating that ripening process has been continued. Sugar content of the pulp therefore was not affected by stages of maturities tested in this experiment.

General Discussion

Results showed that fruit harvested at early stages of maturities developed less peel colour compared that in more mature fruits However, less mature fruits took a long time to developed peel colour, during that time fruits were more susceptible to diseases.

As far as VQR, ^{0}Brix, Titratable acidity of ripened papaya are concerned there was no effect of maturity stage However, percentage weight loss and colour index behaved in opposite way.

Taste panel scores showed particularly those for flesh colour, sweetness and over all acceptability was higher in mature fruits. The latex taste was minimum in those fruits. But sweetness scores were low for all fruits, due to inherent character of the variety.

Based on these results papayas of 'Rathna' variety must be harvested at atleast 50% peel colour development stage High susceptible to disease and less VQR of fruits harvested early maturity indicated that those maturity stages should not be harvested commercially. This variety of papaya can successfully be stored at 15^{0}C for export.

The inherent quality of firmness at advance stages of maturity furthers permit to harvest these fruits at 50% peel colour development Harvested fruits at this stage must be transported carefully as a single layer in a suitable package

Chapter -5

Conclusions

The commercial practice of harvesting papaya at colour break stage cannot be applied for 'Rathna' variety If papaya harvested at colour break stage and green mature stage peel colour development proceeds but quality of ripened papaya was poor. In addition, high susceptibility to diseases of papaya harvested at colour break stage and green mature stage results in very high Postharvest loss Papaya harvested 25% and above gave good quality fruits with lesser disease incidence Relatively high flesh firmness of this variety even at 50% peel yellow colour stage allows to transport without considerable damage. However, fruits of this stage maturity must be transported enclosing in a Styrofoam net in plastic crates to minimize mechanical damage Fruits of 25% or above colour development can successfully be stored at 15^{0}C for 2 weeks Normal ripening of fruits upon removal from the cold room permits to export this variety in large-scale by sea High disease susceptibility of green and colour break fruits show fruits must be harvested at least 25% colour development stage. The reasons for high susceptibility to disease when fruits are harvest relatively low levels of maturity have to be studied.

CHAPTER-6

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CHAPTER-7

APPENDIX-1

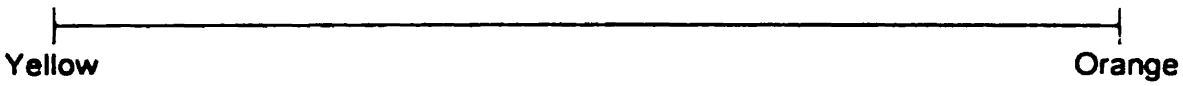
Discriptive Analysis with scaling

Name - Cl:-

Date:-

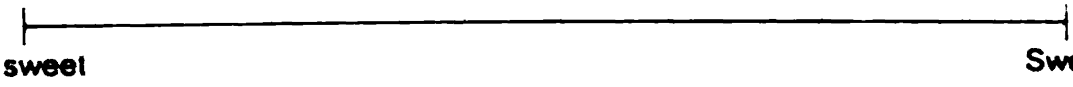
Please Evaluate the sweetness, colour, latex taste and over all acceptance of the samples Make vertical lines on the horizontal line to indicate your rating of each sample Label each vertical lines with the code number of the sample it represent.

1. Colour

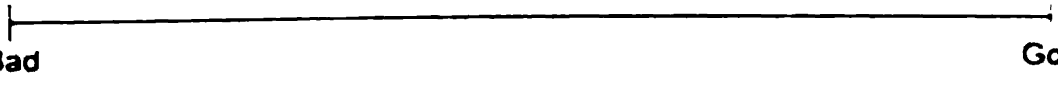


2. Latex taste

3. Sweetness



4 Over all acceptability



Any other comments

Appendix -2

Table for wtloss .stored at 15 °C for 12th days

maturity	1	2	3	4	5	Total	Mean
M1	51 26	26 11	13 48	8 2	13 88	112 93	22 586
M2	8 7	12	15 1	20 76	5 79	62 35	12 47
M3	25 74	19 92	9 03	9 57	13 8	78 06	15 612
M4	16 94	13 13	8 51	24 49	9 36	72 43	14 486
M5	12 46	17 13	11 55	6 49	8 5	56 13	11 226
Grand						381 9	15 276

Analysis of variance for % weight loss stored d at 15° C for 12 dayss

SV	df	ss	ms	F	Tabular	
					5%	1%
Maturity	4	392 246	98 061	1 1046	2 87	4 43
Error	20	1775 507	88 775			
Total	24					

Table for wtloss.stored at ambient T °C for 4 days

Maturity	1	2	3	4	5	Total	Mean
M1	15 48	9 65	15 27	23 28	19 49	83 17	16 634
M2	21 17	13 68	18 85	21 57	13 32	88 59	17 718
M3	22 96	21 05	14 12	24 75	23 34	106 22	21 244
M4	21 92	29 4	18 66	28 85	25 67	124 5	24 9
M5	25 82	16 97	32 39	22 85	24 5	122 53	24 506
Grand						525 01	21 0004

ANOVA for wtloss stored atambient for 4 days

sv	df	ss	ms	F	Tabular	
					5%	1%
Maturity	4	287 06	71 76	8 887**	2 87	4 43
Error	20	161 488	8 074			
Total	24	448 548				

CV=13 53%

Table for wtloss. stored at ambient T° for 3 days

Maturity	1	2	3	4	5	Total	Mean
M1	10 05	6 03	9 16	14 86	11 9	52	10 4
M2	13 71	8 73	11 12	13 56	8 5	55 62	11 124
M3	14 3	12 8	8 23	16	14 7	66 03	13 206
M4	12 59	18 5	11 5	17 9	13 5	73 99	14 798
M5	15 22	10 99	19 44	14 01	13 2	72 86	14 572
Grand						320 5	12 82
Grand						589	13 304

ANOVA for wtloss. stored at ambient T° for 3days

sv	df	ss	ms	F	Tabular F 5%	1%
Maturity	4	79 319	19 829	9 82**	2 87	4 43
Error	20	170 95	8 547			
Total	24	250 276				
CV=22 8						
CV=3 38%	3 38					

Appendix -3

Table for colour development. stored at 15°C for 12 days

Maturity	1	2	3	4	5	Total	Mean
M1	2	3	2 5	4	1 5	7 952	1 59
M2	2	2	3	4	2	7 9746	1 594
M3	4 6	4 5	4 4	4 2	4 5	10 534	2 106
M4	5	5	5	4 9	5	11 157	2 2315
M5	5	5 3	5	5	5	11 246	2 2492
Grand						48 864	1 9544

ANOVA for colour development. stored at 15° C for 12 days

sv	df	ss	ms	F	Tabular	
					5%	1%
Maturity	4	2 243	0 5607	17 719	2 87	4 43
Error	20	0 6329	0 0316			
Total	24					
CV	9 10%					

Table for colour development. stored at ambient T° for 3 days

Maturity	1	2	3	4	5	Total	Mean
M1	1 8	2	2 8	2 3	2 1	7 392	1 478
M2	2 8	2 8	2 7	2 5	2 4	5	1 622
M3	3 4	3 4	3 1	2 8	3 2	8 898	1 779
M4	4 5	4 3	4 6	4 4	5	10 67	2 134
M5	5 2	5 5	5 5	5 6	5 4	11 659	1 943
Grand						43 619	1 7912

ANOVA for colour development.stored at ambient T°

sv	df	ss	ms	F	Tabular F	
					5%	1%
Maturity	4	5 615	1 403	3 392*	2 87	4 43
Error	20	8 276	0 4138			
Total	24	13 891				
CV=35 91%						

Appendix -4

Table for TSS, stored at 15 °C

Maturity	1	2	3	4	5	Total	Mean
M1	9 5	9 5	7 4	7 5	7 6	41 5	8 3
M2	10 5	8 6	9 5	8 5	10	47 1	9 42
M3	11 4	9 8	6 8	8 8	9 5	46 3	9 26
M4	10 5	10 6	11 4	11	10 2	53 7	10 74
M5	9 9	11 8	10 8	9 6	10	52 1	10 42
Grand						240 7	9 628

ANOVA for TSS, stored at ambient 15 °C

sv	df	ss	ms	F	Tabular F	
					5%	1%
Maturity	4	7 946	1 9865	2 242ns	2 87	4 43
Error	20	17 72	0 886			
Total	24	25 666				

Table for TSS, stored at ambient T °
TSS/23

Maturity	1	2	3	4	5	Total	Mean
M1	8 5	8 9	10 1	10 6	9 1	47 2	9 44
M2	10 2	11	11 4	10 9	12	55 5	11 1
M3	9 8	11	8 9	11	11	51 7	10 34
M4	10 3	11 6	10 5	11	10 7	54 1	10 82
M5	12 2	10 5	10 5	10 7	8 2	52 1	10 42
Grand						260 6	10 424

ANOVA for TSS,stored at ambient T °

sv	df	ss	ms	F	Tabular F	
					5%	1%
Maturity	4	7 946	1 9865	2 242ns	2 87	4 43
Error	20	17 72	0 886			
Total	24	25 666				

Appendix -5

Table for severity of disease, stored at ambient T°

Maturity	1	2	3	4	5	Total	Mean
M1	0	0	0	0	0	3 535	0 707
M2	1	1	1	1	0	4 707	0 9414
M3	3	1	0	0	1	5 146	1 029
M4	0	0	0	1	1	4 121	0 824
M5	1	1	1	1	1	5	1
Grand						22 509	0 90028

ANOVA for DI,stored at ambient T°

Sv	df	ss	ms	F	Tabular F	
					5%	1%
Maturity	4	0 357	0 089	2 041ns	2 87	4 43
Error	20	0 874	0 0437			
Total	24	1 231				

CV=23 21

Table for severity of disease, stored at 15 °C

Maturity	1	2	3	4	5	Total	Mean
M1	1	0	3	0	1	5 146	1 029
M2	0	1	3	0	1	5 146	1 029
M3	1	1	0	1	1	4 707	0 941
M4	1	1	1	1	2	5 414	1 082
M5	1	1	2	1	1	5 414	1 082
Grand						25 827	1 0326

ANOVA for DI, stored at 15° C

Sv	df	ss	ms	F	Tabular F	
					5%	1%
Maturity	4	0 0669	0 0167	0 1912	2 87	4 43
Error	20	1 7494	0 0874			
Total	24	1 8163				

Appendix -6

Table for VQR. stored at 15°C

Maturity	1	2	3	4	5	Total	Mean
M1	7	7	4	7	7	12 583	1 797
M2	6	6 5	5	1	1	9 235	1 847
M3	1	7	9	6	1	10 095	2 019
M4	7	8	7	8	7	13 594	2 718
M5	8	6	4	4	6	11 727	2 345
Grand						57 234	2 1452

ANOVA for VQR. stored at 15°C

Sv	df	ss	ms	F	Tabular F	
					5%	1%
Maturity	4	2 539	0 6349	1 8402	2 87	4 43
Error	20	6 902	0 345			
Total	24	9 441				

Table for VQR. stored at ambient T0

Maturity	1	2	3	4	5	Total	Mean
M1	8	8 5	7 5	7	8 5	14 041	2 808
M2	4	6	6	7	8 5	12 46	2 492
M3	7	5	5	8	9	12 946	2 589
M4	6	7	7	6	5	2 426	2 485
M5	9	1	4	5	6	10 685	2 137
grand						52 558	2 5022

ANOVA for VQR. stored at ambient T0

Sv	df	ss	ms	F	Tabular F	
					5%	1%
Maturity	4	1 1765	0 2941	1 035	2 87	4 43
Error	20	5 6829	0 2841			
Total	24	6 8594				

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