A STUDY ON PRODUCT DEVELOPMENT OF PUMMELO

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DECLARATION

The works described in this thesis was carried out by me at the Department of Natural Resources, Faculty of Applied Sciences, Sabaragamuwa university of Sri Lanka, under the supervision of Mr. Senarath Ekanayake and Ms. L.M.N.S. Nadugala. A report on this has not been submitted to another university for another degree.

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ABSTRACT

Pummelo, *Citrus grandis* is a member of the family citrus and produce the largest ever-citrus fruit, which consist of important nutritional and medicinal values. Due to less usage in food processing industry pummelo fruit has been unfortunately discarded from the modern society. Therefore about 70% of the annual production is wasted with out being utilised. This situation implies, the need for practising food-processing technology on pummelo fruits.

Pummelo fruits contain several bitter compounds such as Limonin, Naringin, etc. Presence of these bitter compounds is one of the major stumbling blocks in the process of manufacturing consumer preferable food products. The other major obstacle is that existing pummelo Population in Sri Lanka is extremely heterogeneous. Hence it is difficult to conduct food base experiments on pummelo.

The type P_4 of pummelo develop by the Department of Agriculture, Peradeniya was used for the experiments. During the study some important characteristics of fruit juice of type (variety) P_4 was analysed.

Attempts were plan to develop consumer preferable various food products such as Jelly marmalade, Ready-To-Serve fruit drink (R.T.S.), fresh cuts, and bottling of pummelo juice vesicles, by using pummelo fruits as the raw material. The recipes for marmalade and R.T.S. were developed according to the Sri Lanka Standards (SLS).

Prepared marmalade consisted of fallowing characters: 81 ^{0} Brix Total Soluble Solids (TSS), 0.64% Titrable Acidity (TA) and 1.05pH. And the R.T.S. comprised with 0.47% TA and 48ppm SO_2 values.

The study also focused on developing quality fresh cuts from pummelo fruits. These fresh cuts were stored under refrigerated conditions (10-15 ^{0}C) in a modified atmosphere with out applying chemical preservatives. Variations of the important parameters such as the level of TSS, TA and Vitamin C content were studied within the 15 days of shelf life. Significant variations of above parameters were not recorded within 10 days of storage life and the results of sensory evaluations also recommended the fresh cuts.

Bottling or canning of pummelo juice vesicles was also another scope of the study. It was found that bottled pummelo juice vesicles consisted of fallowing characters: 15.43 ^{0}Brix TSS, 1.47 pH and 0.698% TA.

Pummelo R.T.S. and bottled juice vesicles were slightly bitter in taste; hence there is a need for further development of above products. Pummelo marmalade and fresh cuts were more successful among the proposed four products. Further studies should be carried out to find the nutritional losses during processing and storage of pummelo products and to find microbial safety and sensory quality improvement of the products.

CONTENTS

Title		Page No.
Abstract		I
Acknowledgement		II
Contents		III
List of Abbreviations		V
List of Figures		VI
List of Tables		VII
CHAPTER 1	**INTRODUCTION**	**01**
CHAPTER 2	**LITERATURE REVIEW**	**03**
2.1 Introduction to Pummelo.		03
2.1.1 History of Pummelo.		03
2.1.2 Pummelo in Sri Lanka.		03
2.1.3 Morphology of Pummelo.		04
2.1.4 Varieties and Cultivars.		05
2.2 Pummelo as a Member of Citrus Family.		05
2.2.1 The Relationship with Grapefruit.		05
2.2.2 Fruit Composition.		05
2.2.2.1 Total Soluble Solids (TSS).		08
2.2.2.2 Organic Acids.		09
2.2.2.3 Ascorbic Acids.		09
2.2.2.4 Composition of Vitamins in Some Citrus Juices.		10
2.2.2.5 Pectins.		11
2.2.2.6 Availability of Minerals in Some Citrus Fruits.		11
2.2.2.7 Limonin		12
2.2.3 Solution to Bitterness in Citrus Juices.		12
2.3 Pummelo Processing.		13
2.3.1 James, Jellies and Marmalades.		13
2.3.1.1 Gel Formation.		14
2.3.1.2 Marmalades.		15
2.3.1.3 Procedure for Preparation of Jelly Marmalade.		15
2.3.2 Fruit Juice and Ready-To- Serve (R.T.S.) Beverages.		18
2.3.2.1 Sulphur dioxide as a Preservative for R.T.S.		19
2.3.3 Caning of Fruit Sections.		19
CHAPTER 3	**MATERIALS AND METHODOLOGY**	**21**
3.1 Materials		21
3.2 Methodology		21
3.2.1 Study on Characteristics of Pummelo Fresh Fruits.		21
3.2.1.1 Morphology of Fresh Pummelo Fruit.		21
3.2.1.2 Total Soluble Solid (TSS) Content of Pummelo Juice.		21

3.2.1.3 pH Value of Pummelo Juice. 21
3.2.1.4 Analysis of Titrable Acidity (TA) of Pummelo Juice. 22
3.2.1.5 Analysis of Total Sugar Content of Pummelo Juice. 22
3.2.1.6 Analysis of Ascorbic Acid Content of Pummelo Juice. 22
3.2.2 Preparation of Marmalade. 22
3.2.2.1 Development of Suitable Recipe for Pummelo Marmalade. 22
3.2.2.2 Procedure for Preparation of Pummelo Marmalade. 23
3.2.3 Pummelo Fresh Cuts. 26
3.2.3.1 Preparation of Fresh Cuts. 26
3.2.3.2 Analysis of Quality Changes During Storage Time. 26
3.2.3.3 Evaluation of Sensory Qualities During Storage Time. 26
3.2.4 Bottling of Pummelo Juice Vesicles 27
3.2.4.1 Most Suitable NaOH Concentration for Lye Peeling. 27
3.2.5 Rudy-To-Serve Pummelo Drink. 28
3.2.5.1 The Preparation of Pummelo R.T.S. 28
3.2.5.2 Development of a Suitable Recipe for R.T.S. (according to SLS) 28
3.2.5.3 Procedure and Process Flow Diagram. 28
3.2.5.4 Analysis of Sulphur dioxide Content in Pummelo R.T.S. 29

CHAPTER 4 RESULTS AND DISCUSSION 30

4.1 Results 30
4.1.1 Morphological Study of Pummelo Fruits of Variety / type P4. 30
4.1.2 Juice Characteristics of P4 Variety. 30
4.1.3 Variations of TSS, TA and Vitamin C of Fresh Cuts During Storage. 31
4.1.4 Sensory Evaluation Tests on Pummelo Fresh Cuts. 33
4.1.5 Test Conducted on Pummelo Marmalade. 34
4.2 Discussion 35
4.2.1 Bottled Pummelo Juice Vesicles. 35
4.2.2 Pummelo R.T.S. 37

CHAPTER 5 CONCLUSION AND RECOMMENDATIONS 38

5.1 Conclusion and Recommendations 38

Appendix A
Appendix B
Appendix C
Appendix D
Appendix E

BIBLIOGRAPHY

LIST OF ABBREVIATIONS

R.T.S.	Ready-To-Serve
TSS	Total Suspended Solids
TA	Titrable Acidity
SLS	Sri Lanka Standards

LIST OF FIGURS

	Title	Page No.
2.1	Chemical composition of some citrus fruits.	06
2.2	Availability of total carbohydrates in some citrus fruits.	07
2.3	Composition of different sugars in some citrus juices.	07
2.4	Amounts of total solids in some citrus juices.	08
2.5	Availability of citric acid in some citrus juices.	09
2.6	Availability of vitamin C and energy in some citrus fruits.	10
2.7	Composition of vitamins in some citrus fruits.	10
2.8	Availability of minerals in some citrus fruits.	11
3.1	Process flow diagram for preparation of jelly marmalade.	25
3.2	Process flow diagram for preparation of pummelo R.T.S.	29
4.1	Changes in Total Suspended Solids (TSS) content of fresh cuts during storage.	31
4.2	Variation in Titrable acidity (TA) of Fresh Cuts During Storage.	31
4.3	Changes in Ascorbic Acid (Vitamin C) content of fresh cuts during storage.	32
4.4	Prepared pummelo fresh cuts.	33
4.5	Pummelo marmalade.	35
4.6	Bottled pummelo juice vesicles.	36
4.7	Pummelo R.T.S.	37
4.8	Produced four products during the study.	37

LIST OF TABLES

	Title	Page No.
2.1	Pummelo germplasm collection and their locations in Sri Lanka	04
4.1	Results of the tests conducted to find the most suitable lye peeling concentration.	36

CHAPTER 1

INTRODUCTION

Pummelo, botanically known as *Citrus grandis* grows in most parts of Sri Lanka, especially in wet and intermediate zone. That means pummelo shows a wide distribution all over the island. Due to less usage in commercial food processing, pummelo is consider as an under utilized crop in Sri Lanka. But the economical value of pummelo can be improved using the knowledge of modern food technology. In Sri Lanka there is a high annual production of fresh pummelo fruits at village level from which more then 70% is wasted due to post harvest losses and inadequate processing technology.

The fresh pummelo fruits consist of a thick, spongy peel. This peel minimise the impact of vibration and abrasion damages during post harvest practices, such as harvesting, transportation, storage, etc. With regard to fruit processing industry, these characteristics of pummelo fruit is very valuable, which facilitate easy handling and minimize handling cost. Also pummelo fruits provide some kind of nutritional and medicinal value as describe below.

Nutritive Value (per 100g of edible portion)

Energy	44.0 Kcal
Protein	0.6 g
Fat	0.1 g
Carbohydrate	10.2 g
Calcium	30.0 mg
Phosphorus	30.0 µg
Riboflavin	30.0 µg
Iron	0.3 mg
Carotene	120.0 µg
Vitamin C	20.0 mg

(Source: Tropical Fruits of Sri Lanka, 1997)

Medicinal Value

Pummelo is useful in fever, dyspepsia, constipation, disease of bones, dental diseases, scurvy, cardiovascular diseases, bronchial asthma, bronchitis, chough and cold ache (Sameratunge, 1997).

The market price of pummelo is relatively reasonable than other fruits and a pummelo fruit yield amazing quantity of fruit juice than any other citrus fruit. That implies pummelo based food production may be more profitable in near future.

For the above reasons pummelo is an important fruit, which has not been taken in to consideration yet, but has a great value with regard to human nutrition, medicine and economical to use as raw material in food industry.

Therefore the main objective of this project is to study on product development of pummelo. In order to achieve the main objective of the project, below mentioned specific objectives are taken into consideration.

Specific Objectives:

- Production of ready to serve drink (R.T.S.) from pummelo juice.
- Development of marmalade from pummelo fruits.
- Supplement of edible flesh as a convenient product (Fresh cuts).
- Bottling of pummelo juice vesicles.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction to Pummelo

2.1.1 History of Pummelo

The shaddock or Pummelo (*Citrus grandis* [L.] Osbeck) originated in Malaysia and Indian archipelagos is widely distributed in the Fiji Islands. Hybrids of Shaddock were apparently found by crusaders in Palestine by AD 900 and were distributed to Europe and then to the Caribbean apparently by an East Indian ship's captain named shaddock (Davies and Albrigo, 1998).

Citrus grandis is probably a native of Thailand and Malaysia and spread from there to China, India and Persia. It has reached Europe in the twelfth or thirteenth centuries as curiosity (Purseglove, 1982).

2.1.2 Pummelo in Sri Lanka

Jambola, Jambu-naran, Rata jambola, Ela-jambola are some of the common names, which are using in Sri Lanka for pummelo (*Citrus grandis*). Pummelo is native to Malaysia but commonly cultivated in Sri Lanka as a home garden crop. Existing pummelo population in Sri Lanka is highly heterogeneous since they have been propagated from seeds. Therefore, many varieties have evolved providing a broad genetic base for variety development programs. Pummelo is a varied group of citrus having seedy and seedless, pigmented and non-pigmented fruits. In Sri Lanka broadly there are two types as local white and local pink. Pummelo germplasm and there location are given below.

Table 2.1: Pummelo Germplasm Collection and There Locations in Sri Lanka

Variety	Location (origin)
Local white	Bibile, Gannoruwa
Local pink	Bibile, Gannoruwa
Carters red	Bandarawela, Gannoruwa (Australia)
Webber	Rahangala (Pakistan)
Shamel K-15	Bibile (Pakistan)
Sweet and sour	Gannoruwa
Sweet	Gannoruwa (Malaysia)

(Source: Status Report on Genetic Resources of Citrus in Sri Lanka, 1997)

Grapefruit is included here as a variety of pummelo, although it would probably be more correct to designate it as a hybrid cultivar (Medagoda and Jayawardena, 1997).

2.1.3 Morphology of Pummelo

The tree is small to medium in size. Branches are spiny. Leaves large, the leaf stalks are about one-fourth to one-third of the length of the leaf blade, with broad wings on either side. Flowers large, white, solitary or in clusters of a few. The fruit is large, round to pear shaped, pale green to pale yellow, smooth to pit. The fruit rind is thick, and the flesh is somewhat dry, varying from sweet and juicy to bitter and fibrous, and in colour from pale green yellow through pink to deep red (Watanabe and Dassanayake, 1997).

Pummelo tree is 5-15 m in height, young branches are pubescent, petiole broadly winged, fruits10-30 cm in diameter, pulp vesicles are large, pale yellow or pink, with sweetish juice, seeds large, yellowish, mono embryonic (Purseglove, 1982).

2.1.4 Varieties and Cultivars

There are many cultivars of pummelo but they are generally divided in to three groups namely Thai, Chinese and Indonesian groups. Fruit in the Thai group are generally smaller than those in the Chinese group. Major cultivars in Thai group include Chander (pink-fleshed), Kao Punne and Kao Phuang (white-fleshed); Chinese group includes Goliath, Mato, and Shaftingn (all white-fleshed); Indonesian group include Banpeiyn (white-fleshed) and Djeroek deleema kopjar (pink-fleshed). There are two hybrids developed from pummelo and Grapefruit, Melogold and Oroblanco, which have intermediate characteristics between the two and are being grown to a limited, extend in California and Israel (Davies and Albrigo, 1998).

2.2 Pummelo as a Member of Citrus Family

2.2.1 The Relationship with Grapefruit

Grapefruit appear to have originated as a mutation or hybrid of Shadock in the West Indies, perhaps Barbados. Although the pummelo tree and fruit show similarities to grapefruit, there are some important differences. Leaves, flowers and fruits are usually the largest of any Citrus type, despite some variability among cultivars. The internal quality of pummelo fruit differs from that of Grapefruit. The peel is extremely thick but easy to peel and the juice sacs are very pronounced rubbery in appearance and texture. Generally the rind and the segment walls are peeled before eating. Pummelo juice is not bitter as that of grapefruit and thus it has a sweet, mild flavour. Seed are large and plump, and produce only zygotic progeny for nearly all cultivars (Davies and Albrigo, 1998).

2.2.2 Fruit composition

The composition of Citrus fruits varies with cultivars, climate, rootstock and cultural practices. Most Citrus fruits, like other fruits, are preliminary water, but also contain over 400 other constituents including moderate levels of carbohydrates, organic acids, amino acids, ascorbic acids, minerals and small

quantities of flavonoids, carrotenoids, volatiles and lipids. Citrus fruits are low in proteins and fats.

Recent work (Burns, unpublished) suggests that excised juice vesicles contain less than 1mg/g of protein on a fresh weight basis. But extracted juice has higher levels of proteins than that. Citrus fruit is a good source of pectin and roughage.

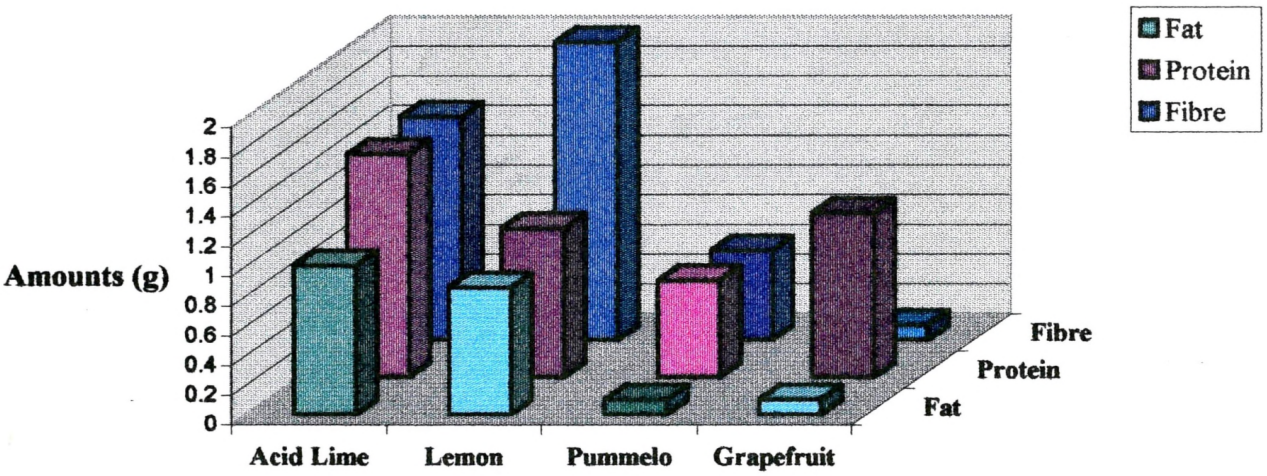


Figure 2.1: Chemical composition of some citrus fruits (per 100g of edible portion)

(Source: Citrus in India, Mankad, 1994)

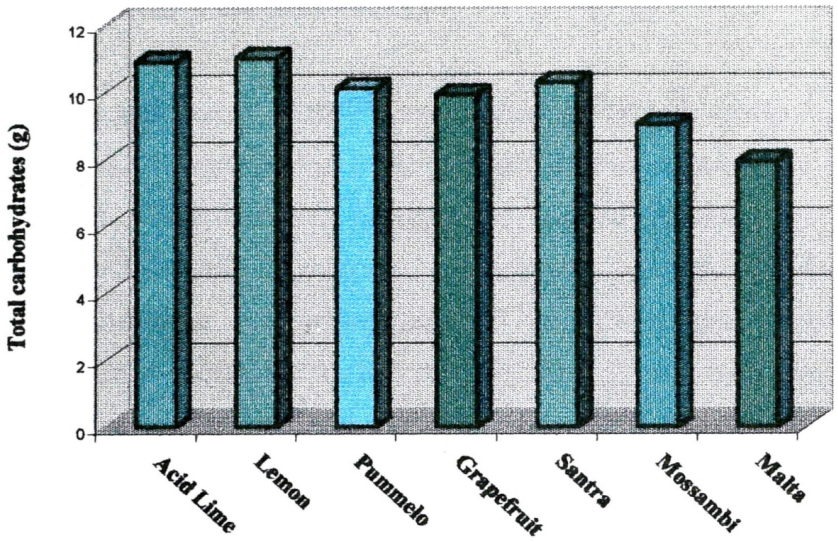


Figure 2.2: Availability of total carbohydrates in some citrus fruits

(per 100g of edible portion)

(Source: Citrus in India, Mankad, 1994)

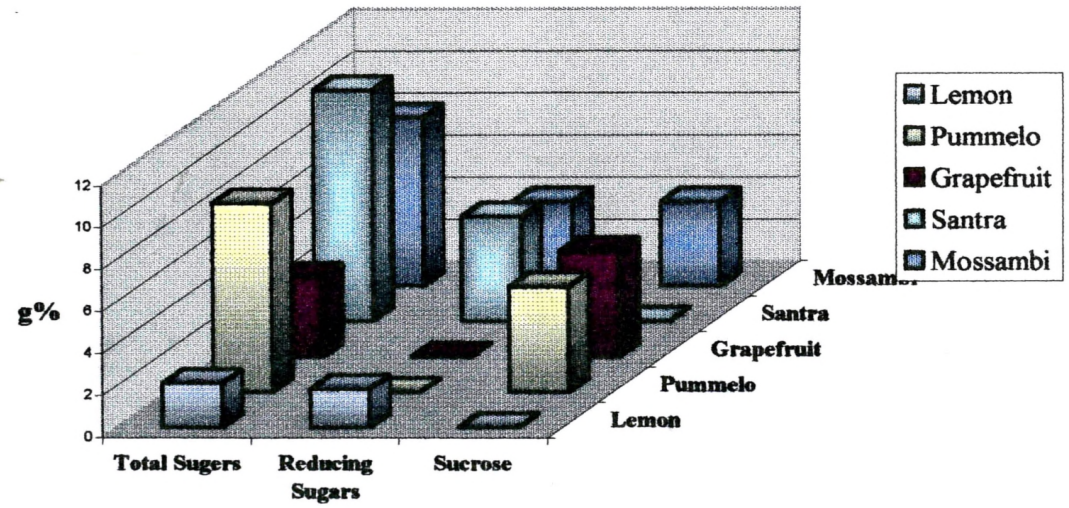


Figure 2.3: Composition of different sugars in some citrus juice

(Source: Citrus in India, Mankad, 1994)

2.2.2.1 Total Soluble Solids (TSS)

Total Soluble Solids (TSS), which includes carbohydrate, comprise from 10-20% of the fresh weight of the fruit. Carbohydrates account for 70-80% of the TSS in the fruit. The major groups of carbohydrates in citrus fruit include monosaccharides (glucose, fructose), disaccharides (sucrose) and polysaccharides (cellulose, starch, hemicelluloses, pectin). Sucrose is the primary non-reducing sugar and is the major trans-locatable carbohydrate. Fructose and glucose are the major reducing sugars and are present at about one half to equal quantities of sucrose in most citrus juices. Small quantities of mannose and galactose have also been found in citrus juices.

Among the polysaccharides, starch is present in small quantities, particularly as the fruit matures, starch convert in to sucrose, fructose and glucose. Pectin is an important polysaccharide in the cell wall matrix.

TSS level increases as fruit size increases, becomes nearly constant or slightly increasing during the development stage.

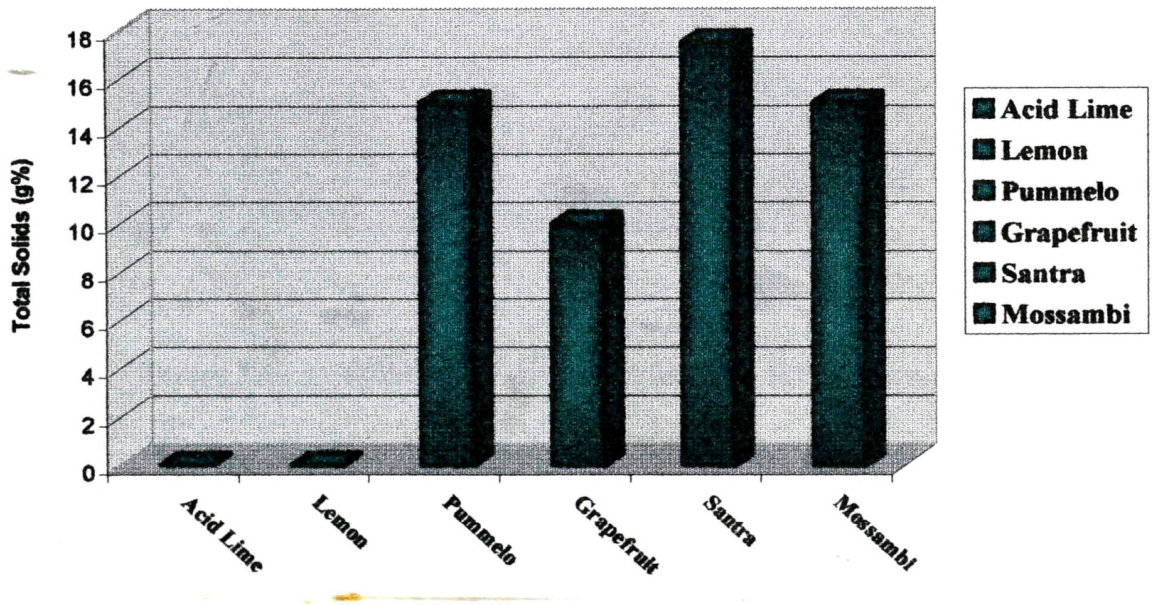


Figure 2.4: Amount of total solids in some citrus juices

(Source: Citrus in India, Mankad, 1994)

2.2.2.2 Organic Acids

Total acidity (TA) of citrus juice is an important factor in overall juice quality and in determining the time of fruit harvest.

In most citrus growing regions the ratio between TSS/TA is used to determine the correct maturity stage for harvesting. Organic acids contribute significantly to overall juice acidity. Citric acid is the primary organic acid (70-90% of total) followed by malic and oxalic acid with lesser amount of succinic, malonic, lactic, tartaric and other related acids. Organic acid levels generally decrease seasonally as citrus fruits mature. The rate of decrease of acidity has a positive correlation with the average temperature of the season. Higher temperatures increase respiration rates causing less storage of acids in the vacuoles and their more rapid utilization in metabolism. The ratio between TSS / TA increases during maturation and is a good indicator of palatability.

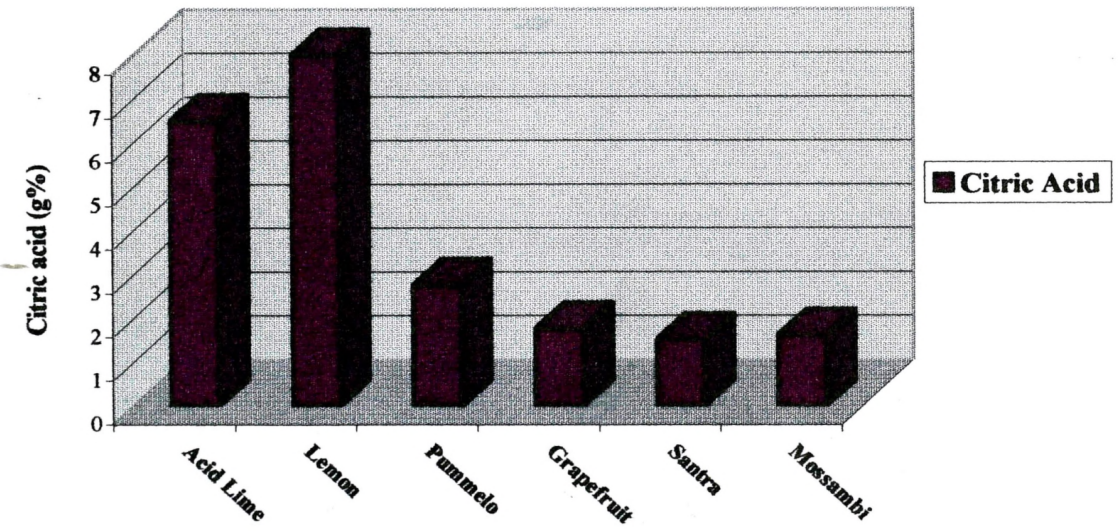


Figure 2.5: Availability of citric acid in some citrus juices

2.2.2.3 Ascorbic Acid

It is known for many years that citrus fruits are a valuable source of ascorbic acid (vitamin C). Vitamin C functions as a coenzyme and is an essential part of the

human diet. Ascorbic acid levels are generally higher in the peel than in the extracted juice.

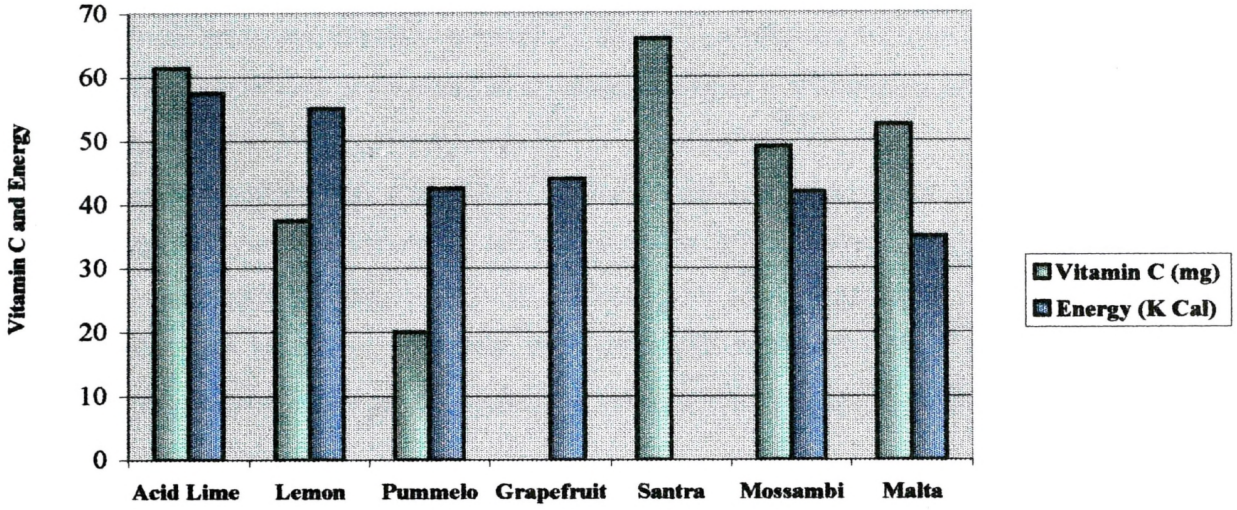


Figure 2.6: Availability of vitamin C and energy in some citrus fruits
(per 100g of edible portion)

(Source: Citrus in India, Mankad, 1994)

2.2.2.4 Composition of vitamins in some citrus juices

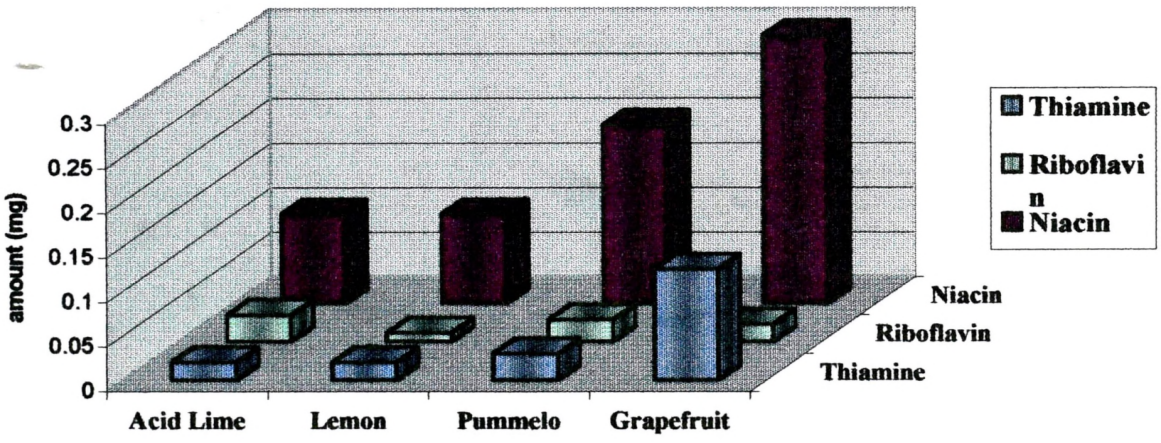


Figure 2.7: Composition of vitamins in some citrus fruits
(per100g of edible portion)

(Source: Citrus in India, Mankad, 1994)

2.2.2.5 Pectins

Pectins are high molecular weight carbohydrates that composed of chain of anhydrogalacturonic linkages. They are stored as intracellular bonding material in many fruit and vegetables including citrus. During maturation of citrus fruits, insoluble pectins are converted in to water-soluble pectins and pectinates.

Total pectic substance decrease in the peel and pulp over the season, and water-soluble pectins increase as percentage of the total pectins. This changes in pectin content signals that fruit softening or over maturing. Pectin levels are generally low in juice. Pectins are used in manufacturing of jellies, jams, preserves, frozen fruits and coating for meats and in baking (Davies and Albrigo, 1998).

2.2.2.6 Availability of Minerals in Some Citrus Fruits

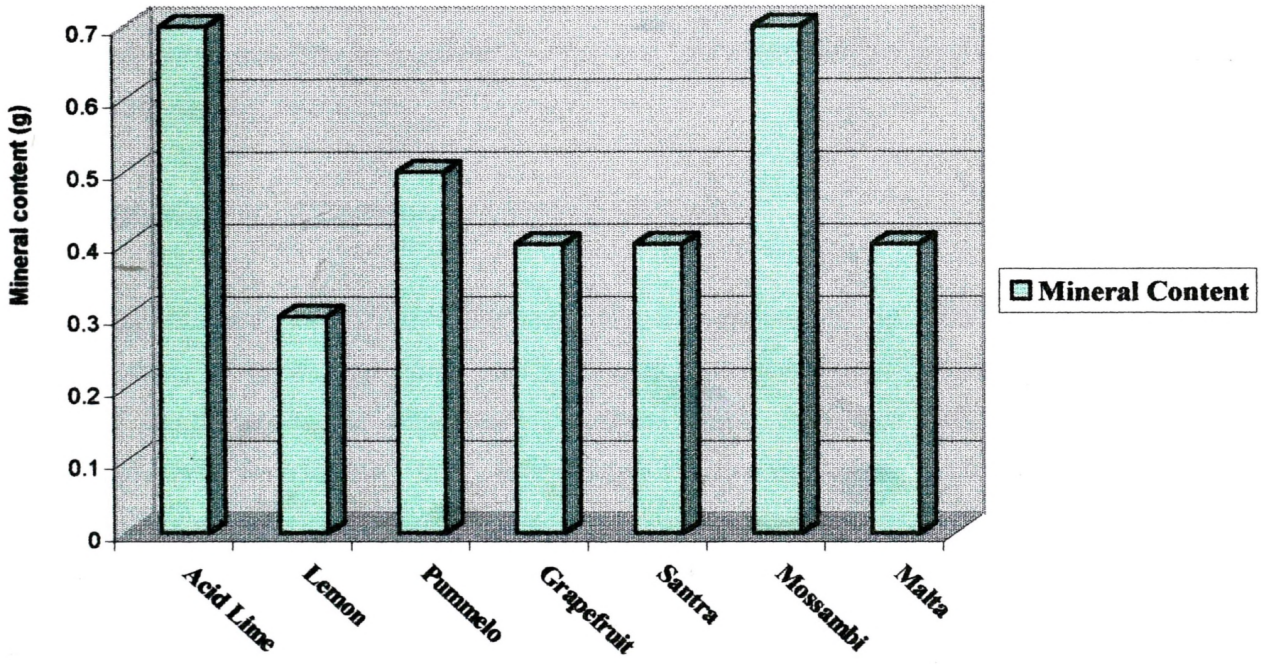


Figure 2.8: Availability of minerals in some citrus fruits
(per100g of edible portion)

(Source: Citrus in India, Mankad, 1994)

2.2.2.7 Limonin

Triterpene derivatives, which produce bitter flavours in the juice, are present in most citrus cultivars. But it affects palatability only in few cultivars. Limonin was first identified as an important bitter principle in novel oranges in the late 1930s.This substance and other limonoids are present mainly in the peel and are released in to the juice at juicing.

Generally 6mg/l of limonin is considered palatable, 9mg/l as bitter and 24-30mg/l as extremely bitter. The range of human detection of limonin in juice is 0.5-32mg/l; this varies considerably from person to person.

Moreover, limonin becomes more difficult to detect as the sugar and acid levels increase. Recently developed methods using resin exchange columns are being used commercially to reduce limonoid levels in juice, allowing processors to blend juices typically high in limonin with other juices. Limonin levels decrease seasonally as fruit are held on the tree. In addition, limonin levels vary with rootstock selection. Lowest levels are normally found in fruit from scions on rough lemon rootstock.

2.2.3 Solution to Bitterness in Citrus Juices

Scientific publication on bitterness was first made during, 1857 in Java. Later two classes of chemical compound namely flavonoids and limonoids were found to be responsible for bitterness in citrus juice. However, there is a difference between flavonoids and limonoids bitterness. The fruits containing high flavonoids are bitter even when consumed as a fresh fruit. The peel (rind) of the citrus fruits contain very high amount of flavonoids like naringin, neohesperidine etc, making it highly bitter. The limonoids are present in the form of non-bitter compound (limonate-A-ring lactone), which is converted to bitter limonin and other bitter limonoids in the presence of enzyme limonate-D-ring lactone hydrolase on storage. Hence, the fresh citrus juice does not taste bitter but turns highly bitter on storage temperature, acidic medium of the juice also play a vital role in the development of bitterness. This is known as "delayed bitterness".

The preservation of citrus juice is also very difficult because the citrus juice became highly bitter in flavour within four hours of extraction. Several efforts have been made to process citrus juice free from bitterness. Research round up in this direction reveals that efforts were made:

- To use rootstocks like trifoliate orange, tangelo, clepatra mandarins which are low in limonin.
- Pre-harvest sprays of 2(4-ethyl phenoxy) triethylamine (250 ppm) and 2(3,4-dimethylphenoxy) triethyl amine (250 ppm).
- Exposure of harvested fruit to 20ppm of ethylene gas for four hours. The ethylene gas is easily available nowadays either in the form of ethylene ampule or ethral formulations.
- Juice extraction without damaging citrus fruit tissues help to lower limonin content in the juice.
- Masking bitterness by addition of sweetener like sucrose to juice.
- Carbonation of juice immediately after extraction under chilling temperatures.
- Enzymatic debittering by using immobilised enzymes or microorganisms in bioreactors.
- Debittering using membrane technology by using cellulose estate polymers.
- Debittering of juice in columns packed with polymer absorbents.

(Premi and Hegde, 1998).

2.3 Pummelo Processing

2.3.1 Jam, Jellies and Marmalade

Preserving as it is applied to the manufacturing of jams, jellies and marmalades, is one of the oldest and most important of the fruit product industries. The earliest published record of jelly making appeared in the later part of the eighteenth century. Preserving of fruits and juices became a home operation, the season for preserving corresponding to the time when the fruits were being harvested.

Pectin finds its chief use in the preparation of jams, jellies, marmalades and similar products. The essential ingredients of these jelled products are pectin, acid and sugar, along with variable amount of fruit juice pulp and water. A definite

interrelationship between these ingredients is necessary for the formation of a gel.

2.3.1.1 Gel Formation

Gel formation and partial gel formation largely regulate the consistency or body of preserves and jellies in their finished condition. In relation to preservation industry, gel formation depends upon water activity and balance of the electrical charges of the colloidally dispersed and highly hydrated pectin.

It is essentially important that commercial preserves recognize the effect pH upon gel formation. Even though sufficient pectin and sugar amounts are present, no gel will form until the acidity has been increased to the critical value, which is determine by the type of pectin. The upper limit at which slow-set pectin will gel is about pH 3.30 and for rapid- set pectin, around pH 3.55. This critical pH above which pectins will not form gel, regardless of the amount of pectin, has been termed the marginal or limiting pH. A small shift in the pH range 3.30-3.55 may make the difference between the success and failure of a jelly batch.

Instead of physical appearance and taste many other physical qualities such as texture, firmness, elasticity and fracture are important for a complete functional evaluation of the gel. Generally rapid-set pectins will reach their full gel strength or firmness with less acid than with slow-set pectins. However, slow-set pectins have a greater tolerance for acidity.

Since incomplete hydration will cause an inferior gel, the technique use to dissolve powdered pectin is of great importance. When added slowly with adequate stirring, powdered pectin dissolves satisfactorily in hot or cool water or in fruit juice. A particularly suitable method involves sifting the pectin slowly in to the vortex caused by high-speed agitation of the liquid. However, when added rapidly, clumps of pectin are formed in which an undissolved core is enclosed with in a gammy outer coat. The clumping tendency may be overcome by mixing pectin with a spacer such as sucrose or dextrose. Ordinarily 3-5 times as much sugar as pectin solves the dispersion problem. This technique is not satisfactory

if the pectin-sugar mixture is added to concentrated fruit juices, since sugar concentration over 20-25% inhibit solubilization of pectin.

Some preserves avoid hydration problems by making their own liquid pectin prior to its use in the gel batch. Several special pectins are also available which are processed in a manner to avoid the clumping problem (Steven *et al*, 1977).

2.3.1.2 Marmalades

These are produce mainly from clear citrus juices and have fine shreds of peel suspended in the gel (Peter and Ann, 1992).

The product obtained from a suitable citrus fruit ingredient which may be whole fruit, fruit pulp, or fruit puree with some or all of the peel removed, mixed with a carbohydrate sweetener and water and processed to a suitable consistency (SLS 265: 1985, UDC 664.858).

In preparation of marmalade, all the conditions use in jelly making can be applied. Pectin and acid contents of the marmalades should be kept slightly higher than what has been recommended for jellies. Citrus marmalades are of two types:

1) Jelly marmalades
2) Jam marmalades

2.3.1.3 Procedure for Preparation of Jelly Marmalade

- **Selection of Fruits**

  Fruits that are ripened under normal conditions should be used. The size of the fruit is immaterial as long as the fruits are free from blemishes.

- **Preparing the Fruit**

  The outer yellow portion of the citrus fruits contains colouring matter and volatile oils, while the white inner portion contains pectin. The yellow skin is peeled off from the fruit. The peels after proper shredding are kept separate and are incorporated in jelly marmalade. Care should be taken to see that a very little

portion is removed. The peeled fruits are cut in to $^1/_8$" – $^3/_{16}$" thick slices or crushed in an apple greater to facilitate extraction of pectin.

❖ **Boiling for Extraction of Pectin**

The sliced fruits are boiled with 2-3 times its weight of water to extract pectin. While it is being, a teaspoonful of the clear extract is drown out from the pan and tested with alcohol for its pectin content. Boiling is stopped when sufficient pectin has been extracted. The process usually takes 40-45 minutes. Pressing the fruit in a rack and cloth press separate the aqueous pectin solution from the boiled fruit.

❖ **Clearing of Pectin Extract**

At small scale processing level, extracted pectin is placed in aluminium or stainless steel container and clear juice is siphoned off or decanted. For large-scale work, the juice is mixed with wood or with other filter aids and pressed through jelly bags or a filter press.

❖ **Preparation of Peels**

While the pectin solution is being clarified, the peels are cut in to shreds of ¾"–1" long and about $^1/_{32}$"-$^1/_{20}$" thick. The peels became tough if they are boiled as such with the sugar solution. It is therefore, necessary to soften them before use.

Generally the following methods are used for this:

(1) Boiling the shredded peels for 10-15 minutes in several changes of water.
(2) Boiling the peels in 0.25% solution of sodium carbonate of 0.1% ammonia solution.
(3) Heating the peels in an autoclave at 240-250 ^{0}F. The time require to soften the peels depends on their size and shape.

❖ **Cooking**

In order to determine the quantity of sugar to be added, the pectin solution is tested with alcohol or with gel a meter. The solution is brought to boiling point and the requisite sugar is added to it. The boiling is continued till the gelling point is reached. Sheeting test, and weighing test can determine the end point.

Marmalade containing 65% sugar boiling at 221^{0}F(at sea level), boiling should not be practice more than 20 minutes. The end point can be found by:

(i) Determining the boiling point with thermometer.

(ii) Sheeting or ladle test.

(iii) Weighing.

(i) Determination of Boiling Point

A solution containing 65% solid boil at 220.7^{0}F at sea level. Heating of jellies to this temperature would automatically bring about the concentration of solids to 65%. This is the easiest way to ascertain the end point. Correction is however, necessary for the altitude of the place. Generally the end point of the marmalade should be 8-9^{0}F, higher than the boiling point of water at that place.

(ii) Determination by Sheeting or Ladle Test

Here some portion of marmalade is taken in a large spoon or wooden ladle and cooled slightly. It is then allowed to drop. If the marmalade drips like a syrup, it requires further concentration, but if falls in the form of flake or a sheet the end point is reached.

(iii) Determination by Weighing

Here the boiling pan is weighed before and again after putting the fruit extract and sugar in it. The weight of the finished marmalade should be about $1^1/_2$ times the weight of sugar used.

❖ **Cooling**

When the marmalade is ready, it is cooked in shallow or water-cooled pans in which it is stirred slowly. When the temperature reaches 180-190^{0}F a thin skin being to form on the surface of the marmalade. And it became sufficiently thick to prevent floating of the shreds.

❖ **Flavouring**

It is desirable to add flavour because the natural flavour evaporates during boiling and cooking. Generally, a small quantity of orange oil may be added to

the marmalade at the time of packing (Source: Modern Technology of food Processing and Agro based Industries, N.I.I.R, 2000).

2.3.2 Fruit Juice and Ready-To-Serve (R.T.S.) Beverages

Ready-to-serve fruit drink is a fruit drink, intended for consumption with out dilution and prepared from unfermented pure fruit juice with or without some of the pulp and containing any soluble carbohydrate sweetener and water (SLS 729:1985, UDC663.81).

It is prepared from fresh or pasteurised concentrated juice. It must have a minimum of 10% juice, not less than 10% soluble solids and 0.5% acidity as anhydrous citric acid (weight /weight). According to the Indian Public Health Laws, it should contain not more than 70 ppm of sulphur dioxide or 120 ppm of sodium benzoate. Permitted food colours and flavourings are added. It may be carbonated or non-carbonated. In the preparation of carbonated beverage, syrup and water are mixed with the fruit base in a large tank, chilled almost to the freezing point and carbonated at low pressure, which gives it a finer flavour and overcomes excessive forming during bottling. The bottles are crown-capped and pasteurised at 65.6 ^{0}C for 30 minutes and cooled rapidly.

Citrus beverages may also be prepared using only the flavourings. They contain sugar, sweetening agent, citric acid, flavouring, colour and stabilizer (Mankad, 1994).

The most important steps in processing fruit juice are: selection and preparation of fruits, extraction of juice, deaeration, straining, filtration and clarification, and preservation. The quality of the Juice will depend on the manner in which above processes are carried out (Girdhari *et al*, 1986).

The most common sugar used in soft drinks is high-fructose corn syrup or related corn sugars (Potter and Joseph, 1995).

In the case of R.T.S. nutritional quality is not considered as important. However it is always better if the nutritional quality is maintained at optimum possible level. Heat processing causes reduction of most important nutrient, ascorbic acid. Cold pressed juice helps retained higher levels of nutrients. Blanching has increased the yield of juice but badly affects on nutrient quality (Saikia and Dutta, 1995).

2.3.2.1 Sulphur dioxide as a Preservative for R.T.S.

Potassium metabisulphite ($K_2O,2SO_2$ or $K_2S_2O_5$) commonly use as a stable source of sulphur dioxide. Being a dry chemical, it is easier to use than liquid or gaseous sulphur dioxide. Potassium metabisulphite is a crystalline salt and is fairly stable in neutral or alkaline media. It is however decompose by weak acid like carbonic, citric, tartaric and malic acid. When it is added to the fruit juice or squash, potassium radical reacts with the acid of the juice forming the corresponding potassium salt, and the sulphur dioxide, which is liberated, from sulphurous acid with the water of the juice. The reactions occur as follows.

(1) Potassium metabisulphite + Citric acid = Potassium citrate + Sulphur dioxide + water

(2) Sulphur dioxide + water = Sulphurous acid

The preservative effect of sulphurous acid depends not on its total quantity, but on available amount of SO_2 (Girdhari *et al*, 1986).

2.3.3 Canning of Fruit Sections

The canning and bottling of fruit sections have become a popular way to preserve citrus fruits. Grapefruit sections have found acceptance in the Unite States, and Mandarin sections are well accepted in the Far East. Canned or bottled citrus fruit sections have the advantage of long shelf life and retention of most of the whole fruit nutrition, which can be conveyed to non citrus or off season geographical areas that otherwise might not be able to partake of the benefit of citrus (Dan, 1999).

The peel of the loose skinned is removed easily with hand. The tight-skinned oranges are dipped in boiling water to loosen the peel. The segments are separated and the adherent fibres are removed. They are then dipped in a boiling lye solution (alkaline solution 1-2%) for 20-30 seconds, rinsed in worm water, dipped in dilute hydrochloric acid (0.5-1.0%) to remove traces of alkali and finally rinsed in cold water. Any adhering membrane and seeds are removed by hand. The segments are filled in to cans and covered by 50^0Brix syrup and orange flavour is added. The cans are exhausted and processed for 15-20 minutes at 82-87 ^{0}C. They are then cooled.

Orange segments can also be canned as along with other fruits like mango, pineapple, jackfruit and banana. Sliced orange, without removing the covering membrane of the segments, can also be canned. Broken segments can be utilized for jam, juice, squashes, etc (Mankad, 1994).

CHAPTER 3

MATERIALS AND METHODOLOGY

3.1 Materials

- Matured pummelo fruits.
- Normal food laboratory equipments such as refrigerators, refractometers, pH meters, etc.
- Normal food laboratory facilities such as chemicals, pipettes, burettes, etc.
- Packaging materials (glass bottles and lids, polyethylene, etc).

3.2 Methodology

3.2.1 Study on Characteristics of Pummelo Fresh Fruit

3.2.1.1 Morphology of Fresh Pummelo Fruit

In order to study the morphology of pummelo fresh fruit, the P4 variety was used. This variety is still under experimental level at the farm of Agriculture Department of Sri Lanka, Gannoruwa, Peradeniya. Special attention was given to some important morphological characteristics, such as the peel colour, thickness of peel, flesh colour, distribution of oil sacks in peel, size of juice sacks, shape of seeds, etc.

3.2.1.2 Total Soluble Solid (TSS) Content of Pummelo Juice

The pummelo juice was extracted manually and the total suspended solids (Brix value) were measured using a refractometer according to method described in appendix A. (The range of refractometer is 0-30^0 Brix).

3.2.1.3 pH Value of Pummelo Juice

Pummelo juice was extracted manually and pH value was measured using a microprocessor-based pocket pH tester. The P4 variety was used for the test. Firstly the pH tester was calibrated with two buffer solutions. Then the pH value of pummelo juice sample was measured. The bulb of the pH tester was

washed with distilled water and cleaned using a tissue paper after and before taking measurements.

3.2.1.4 Analysis of Titrable Acidity (TA) of Pummelo Juice

According to the procedure mentioned under appendix B, the titrable acidity (TA) was measured.

3.2.1.5 Analysis of Total Sugar Content of Pummelo Juice

The total sugar content was determined according to Lane and Eynon method.

3.2.1.6 Analysis of Ascorbic Acid Content of Pummelo Juice

The ascorbic acid (Vitamin C) content of pummelo juice was determined according to method described in appendix C.

3.2.2 Preparation of Marmalade

3.2.2.1 Development of a Suitable Recipe for Pummelo Marmalade

A recipe for pummelo marmalade was developed according to Sri Lanka Standards (SLS).

The developed recipe:

Sugar	650g
Pummelo Juice	330g
Peel Shreds	14g
Pectin	4g
Citric Acids	2g
Total Weight	1000g

3.2.2.2 Procedure for Preparation of Pummelo Marmalade

- **Extraction of Juice**

  The fresh pummelo fruits were washed and peeled. Pummelo segments were separated carefully and juice was extracted using a cotton cloth, manually.

- **Preparation of Peel Shreds**

  The outer green colour portion of the peel was separated using a sharp knife. Care was taken to not include too much of white pith of the peel. The separated green colour portion of peel was cut into shreds, which were 1-2.5cm long, 2-4mm wide and 1-2mm thick.

  These shreds were boiled within the temperature range of 70-80 ^{0}C, with several changes of water (usually four times), until shreds become soft in texture.

- **Mixing and Cooking**

  Exact amount of citric acid was measured according to the recipe and dissolved in extracted pummelo juice. The mixture was put into a jam pan and boiled about five minutes at 70-80 ^{0}C temperatures. Then sugar and pectin were mixed together and poured into the jam pan, which contains the juice and citric acid mixture. The whole mixture was stirred thoroughly, until sugar dissolves completely. Then prepared peel shreds were added and the whole mixture was cooked until it reached to the setting point.

- **Determination of End Point**

  The end point was determined according to ladle test (sheeting test), which was described in chapter 2.

- **Cooling**

  After reaching to the setting point, the cooking and stirring process was stopped and allowed to cool under room temperature, with out any disturbance.

- **Packing/Bottling**

  The scum formed on the surface of the marmalade was broke off and poured in to disinfected/sterilized glass bottles. The bottles were hermetically sealed and labelled.

  After preparing marmalade, the pH value, titrable acidity (TA), total suspended solids content (TSS) were determined.

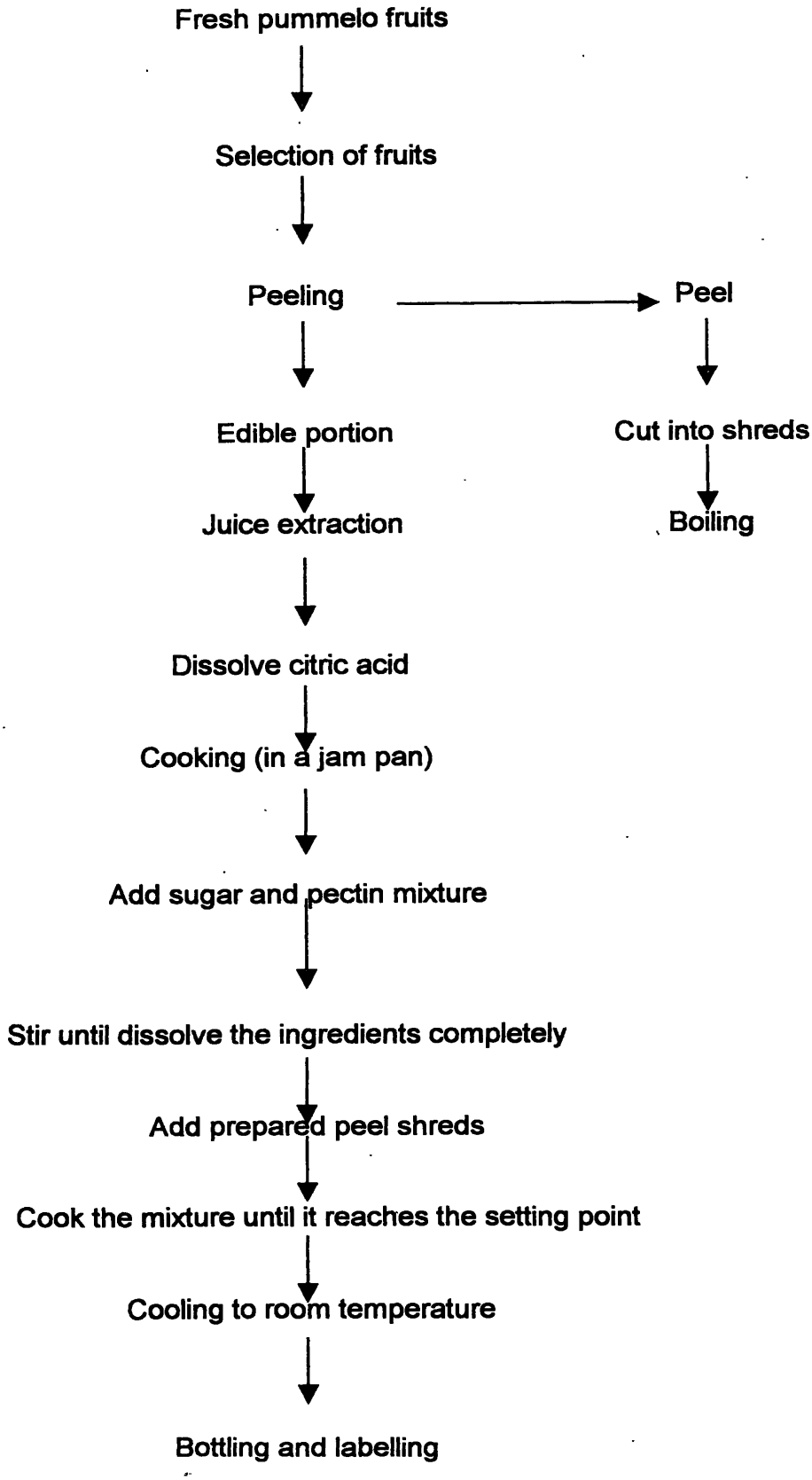


Figure 3.1: Process flow diagram for preparation of jelly marmalade

3.2.3 Pummelo Fresh Cuts

3.2.3.1 Preparation of Fresh Cuts

Fresh pummelo fruits were peeled off and edible segments, which contain juice vesicles (juice sacks) were separated carefully, with out damaging outer wall of the segments. These pummelo segments were packed in 150 gauge polyethylene bags, which can provide modified atmosphere conditions. Two segments were packed in one 5"×5" polyethylene bag and stored under refrigerated conditions (10-15 ^{0}C).

3.2.3.2 Analysis of Quality Changes During Storage Time

Observations were taken with regard to below mentioned quality parameters during the storage time of 15days.

(1) Total Suspended Solids (TSS)

(2) Titrable Acidity (TA)

(3) Vitamin C (Ascorbic acid)

Both parameters TSS and TA were recorded daily during the 15days of storage time and vitamin C level was recorded within 5 days intervals during storage time. TSS, TA and vitamin C content was determined according to methods described under appendix A, C, and E respectively.

3.2.3.3 Evaluation of Sensory Qualities During Storage Time

Sensory evaluation tests were conducted, in order to test the changes of sensory qualities, such as taste, appearance and colour during the storage period. Two triangle tests were conducted to compare the fresh cuts with fresh fruits, after 5 days and 10 days of storage time in a refrigerator at 10-15 ^{0}C temperatures. The procedure for conducting triangle test was described under appendix F.

3.2.4 Bottling of Pummelo Juice Vesicles

Fresh matured pummelo fruits were peeled off and segments were separated. Separated segments were dipped in boiling alkaline solution for 20-30 seconds in order to peel (lye peeling). These peeled segments (naked juice vesicles) were dipped again in dilute (0.5%) citric acid solution to neutralize the alkalinity. Then juice vesicles were washed with cooled water and allowed to drain off excess water. After that they were packed in sterilized glass bottles, and covered by 30^0 Brix sugar syrup. The glass bottles were exhausted for 10 minutes at 70-80 ^{0}C temperatures. Then the bottles were sealed, leaving a 3-4 mm headspace. These sealed bottles were pasteurised at 82-87 ^{0}C temperatures for 20 minutes. Finally the bottles were cooled rapidly in a water bath and labelled.

The pH value, titrable acidity (TA) and total suspended solid content (TSS) of bottled pummelo juice vesicles were measured.

3.2.4.1 Most Suitable NaOH Concentration for Lye Peeling

According to available literature most suitable NaOH concentration for lye peeling of citrus fruits was 1-2%. In order to find out most suitable concentration of NaOH for lye peeling of pummelo segments, below mentioned strengths of NaOH solutions were prepared.

(1) 1.00%NaOH
(2) 1.25%NaOH
(3) 1.50%NaOH
(4) 1.75%NaOH
(5) 2.00%NaOH

The test was conducted with each and every NaOH solution separately. Firstly the alkaline solution (NaOH) was boiled, and then mature pummelo segments were dipped for 20-30 seconds in that boiling alkaline solution. The test was replicated seven times for both white flesh pummelos and pink flesh pummelos. The results were analysed using computerized statistical program, named MINITAB.

3.2.5 Ready-To-Serve Pummelo Drink

3.2.5.1 The Preparation of Pummelo R.T.S.

A ready-to-serve food drink (R.T.S.) was developed from pummelo fruit juice according to the below mentioned recipe and procedure. The recipe was developed according to Sri Lanka standards, which were published under specification for ready-to-serve fruit drinks (SLS 729:1985, UDC663.81.).

3.2.5.2 Development of a Suitable Recipe for R.T.S. (according to SLS)

Fresh pummelo juice	75.0g
Sugar	65.0g
Water	360.0g
Citric Acid	1.5g
Potassium Metabisulphite (KMS)	50.0mg

3.2.5.3 Procedure and Process Flow Diagram

Matured fresh pummelo fruits were peeled off and juice was extracted manually. All the ingredients were weighed as mentioned in the recipe, using an electrical balance. Ingredients were mixed together and completely dissolved in 360g of water. The resulted liquid mixture was filled into sterilized glass bottles and sealed. These bottles were pasteurised at 65-80 ^{0}C temperatures for 30 minutes and cooled rapidly. Finally bottles were labelled and stored under refrigerated conditions.

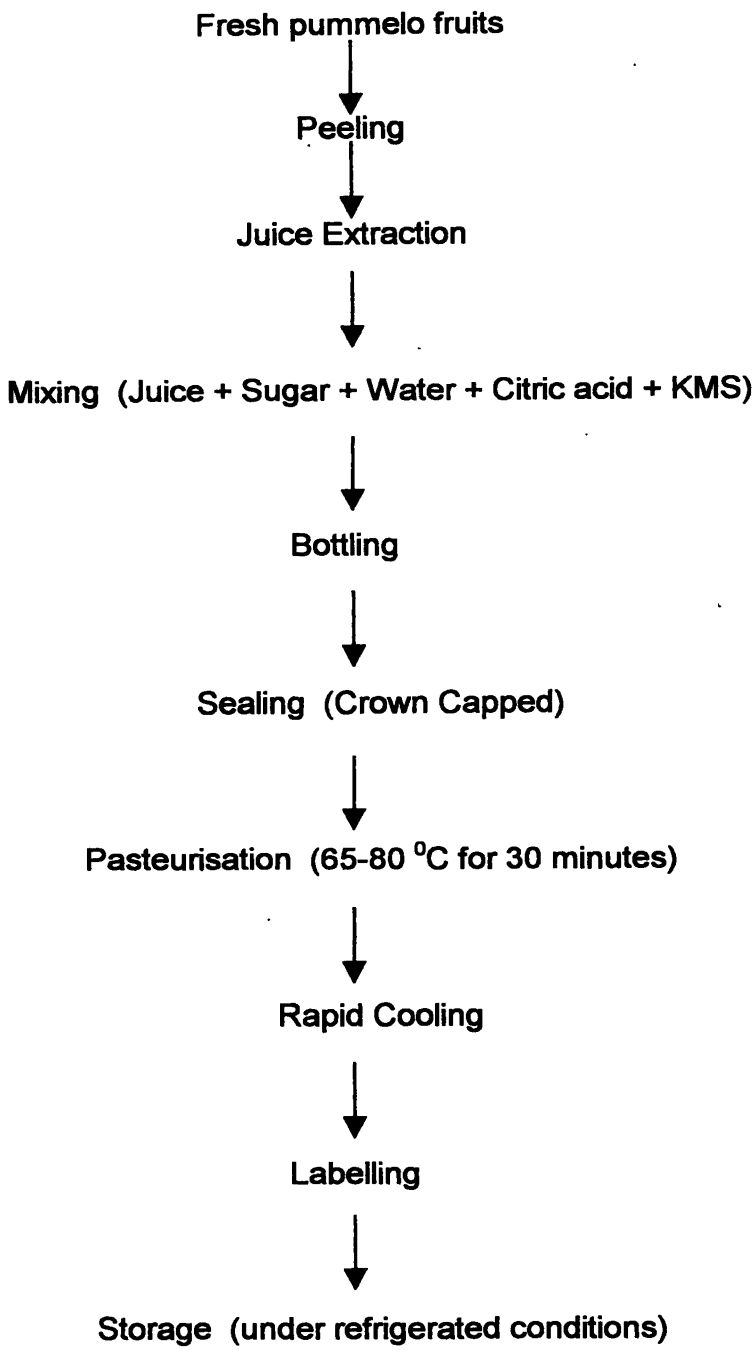


Figure 3.2: Process flow diagram for preparation of Pummelo R.T.S.

3.2.5.4 Analysis of Sulphur dioxide Content in Pummelo R.T.S.

The Sulphur dioxide content was analysed, according to Monier William method. Five days old samples, which were stored under refrigerated conditions within five days after preparation were tested.

CHAPTER 4
RESULTS AND DISCUSSION

4.1 Results

4.1.1 Morphological Study of Pummelo Fruits of Variety / type P4

The matured fruits of P4 variety are large, peel is green to Yellowish green in outer colour and the fruit is round to pear shaped. The peel is extremely thick, but easy to peel. The peel contains two layers, namely:

(1) Outer, thin, pale green layer

(2) Inner, thick, white layer

The thickness of pale green layer is uniform (about 2mm) and oil sacks are randomly distributed in the peel. In the blunt end area of the fruit, the gatherings of oil sacks are relatively higher than in stem end area.

The white layer looks like sponge and the thickness is higher at the stem end than at blunt end. The thickness of peel at stem end is around 3.3-3.5cm and at middle it is around 2.2-2.8cm, it became around 1.5cm at the bottom. The edible flesh that contains juice vesicles is pink in colour. The juice vesicles are about 2-3cm in length.

The seeds are oval in shape and yellow in colour with wrinkled outer cover.

4.1.2 Juice Characteristics of P4 Variety

pH value	4.00
TSS	9.00 ^{0}Brix
Total Sugars	7.2%
Invert sugars	0.002%
Titrable Acidity	1.11%
Ascorbic acid (Vitamin C)	19.4mg per 100ml of Juice

4.1.3 Variations of TSS, TA and Vitamin C of Fresh Cuts During Storage

The measured changes of TSS, TA, and Vitamin C levels during 15days of storage time are given in figure 4.1, 4.2, and 4.3 respectively.

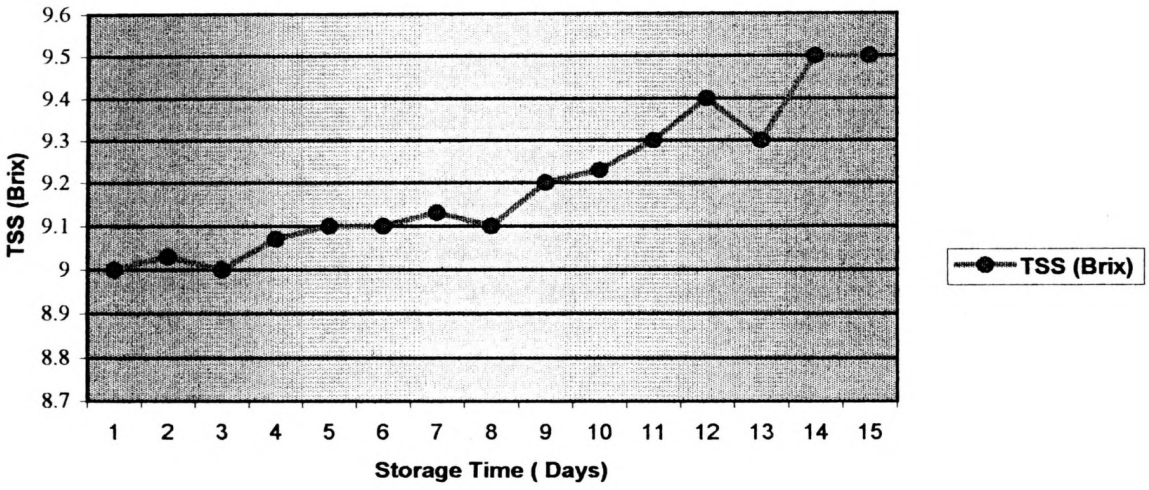


Figure 4.1: Changes in Totel Suspended Solids (TSS) content of fresh cuts during storage

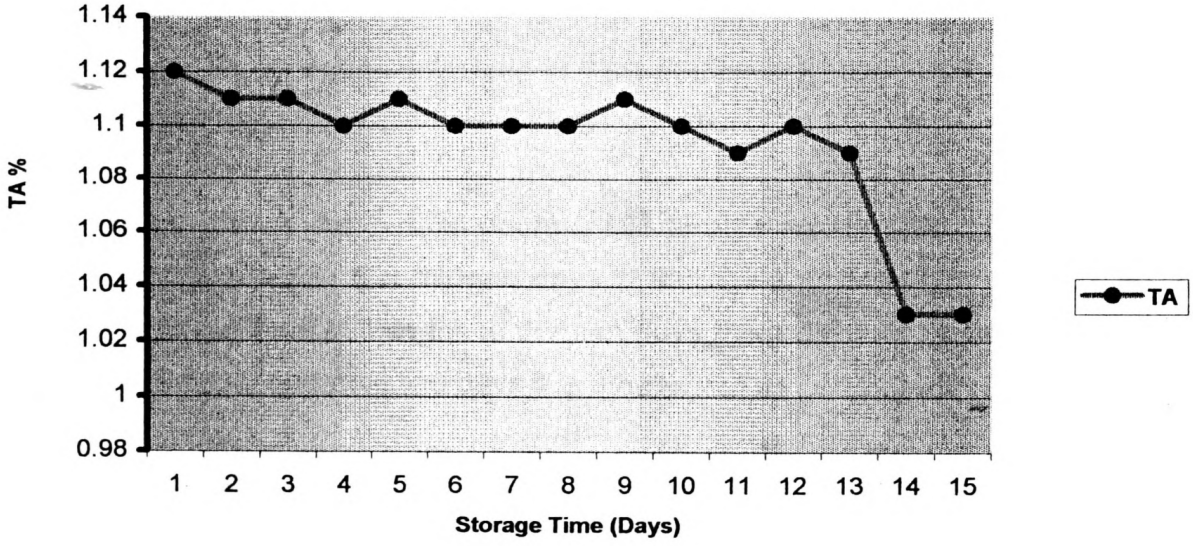


Figure 4.2: Variation of Titrable Acedity (TA) of fresh cuts during storage

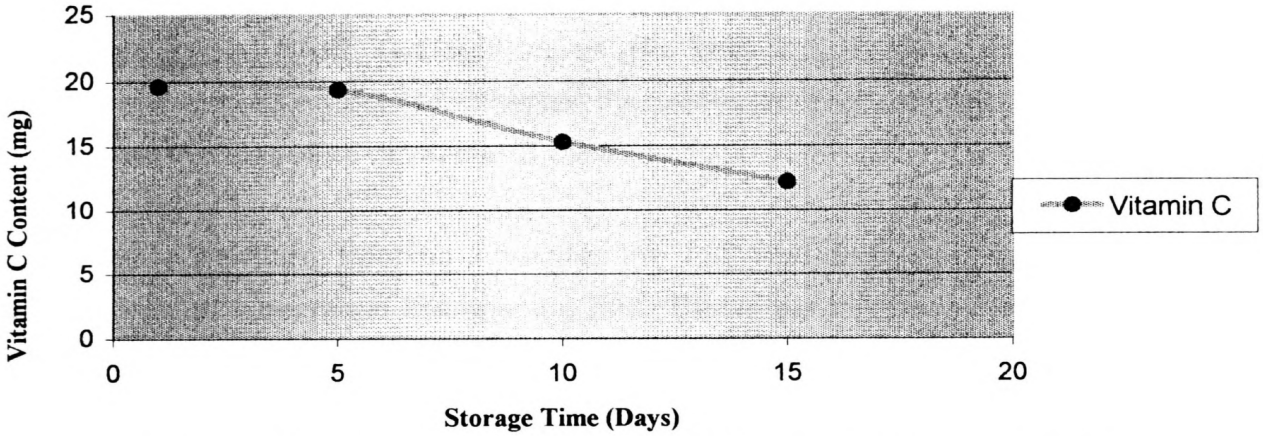


Figure 4.3: Changes in Ascobic acid (Vitamin C) content of fresh cuts during storage

According to figure 4.1 we can see increase in ^{0}Brix value (TSS) with time. The figure shows only 0.5 ^{0}Brix variation from first day to fifteenth day. This variation may due to break down of pectic substances of the cell wall. The rate of change of TSS is very little within the first eight days of storage then during the rest of storage period it increased at higher rate. That implies there is no considerable variation with regard to TSS in first eight days of storage time. The percentage change in TSS after 15 days was 5.56% only. Therefore it is clear that, there was no larger variation of TSS was reported during the storage time. Figure 4.1 shows an unexplainable decrease in TSS at thirteenth day. That may be due to an experimental error.

Figure 4.2 shows the overall decrease in titrable acidity (TA), which is a very slight variation within first thirteen days of storage and drastically change in rest of the storage time. Within these thirteen days the maximum percentage change of TA is 2.68%, and next two days it is 9.82%.

As figure 4.3 implies, the ascorbic acid content also decrease with time, but the rate of decrease is some what little at beginning (since first five days) and became higher later on. The maximum percentage change of vitamin C is 35.2%. But within first five days of storage time there no significant change in ascorbic acid content. According to literature there is a possibility to decrease in vitamin C

content due to oxidation and low temperature storage. Both of above reasons may affect in the case of fresh cuts, since we removed the outer cover of the fruit and stored under 10-15 ^{0}C temperatures. But according to literature, modified atmospheric conditions able to minimise the oxidation. That may be the reason for delaying the decrease of vitamin C content.

According to literature, ripening increases the TSS and decreases the TA. But low temperatures decrease the ripening rate. These two evidences express the reasons for the variation pattern of figure 4.1 and 4.2.

Figure 4.4: Prepared Pummelo fresh cuts

4.1.4 Sensory Evaluation Tests on Pummelo Fresh Cuts

Five days old fresh cuts are tested by ten-train-panellist. Out of them nine panellist were unable to identify the different sample accurately. Only one member was able to identify different sample accurately. According to the statistical table, which is shown under the appendix F there is no difference between five days old fresh cuts and fresh pummelo fruits.

Ten days old fresh cuts are tested by ten-train-panellist. Out of them seven members identified the different sample accurately. According to the statistical table there is a difference between fresh cuts and fresh fruits with regard to sensory qualities at 5%level of significant. But most of panellists (seven out of ten) recommended that, the ten days old fresh cuts are tastier than fresh fruits.

4.1.5 Tests Conducted on Pummelo Marmalade

According to the tests conducted on pummelo marmalade, below mentioned parameters were measured:

- TSS 80 ^{0}Brix
- TA 0.64%
- pH 1.05

During this study attempted to extract pectin from pummelo fruits. Literature also implies that, pummelo fruits (specially peel) consisting with higher levels of pectin. But the attempt was unsuccessful, since it gave unacceptable bitterness in final product. At sample preparation, it was experienced that low pectin levels (Pectin 1g per 1Kg of final product), results low-set marmalades and high levels of pectin (7g of pectin per 1Kg of final product), results stone like (hard) marmalades.

Determination of end point is very important in preparation of marmalade. It was experienced that, over cooked and less cooked marmalades were low in quality. Use of higher concentrations of sugar caused sugar syruping and lower consistency in final product and use of lower sugar amounts resulted less palatable products, with high susceptibility to microbial decomposition.

According to literature it was found that, boiling of peel shreds reduce the bitter component of the peel. During the study this process was practised accidentally, for juice segments before juice extraction. And experienced a reduction in the bitterness of prepared marmalade (Here, juice segments were dipped in boiling water for 30 seconds).

However the prepared marmalade according to the recipe mentioned under the chapter 3 was better in appearance, taste, colour and consistency.

Figure 4.5: Pummelo marmalade

4.2 Discussion

4.2.1 Bottled Pummelo Juice Vesicles

The results of tests, which were conducted on bottled Pummelo juice vesicles, are:

- TSS 15.43 ^{0}Brix
- pH value 1.47
- TA 0.698%

Initially a 30 ^{0}Brix sugar solution was used to cover the canned pummelo juice vesicles. But after bottling it was decreased to 15.2 ^{0}Brix.The reason for this may be the diffusion of water from pummelo juice vesicles (9.0 ^{0}Brix) to sugar syrup. According to literature bottled fruits are susceptible to growth of *Clostridium botulinum*, which is one of major food poisoning bacteria. Fortunately the growth of *Clostridium botulinum* is retarded below 4.6 pH level. Since bottled pummelo juice vesicles showed 1.47 pH level, above danger is eliminated.

Pummelo segments were lye peeled in order to liberate juice vesicles. So the results of the test conducted to determine the most suitable concentration of NaOH for lye peeling has been mentioned below:

Table 4.1: Results of the tests conducted to find the most suitable lye peeling concentration

NaOH concentration	Total number of observations	Amount of well-peeled segments	Amount of non-peeled segments
1.00%	7	1	6
1.25%	7	2	5
1.50%	7	4	3
1.75%	7	7	0
2.00%	7	7	0

According to a computerised statistical analysis system, found that 1.75% is the best NaOH concentration for lye peeling.

Finally it can say, the bottled pummelo juice vesicles are good in appearance and colour, but bitter in taste.

Figure 4.6: Bottled Pummelo juice vesicles

4.2.2 Pummelo R.T.S.

The tests conducted on pummelo R.T.S. were ended up with below mention results:

SO_2 content	48 ppm
TA of final product	0.47%
TA of fruit juice	1.6%
TSS of final product	14.9 ^{0}Brix
TSS of fruit juice	8.9 ^{0}Brix

The prepared R.T.S. was good in colour but bitter in taste, So that it should be further developed.

Figure 4.7: Pummelo R.T.S.

Figure 4.8: Prepared four food products during the study

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions and Recommendations

The suggested products that are Marmalade, Fresh Cuts, R.T.S, and bottling of juice vesicles can be successfully produce from pummelo fruits. But it is essential to develop these products further and further, especially in the case of pummelo R.T.S. and bottling.

Suggestions for Further studies:

- Study on nutritional losses during processing and storage.
- Study on debittering or masking of bitterness of these products.
- Study on microbial safety and sensory quality improvements of these products.
- Shelf life evaluation.

Appendix A

Total Soluble Solid (TSS)

Equipment and supplies

- Refractometer
- Thermometer if refractometer does not provide for the measurement of the temperature
- Dropper or plastic stirring rod
- Water and cleaning tissue

Procedure:

(1) Using the cleaning tissue clean and dry the prism and the surface of the fogged glass used to scatter the light.

(2) Prepare the sample by stirring with the plastic stirring rod and/or swirling; then using the plastic stirring rod or sample applicator, place few drops of sample on the prism. Bubbles or foams will distort the Brix reading.

(3) Close the refractometer by lowering the fogged glass into the sample, and make sure it is securely in place.

(4) Position the light source to shine through the fogged glass. Adjust the shadow to the crosshairs and read the brix value, or read the brix directly if the shadow falls directly on the brix scale it self. Cold samples may need to sit a few minutes so that the temperature cans equilibrate (Dan, 1999).

Appendix B

Titrable Acidity

To obtain the sample in suitable liquid forms, fallowing procedure was employed.

Juices: Mix thoroughly by shaking and filter through previously washed and dried muslin cloth.

Jellies and syrups: Mix thoroughly. Dissolve a known weight of the sample in water. Heat in a steam bath to dissolve, if necessary. Cool and make up to a known volume. Take aliquots for determination. If insoluble material is presented, filter before taking aliquots.

Fresh fruits, dried fruits, preserves, jams and marmalades: Pulp the sample in a blender or in a mortar, and mix thoroughly. Weigh the pulped material and add water and boil for 1hr replacing the water lost by evaporation. Cool, transfer to a volumetric flask and make up to volume. Filter if necessary.

Procedure:

Colourless or slightly coloured solutions:

Dilute an aliquot of the sample prepared as above with recently boiled distilled water. Titrate with 0.1N NaOH using a few drops of 1% phenolphthalein solution as the indicator. Note the end point. Calculate the results as percent anhydrous citric acid or other acids. Highly coloured solutions: Dilute the sample with distilled water and titrate just below end point with 0.1N NaOH, using phenolphthalein indicator. Transfer a measured quantity (2-3ml) of this solution in to approximately 20ml of neutral water in a small beaker (In this extra solution, colour of fruit juice became so pale that the phenolphthalein colour is easily seen). If the test show that the end point has not been reached, pore extra diluted potions back in to the original solution, add more alkali and continue the titration to the end point. By comparing dilution in a small beaker, differences produce by a few drops of 0.1N alkali can be easily observed.

The coloured solution can also be titrated by diluting a small volume of sample (e.g. 5ml of purple grape juice) with a large volume of distilled water (300-400ml). The colour become so pale that the indicator colour change during titration can easily be observed.

Calculation:

$$\%\text{Titrable Acidity} = \frac{\text{Titre} \times \text{Normality Of alkali} \times \text{Volume Made up*} \times \text{Equivalent Wt of Acid} \times 100}{\text{Volume of sample Taken for estimation*} \times \text{Wt or Volume of Sample} \times 100}$$

*This is not applicable if the sample is directly taken for estimation as given in juices (Ranganna, 1986).

Appendix C

Ascorbic Acid

Fruits and vegetables are important sources of ascorbic acid. The most satisfactory chemical method of estimation of 2,6-diclhlorophenol indophenols by ascorbic acid and those based on the reaction of dehidroascorbic acid with 2,4-dinitrophenylhydrazine.

2,6-Dichlorophenol-Indophenol Visual Titration Method

The dye, which is blue in alkaline solution and red in acid solution, is reduced by ascorbic acid to a colourless form. The reaction is quantitative and practically specific for ascorbic acid in solutions in the pH rang 1-3.5.

Reagents:

(1) 3% Metaphosphoric acid (HPO_3): Prepare by dissolving the sticks or pellets of HPO_3 in glass-distilled water.

(2) Ascorbic acid standard: Weigh accurately 100mg of 1-ascorbic acid and make it up to 100ml with 3% HPO_3. Dilute 10ml to 100ml with 3% HPO_3 (1ml= 0.1mg of ascorbic acid).

(3) Dye solution: Dissolve 50mg of the sodium salt of 2,6-dichlorophenol-indophenol in approximately 150ml of hot glass distilled water-containing 42mg of Sodium bicarbonate. Cool and dilute with glass-distilled water to 200ml. Store in a refrigerator and standardize every day.

Procedure:

Standardisation of dye

Take 5ml of standard ascorbic acid solution and add 5ml of HPO_3. Fill a micro burette with the dye. Titrate with the dye solution to a pink colour, which should persist for 15 seconds. Determine the dye factor, i.e. mg of ascorbic acid per ml of the dye, using the following formula:

$$\text{Dye Factor} = \frac{0.5}{\text{Titre}}$$

Preparation of samples

Fruit juices: take 10-20ml of sample and make up to 100ml with 3% HPO_3, filter or centrifuge.

Solid or semisolids foods:

Take 10g of sample, blend with 3%HPO_3 and make up to 100ml with HPO_3, filter or centrifuge.

Assay of extract

Take an aliquot (2-10ml) of the HPO_3 extract of the sample and titrate with the standard dye to a pink end-point which should persist for at least 15sec. Titrate rapidly and make a preliminary determination of the titre. In the next determination, add most of the dye required and then accurately. The aliquot of the sample taken should be such that the titre should not exceed 3-5ml.

Estimation of Interference due to Sulphur Dioxide

Sulphur Dioxide, when present in sample, reduces the indophenols dye and thus interferes in ascorbic acid analysis. If the sample contains SO_2, eliminate the interference by following the formaldehyde condensation procedure given below.

To10mlof the filtrate in a test tube, add 1ml 0f 40% formaldehyde and 0.1ml of HCl, keep for 10 minutes and titrate as before.

Calculation

Calculate the ascorbic acid content of the sample from the fallowing formula:

$$\text{mg of Ascorbic acid (per 100g or ml)} = \frac{\text{Titre} \times \text{Dye Factor} \times \text{Volume Made up} \times 100}{\text{Aliquot of Extract Taken for Estimation} \times \text{Wt or Volume of Sample Taken for Estimation}}$$

(Ranganna, 1986).

Appendix D

Triangle Test

Description of panellist task: panellists are presented with three coded samples, one different and two the same, and ask to select the different sample. Panellists are required to select the different sample even if they cannot discern any differences among samples. (i.e. panellists must guess when in doubt).

Presentation of samples: The two different samples (A and B) are presented to the panellists in sets of three. Panellists receive either two A's and B, or two B's and one A. The three samples are presented in identical sample containers coded with three digits random numbers. All three code numbers on the samples presented to each panellist must be different even though two of the samples are identical.

There are six possible serving orders for the triangle test and those are shown in billow mention table.

Table A.1 Six Possible Serving Orders for Triangle Test

Panellist Number	Order of Sample Presentation		
	First	Second	Third
1	256 (A)	831 (A)	349 (B)
2	256 (A)	349 (B)	831 (A)
3	370 (B)	256 (A)	831 (A)
4	349 (B)	670 (B)	256 (A)
5	349 (B)	256 (A)	670 (B)
6	831 (A)	349 (B)	670 (B)

A- fresh pummelo segments B- pummelo fresh cuts.

Each order should be presented an equal number of items, for a balance serving order. This is possible, however, only if there are six or some multiple of six, panellists. Alternately the order can be randomised so that each panellist has an equal chance of receiving any of the six possible serving orders.

The samples are presented simultaneously in the order selected for each panellist so that the panellist can evaluate the sample according to that selected order. The order in which the panellists are to evaluate the samples should be indicated in the ballot. The ballot, which is used for the triangle test, is given billow.

The ballot paper, which is used in the triangle test

Name ..... Date .....

(1) You have been given three samples of Pummelo fresh fruits. Two of These samples are identical and one is different. Taste the samples in listed order given billow and place a check beside the code number of the sample that is different.

Code	The different sample is,
(1)	.....
(2)	.....
(3)	.....

(2) Did you check by guess?

Yes ☐ No ☐

(3) Indicate the degree of difference between identical and different samples,

(i) Non
(ii) Slight
(iii) Moderate
(iv) Much

(4) Comments, if any.

Analysis of data: Results are analysed using a one- tailed binomial test for significance. The number of panellist correctly identify the different sample is totalled and the total tested for significance using table A.2

Since a probability of 0.05or less is usually required for significance, it would be concluded that there was no significant difference between the samples.

n\x	0	1	2	3	4	6	7	8	9	10
5	868	539	210	045	004					
6	912	649	320	100	018	001				
7	941	737	429	173	045	007				
8	961	805	532	259	088	020	003			
9	974	857	623	350	145	042	008	001		
10	983	896	701	441	213	077	020	003		
11	988	925	766	527	289	122	039	009	001	
12	992	946	819	607	368	179	066	019	004	001

Initial decimal point has been omitted

x- number of panellists, who choose the different sample correctly

n-total number of panellists participated the test

Table A.2 (Watts *et al*, 1989).

Appendix E

Results of Statistical Analysis of Data on Lye Peeling

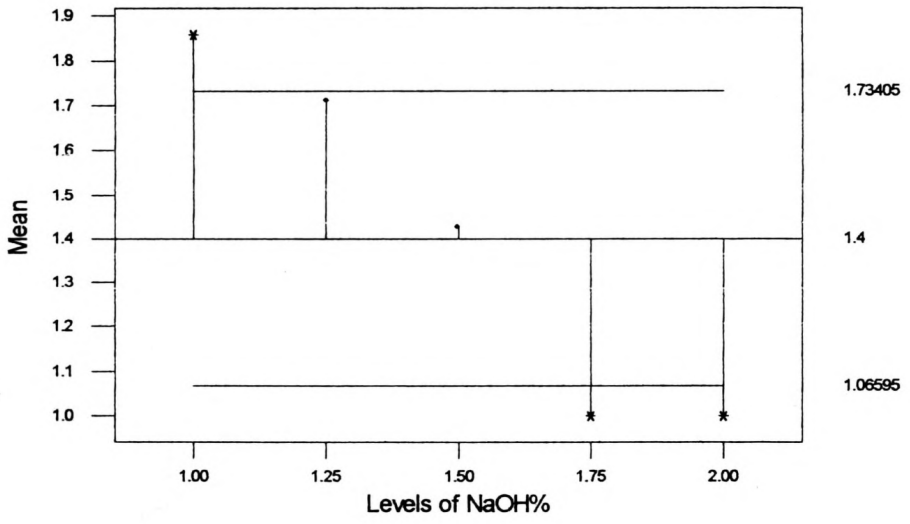
NaOH%	Peeled/not Peeled
1.00	1
1.00	2
1.00	2
1.00	2
1.00	2
1.00	2
1.00	2
1.25	1
1.25	1
1.25	2
1.25	2
1.25	2
1.25	2
1.25	2
1.50	1
1.50	1
1.50	1
1.50	1
1.50	2
1.50	2
1.50	2
1.75	1
1.75	1
1.75	1
1.75	1
1.75	1
1.75	1
1.75	1
2.00	1
2.00	1
2.00	1
2.00	1
2.00	1
2.00	1
2.00	1

Rows: NaOH%

	Peeled/not N	Peeled/not Mean	Peeled/not StDev
1.00	7	1.8571	0.3780
1.25	7	1.7143	0.4880
1.50	7	1.4286	0.5345
1.75	7	1.0000	0.0000
2.00	7	1.0000	0.0000
All	35	1.4000	0.4971

- Well Peeled segments: 1
- Not Peeled segments: 2

Results of statistical analysis of data on lye peeling



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