DEVELOPMENT OF TENDER COCONUT JAM

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DECLARATION

The work described in this thesis carried out by me at the 'Vasmee', Midigama Fruit Farms (Pvt.) Ltd., Midigama, Ahangama, under the supervision of Mr. S. B. Navarathna and Dr. K.K.D.S. Ranaweera. A report on this has not been submitted to another university for another degree.

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Affectionately Dedicated

To

My loving parents

And

Teachers

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ABSTRACT

Jam is a very popular processed food among the people all over the world. As the demand for processed foods increases with the concept of globalization the demand for the jams also increases as it saves a lot of time that spend to preparation of foods.

As there are a lot of types of jams available in the market, the objective of this project was to develop an innovative jam for the dynamic market, and to diversify the jam market by developing tender coconut jam out of tender coconut kernel.

Jam samples were prepared according to the method adopted for the other jam formulae. However antioxidants and emulsifiers were used as additional ingredients in order to prevent fat oxidation of the coconut pulp, the coconut kernel after blending.

Tender coconut kernel extracted from the form typica belonging to the variety *typica*, was taken to the experiment. Kernel from 9 and 10 months old nuts were scooped and blended to a pulp. Then jam samples were prepared according to 16 treatment combinations by using 4 variables at two levels. The variables taken were maturity level sugar level, pH level and antioxidants each using at two levels; low and high. Each treatment was replicated three times.

All the 16 samples were tested for pH and Brix values and organoleptic properties after one month and three months respectively. The results obtained were analyzed statistically and there were no significant differences between 16 samples according to the results. That implies all the 16 samples were at satisfactory level to the consumer for 3 months of period

pH value of individual samples was found constant up to three months. However different samples had various pH values ranging from 2.9 –3.2. One of the reasons for retaining the pH value constant can be suppression of microbial and autooxidation due to ingredients of the product. Brix value of the samples were at the range of 67^0 -70^0.

According to the results obtained it can be noted that the product has a shelf life of minimum of three months. Studies can be recommended to investigate on the shelf life of the product further

CONTENTS

List of tables

List of figures

CHAPTER 1

1.1:Introduction

Whole world moves to the concept of global village. People all over the world getting closer. Not like old days, specific works are being done by the people who are specified in the respective field and the time is a very important factor to them. Both women and men equally contribute to the development of their country, which does not provide much time for them to prepare foods for themselves. Processed foods therefore play an important role in solving this problem.

Jam is prepared by boiling the fruit pulp while adding a sufficient quantity of sugar in order to achieve a reasonably thick consistency, firm enough to hold fruit tissues in position. It is a very popular processed food among all the age groups. The consumer prefers to consume bread, sweet rolls and biscuits with jam for the breakfast, dinner or as snacks at the tea times.

The major ingredient of Jams are fruits. Including tropical fruits like Mango, Pineapple, Banana, Papaw, Woodapple and temperate fruits namely strawberry, Gooseberry, Blackcurrant, Raspberry etc.

Although the demand for fruits is constant in the market, most of the fruit varieties are seasonal. Therefore development of methods for preservation of fruits is need in order to keep these fruits in the off season too. During the fruit season, post harvest losses are remarkably high due to high yield, poor handling and storage practices and lack of technical facilities. As fruits are very rich in simple sugar available for microorganisms, microbial attacks too are high. Farmers especially in developing countries loss their harvest due to above reasons.

In this context, making jam from fruits is one of the best solutions to this problem. Additional yield of the season can be rationally used for jam production, enabling consumers to consume fruits in a different form in the off season. On the other hand, farmers can reduce post harvest losses thereby having an additional income.

Consumers' expectations and needs vary due to various reasons. Consumers demand for diversified food items is now one of the factors determining the market and its structure.

Jams made of different fruits presented in different forms can satisfy the needs of the consumer to a certain extent. Therefore jams also in various types, made from various types of fruits. Accordingly Food scientists make attempts to diversify the jam market by introducing numerous innovative types of jams; hence broad spectrum of jams available.

Jam preparation is carried out by using conventional, semi modern and modern methods. Conventional methods are mostly used in household levels and they make it hygienically.

Although tender coconut flavour is new to the jam market, aim of this project is to develop a tender coconut jam out of tender coconut kernel.

Coconut jam is prepared in several countries by using whole coconut milk as well as the skim milk or aqueous portion of the milk. They used matured coconut to extract coconut milk. The stages of *'kurumba'* and *'kalati'* can be stated as tender coconut and this stage reached in about 7 months after flowering.

Variety of food products such as dried coconut milk, coconut flour, coconut water based products etc. are produce using coconut in other countries. Although coconut industry occupies a pre-eminent position in the Sri Lanka's agriculture, its basically used in household consumption for culinary purposes and only the balance is converted to either copra or desiccated coconut for the export market.

Though making of this tender coconut jam exists in a few countries, still this process is novel. As the nutritious value of the tender coconut high, this jam has a high nutritional value than other jams.

1.2:Objctives

- Development of an innovative jam from tender coconut for the competitive market
- Diversification of jam market

CHAPTER 2

2.1: Jam

Jam is prepared by boiling the fruit pulp while adding a sufficient quantity of sugar in order to achieve a reasonably thick consistency, firm enough to hold fruit tissues in position. Jams may be made either from a single fruit or from a combination of two or more fruits. In preparing jam, the fruit is crushed or otherwise finely cut, so that when cooked, the mass is fairly uniform throughout. A jam is more or less a concentrated fruit possessing a fairly thick consistency and body.

High concentration of sugar facilitates preservation. A great advantage in its preparation is that it can be made completely in a single operation. (Giridhari et al., 1960).

Making jam from coconut is a new approach. A jam from tender coconut is not yet commercially available in Sri Lanka.

2.2: Ingredients in jam processing

2.2.1:Fruits

Fruit is the major component in the jam manufacturing. Various types of fruits are used all over the world in the jam industry. As far as the choice of fruit for jam is concerned, three main factors have to be taken in to consideration.

(i) Variety of fruit.
(ii) Condition of fruit.
(iii) Suitability in regard to preparation.

Strawberry, Raspberry, Blackberries, Blackcurrant, Gooseberry, Plums and Cherries are suitable varieties found in temperate countries for jam manufacturing. Citrus fruits are generally recognized maxim in the manufacture of marmalade. In Sri Lanka, we use number of fruit varieties in the jam manufacturing. Pineapple, Mango, Woodapple and Papaw are the main varieties. Matured coconut kernel also uses in some countries to make jams.

2.2.2:Coconut

Making jam from coconut is a new approach. A jam from tender coconut is not yet commercially available in Sri Lanka.

2.2.2.1:The place of the coconut in the world and its position in the Sri Lanka

The coconut palm is one of the most useful and important trees in the world and it has had a long association with human history. In the scientific nomenclature, the coconut palm is named as *Cocos nucifera.*

Worlds total coconut extent is over 5,923,000ha. 90% of this extent acreage of coconut lies in the zone between 20° N and 20° S latitude where six primary coconuts producing countries are situated. There are the Philippines, India, Indonesia, Sri Lanka, South Sea Islands and Malaysia.

Coconut comprises an important part of the diet in Sri Lanka in addition to being a very important source of export earnings. The worlds total production is about 35 million metric tons of coconuts a year and 80%, of this comes from the Asiatic region. Philippines rank the highest amongst the worlds coconut products. (Pethiyagoda, 1980)

Many industrialized countries import coconut products. Among the countries that consume coconut products the USA, Russia and the European Economic Community (EEC) appear to be important as major importers.

2.2.2.2:Coconut industry in Sri Lanka

Coconut industry occupies a pre-eminent position in the Sri Lanka's agriculture, that it is only second to lowland rice in land use (Pethiyagoda, 1980). The census of agriculture 1973, estimated the Sri Lanka's coconut area at 45,142ha of which 90% was managed by the small-holders having less than 8 1ha (20acres) (Pethiyagoda, 1980)

The coconuts are grown exclusively for nut production in Sri Lanka Only a minor proportion is being tapped for toddy The annual nut production has a declining trend It has been the result of several attributes, but mainly to the adverse weather conditions and reduced fertilizer applications (Pethiyagoda, 1980)

The countries nut production is basically used in household consumption for culinary purposes (58%) and balance is converted to either copra or desiccated coconut, while former in turn is further processed to oil before being exported or used for local consumption.

Sri Lanka's coconut exports are basically of two categories: kernel products and by products. All items derived from the kernel including Desiccated Coconut (DC), oil, copra and also fresh nuts are grouped into kernel products and the rest including fiber, shell products and other by products constitute the by-products.(Pethiyagoda, 1980)

2.2.2.3:Morphological features of the coconut

Order: Palmae

Family: cocoideae

Genus: *Cocos*

Species: *nucifera*.

An average palm produces 12-14 fronds per year. Each frond bears an inflorescence in its axils once the palm has reached maturity. A dozen or so fruit bunches bearing fruits at various stages of maturity and ten to twelve unopened spathes occur in the crown at a given time. The leaves occur in the five spirals with the sixth leaf roughly below the last emerged leaf and the eleventh leaf roughly below the sixth leaf and so on. The leaf spiral may be right handed or left handed depending upon which side of the cotyledon the second leaf develops from. The leaf spirality is visible in the leaf scars on the trunk. (Pethiyagoda,1980)

- **The inflorescence**

Typical tall variety coconut palms come into flower in about the sixth year if water, light and nutrient conditions have been favourable. Dwarf types generally flower in about the fourth year or sometimes even earlier. Following emergence of the first flower, inflorescences are continually produced in each successive leaf axil.

The inflorescence is encased in a sheath or spathe which when fully grown splits along the under side and releases the inflorescence. The spathe and the inflorescence are collectively called the 'spadix'. The inflorescence has many bunches on which female and male flowers occur. The female flowers can become fertilized by self-pollination or by cross-pollination.

The button nut enclosed partly in the perianth expands fast and develops a cavity within it which enlarges and gradually fills with liquid. The kernel then begins to thicken and other internal changes such as changing of constitution of the nut water and the laying of endosperm takes place from then on, up to about a period of another six months.(Pethiyagoda, 1980). The observed changes during the development of coconut from flower to fruit are given in the table 2.a. (Balasubramaniam, 1981)

The fruit of the coconut is basically referred to as a drupe. The husk comprises an outer smooth epicarp and a fibrous mesocarp. The shell is the endocarp and the kernel is the endosperm, which has embedded in it, the embryo at its proximal end. The water in the nut is also part of the endosperm referred to often as a liquid endosperm.

Table 2.a. Development of coconut from flower to fruit

Bunch Number [a]	Volume of liquid endosperm	Solid kernel		Description of the nut
		Weight G	Moisture %	
1	0.0	0.0	0.0	Button stage, not pollinated.
2	0.0	0.0	0.0	Pollinated. Cavity not yet formed.
3	2.5	0.0	0.0	Very small cavity, but full of liquid endosperm. Salty in taste.
4	30.0	0.0	0.0	Cavity enlarges. Liquid endosperm fills cavity.
5	84.0	0..0	0.0	Liquid endosperm is sweet.
6	240.0	0.0	0.0	Nucellus soft, only liquid endosperm in cavity.
7	443.0	9.1	93.5	Tender '*kurumba*' soft endosperm just beginning to form.
8	490.0	39.8	89.5	'*kurumba*', solid kernel seen in distal one third.
9	411.0	122.0	83.0	Mature '*kurumba*' kernel jelly-like and covers the entire area.
10	285.0	132.0	75.0	Very tender '*kalati*' kernel can be scooped out in one piece.
11	260.0	210.0	65.0	'*kalati*' kernel very firm.
13	98.0	203.0	51.0	Mature '*kalati*', water sloshes, shell hard
15	72.0	210.0	45.0	Mature drupe: ready for picking.
17	67.0	237.0	44.0	Ripe drupe, about to fall

a Coconut bunches are numbered in the order of increasing maturity from the top of the stem

Source. Balasubramaniam, (1981).

2.2.2.4:Types of coconuts

A variety (or strain) generally means a single population having morphological characters recognizably differing from any other population. A variety can cross-fertilize with another to produce a hybrid. The species *Cocos nucifera*, due to its global distribution and out breeding habit, encompasses a number of types varying widely in such characteristics as stature, size, shape and colour of the nut, floral biology, age at first flowering etc.

There is consequently much confusion in the recognition and naming of varieties, and different countries have established their own nomenclature of varieties and therefore a tree with similar characters may be named as differently in different countries Estimates of the number of coconut varieties (or types or forms) of coconut vary widely and range from about a dozen to as many as four times that number. Thus, a universal classification of coconut varieties is still lacking although Liyanage (1958) proposed a workable distinction into three principal varieties (typica, nana, and aurantiaca) with fourteen 'forms' within them.

- **Varieties of coconut in Sri Lanka**

Several varieties of coconut have existed in Sri Lanka, from very early times. As early as in 1856, five coconuts were describe as Thembili, Navasi, Dwarf, Thembili with large nuts and common tall type. A more recently proposed classification of the coconut palms in Sri Lanka is based on morphological characters and breeding behaviour. The following is a brief account of the proposed classification of the varieties and forms of coconut found locally. It is probable that many, if not all of the types existing in other countries in the region can be fitted in to these descriptive classes for all practical purposes.

The first distinction in to varieties is based on the stature of the plant and on nut colour. The *typica* Nar, is tall in stature with nuts ranging from green through shades of olive colour to brown. *Nana* griff, are dwarf in stature. Variety *aurantiaca* Liy. Is semi-tall with bright orange fruits. (Pethiyagoda, 1980) The salient characters of these three varieties are as follows

(a) Varity *typica* Nar.

This variety predominantly outbreeding due to the male flowers in a spadix opening earlier than the female flowers. Trees have broad trunk with an average circumference of about 84cm and attain a height of about 18m.

The flowering is late and it takes place normally 6 - 8 years after planting. Flower production is continuous. Nuts are medium to large in size. These are hardy palms tolerating a wide variation of soil types and climate. Under a favourable environment, the period of economic production is about 60 years. (Pethiyagoda, 1980).

(b) Variety *Nana* Griff.

This variety is predominantly in breeding as the male and female phases of the inflorescence overlap. They have a narrow stem with a mean trunk circumference of about 56cm and they attain a height of about 10.7m. Flowering takes place early at 3-4 years after planting. Flower production is seasonal. The nuts are generally small in size. Palms of this variety thrive on deep fertile soils in regions with a well-distributed rainfall, but they are susceptible to pest and diseases and sulfur markedly from drought. The period of economic production of this variety is no more than forty years. Palms belonging to this variety are however not considered an economic proposition, for growing on a plantation scale in Sri Lanka. (Pethiyagoda, 1980)

(c) Variety *aurantiaca* Liy.

Palms of this variety are predominantly inbreeding because the male and female reproductive phases of the inflorescence overlap. The stem is medium sized with a mean girth of about 71cm and attaining a height of about 12.2m. The flowering is late and it usually takes place6-8 years after planting, and is seasonal. The nuts are of medium size, the epicarp of the nut is orange in colour. Endosperm is thin. These palms thrive in fertile soils with a high water table and areas with a well-distributed rainfall. Economic production period is not more than forty years. (Pethiyagoda, 1980)

- **Forms within varieties**

The three varieties whose main features have been briefly described can be further sub-divided. These sub-divisions are known as 'forms' and their main distinguishing characters are as follows.

1 forms of the variety *typica* Nar:

(a) Form typica: The nuts are generally oblong. The epicarp (outer skin) of the nut is of different shades of green to reddish brown (copper). The mesocarp (fibrous husk) is a good source of fibre. The endosperm (kernel) is thick and averages about 199g dry weight per nut.

(b) Form Navasi: The epicarp is green in colour. Mesocarp of the immature fruit is sweet and edible. The husk of the mature nut is soft and the nut water is insipid.

(c) Form gon thembili: The epicarp of the nut and the mid rib of the frond is ivory yellow, in colour. Water of the tender nut is usually insipid. The nuts are large. The kernel has high oil content. (69.2%)

(d) Form ran thembili: The epicarp is green and the mesocarp when cut is pink in colour. The endocarp (shell) is thin. The endosperm is thick and hard. Oil of ran thembili is said to be of medicinal value.

(e) Form pora-pol: Husked nut is very small and elongated. Endocarp is hard and very thick (About 6mm). These nuts are used in a type of festive sport (*'pora-pol gaseema'- sinh.*), occasionally seen in the southern parts of Sri Lanka.

(f) Form bodiri, Palms of this form are prolific bearers. The nuts are small. Each bunch carries 50-100 nuts. Oil content of the kernel is high (69.6%).

(g) Form kamandela: Nuts are about 1.5 times as large as these of the form typica. Only a few nuts are produced per bunch The distribution of this form is generally restricted to the southern province of Sri Lanka.

(h) Form dikiri pol: Endosperm of this form is soft and is 2-3cm in thickness. Certain portions of the endosperm (or the entire endosperm of certain nuts) are of a buttery consistency and getatinous. The soft meat of the kernel is considered as a delicacy. This form appears to be closely allied to the Philippines 'macapuno'.

2. Forms of the variety *Nana* Griff

(a) Form Pumila (the green dwarf): Inflorescence is yellowish green and the epicarp of the nut is green. Follwing takes place early generally in 21/2 to 4 years from planting

(b) Form ebumea: (the yellow dwarf) :Inflorecsence is ivory yellow and the epicarp of the nut is yellow.

(c) Form regia: (the red dwarf):Inflorescence is orange in colour while the epicarp of the nut is apricot red.

The red and yellow dwarf appear to bear larger nuts than the green dwarf found in Sri Lanka. However, there are green dwarfs with large nuts known from other countries.

3. Forms of the variety *aurantiaca*

(a) Form Thembili: This form is known by the popular name, King Coconut in Sri Lanka. Upper surface of the leaf midrib, inflorescence and epicarp of the nut is orange. Sucrose content of the tender nut-water is relatively high (5- 6.5%) furnishing a delicious refreshment. Oil is said to be of medicinal value and it has the peculia characteristiic of having a higher melting point than ordinary coconut oil This form breeds true to type. (80%)

(b) From navasi thembili: Upper surface of the leaf mid ribs, inflorescence and the epicarp of the nut is orange. Mesocarp of the tender nut is sweet and edible. Endocarp is very thin. Endosperm is thin and hard

The variety aurantiaca appears to be confined in distribution to only Sri Lanka. The form typica is the best producer as a commercial plantation crop. Other types are grown on a minor scale the form thembilli for consumption as immature nuts. Table 2.b. presents a summery of some quantitative characters of nut components of the forms of coconut in sri Lanka. (Pelhiyagoda, 1980)

Table 2 b : Quantitative characters of nut components of the forms of coconut in Sri Lanka.

Variety *Typica*	Unhusked nut			Husked nut		Shell		Thickness of endosperm (mm)
	Length (cm)	Width (cm)	Volume(ml)	Volume(ml)	Wei it (g)	Thickness (mm)	Weight (g)	
Form typica	21.8	19.8	3200	870	0 1	3	159	15
Form Navasi	22.6	19.3	3175	877	0 2	3	170	13
Form gonthembili	22.6	16.5	2535	787	0 8	3	198	13
Form ran thembili	21.8	19.3	3728	857	0 2	3	198	14
Form pora pol	22.9	16.5	1870	683	0 4	6	227	13
Form bodiri	11.4	9.1	606	218	0 0	2	51	10
Form kamandala	26.9	22.6	5922	1760	1 9	3	323	14
Form dikiri pol	–	–	–	–		–	–	–
Variety *Nana*								
Form pumila	19.8	13.7	1457	367	0 3	2	71	11
Form eburnea	19.1	14.7	1591	474	0 [illegible]	2	88	12
Form regia	19.1	12.4	1140	334	0	2	57	11
Variety aurantiaca								
Form thembili	20.8	13.5	1394	559	0 [illegible]	2	170	12
Form navasi thembili	19.3	14.5	1573	525	0 [illegible]	2	99	12

Source Pethiyagoda, (1980)

2.2.2.5:Food products from coconut

- **Preservation of tender coconut kernel:**

Tender coconut kernel cut in to strips and put into cans covered with hot syrup. Exhausted to centre temperature of 80°C, sealed and processed. This product has a shelf life of four to six months at ambient temperature and has been found to be microbiologically safe even after one year. (Thampan, 1993)

- **Coconut milk and related products:**

Coconut milk diluted with water is reported to be used as an adulterant for cow's milk in certain places in India. Preserved forms of coconut milk such as canned cream or milk and dehydrated whole milk is now becoming available in many coconut growing countries. Commercial production of these products has been promoted in the Philippines, Thailand, Indonesia, Western Samoa, Sri Lanka and Malaysia.

Coconut milk is also preserved as sugar concentrates for direct food use as soft drink base, desert, bread-spread etc The familiar preparations are coconut jam, coconut syrup, coconut cheese, and coconut honey and sweetened condensed milk.

Coconut jam is prepared using whole coconut milk as well as the skim milk or aqueous portion of the milk. Another useful product prepared either from the fresh coconut milk or skim milk is coconut honey, which is an excellent substitute for real honey in many household and confectionery applications. The coconut honey is a golden coloured thick paste with a nutty flavour.

- **Coconut skim milk and related products:**

Coconut skim milk is a solution of the soluble components of coconut after the cream is separated in a cream separator. It can be used for the preparation of a variety of products like coconut jam, coconut honey and sweetened condensed milk.

The skim milk is an excellent soft drink base either as instant flakes and powder or as liquid. The skim milk on spray drying yields a tasty product with a pleasant coconut flavour. It resembles the non-fat dry milk and can be a valuable commodity in the food and beverage industry. It could also be an excellent beverage base. Skim milk is also a source of vegetable casein.

In Brazil, the gastrointestinal disturbances were successfully treated in infants by feeding coconut milk, which shows that coconut skim milk having the same protein level (1.6%) as mothers milk is well utilized by infants. Both produce a soft curd when acted on by the gastric juice.

- **Desiccated Coconut:**

Desiccated coconut is the dried out disintegrated coconut meat. It is a very important commercial product having demand all over the world in the confectionery and other food industries. Major producing countries are Sri Lanka and Philippines.

- **Coconut flour:**

In the production of coconut cream and other related products the fibrous residue obtained after expelling the milk is dried and powdered to obtain a product called coconut flour. It can be used as an ingredient in weight control foods because of its high fibre content.

- **Edible copra:**

Edible copra is available in two different forms – ball copra and cup copra. The Lakshadweep Micro, a local type grown in the Lakshadweep Islands is considered to be the best for the manufacture of ball copra. Edible cup copra is prepared either from fully matured nuts or from stored nuts in Sri Lanka and in some parts of India.

- Fresh coconut meat is processed and converted in to chips for edible purposes in some countries, especially in the Philippines

- **Coconut water:**

The National Institute of Science and Technology, Philippines, has developed a variety of products from the coconut water and one of the products called, 'Nata – de – Coco' is a delicious food article and appears to have a promising future in the coconut based food industry

Nata –de –Coco is a gelatinous product formed by the action of microorganism, *Acetobacter xylinum* in a culture medium of sugared coconut water

Vinegar is a common product made from coconut water

The coconut water also yields an excellent sauce, very similar to Worcester sauce on being boiled down to thick brown syrup and spiced with red chili, onion powder and a little vinegar.

Coconut lemonade is good syrup like product, which is made by boiling coconut water; sugar and lemon juice until about 65° Brix is reached.

- **Toddy and toddy products:**

A sugar containing juice, known as toddy, is obtained by tapping the unopened spadix of the coconut palm. The fresh toddy is an excellent beverage and a rich source of sugar.

- **Jaggery:**

By preventing fermentation either at the time of collection or immediately after the fresh toddy is obtained from the palm, sugar or jaggery is prepared by evaporating the liquid through careful boiling in open vessels

- **Treacle:**

This is concentrated syrup of sweet toddy obtained by boiling down the toddy, while super heating is avoided and the syrup is progressively strained. The final product is golden coloured syrup and the recovery is about 16% of the toddy used

- **Fermented toddy:**

Sweet toddy under normal conditions of collection undergoes fermentation and gives rise to the common alcoholic drink 'fermented toddy'.

- **Arrack:**

Arrack is the product obtained by the distillation of fermented toddy.

- **Other products:**

When the nuts are stored for a long period the spongy ball – like haustorium's develops inside the nut. This is utilized for the preparation of various products like jam, marmalade etc. It is sometimes sliced and preserved in sugar syrup for use as a dessert or as a constituent of fruit salad. (Thampan, 1993)

2.2.3:Pectin

The gelling power of pectin has been used in foodstuffs ever since the first fruit preserves were made. Pectin itself was first isolated and named by Braconnot (1825) who carried out some of the first systematic studies on the subject.

Pectin materials occur in most land plants, especially in soft tissues such as young shoots, leaves and fruits. In plants they have an important role in the middle layer of the plant cell wall helping to bind cells together, in association with cellulose, hemicellulose and glycoproteins.

Despite this wide occurrence, only a few source materials have been used to provide commercial pectin as an additive for use in foods. One of the reasons for this is that many of the pectin materials present in nature do not have the functional properties, especially the ability to gel acid sugar systems, which has been the main requirement of commercial pectins until recently. The broad class of pectic substances includes many containing high proportions if neutral sugar units or highly substituted with acetyl or other groups and these frequently prevent gelation.

2.2.3.1:Sources of pectin

Pectin industry has been developed as a by-product industry, using waste materials from the food industry especially from the production of fruit juices and juice based drinks. Mainly apple pomace and citrus peel have provided the raw materials for the commercial pectin industry. Other by-products from the food industry, which contain significant quantities of pectins, include sugar beet pulp and sun flower heads (May, 1999)

2.2.3.2:Chemical nature of pectin

The molecular structure of pectin is composed of D- galacturonic acid molecules, which are linked to each other in alpha 1-4 - glycosidic formations to polygalacturonic acid. Parts of the carboxyl groups are methoxylated with methanol. Pectin is a heteropolysaccharide, because neutral sugars like galactose, arabinose and xylose are linked to the pectin macromolecule by side chains, and the main chain is ruptured by rhamnose (Kratz, 1993)

Pectin as first extracted has a relatively high degree of esterification, around 70 - 75% of the acid groups in the molecule being naturally esterified with methanol. Such pectin is ideal for use in a conventional jam and will give a rapid set to prevent the

setting characteristics.

Esterification %			
80	High methoxyl	Rapid set	Acid milk products
70		Slow set	Jam
60		Special uses	Jellies, confectionary
50			
40	Low methoxyl	Low	reduced sugar-
30		Medium } calcium	- products
20		High reactivity	Low sugar or low-
10			-acid products.
0			Non-acid foods
			juice fining.

Fig.2.a. De- esterificaton of pectin to give a range of products

Pectin is modified by reducing the degree of esteification. (Commonly referred to as DM or degree of methylation.) If the DM is reduced to around 60%, the pectin is slow set type and is capable of gelation only in systems with a high sugar content under similar conditions, the gel will set more slowly or at a lower temperature compared with the original rapid-set pectin.

However, it will also tolerate either higher sugar concentrations or a lower pH. Once the DM is below 50%, the pectins are known as low methoxyl and become steadily more reactive with calcium. They can be gelled under progressively lower soluble solids conditions, provided an appropriate amount of available calcium is present Amidated pectins are mostly of the low methoxyl type and have the advantage of tolerating more variation in calcium content

2.2.4:Pectin gel formation

The formation of pectin gel is an extremely complex subject, not least because pectin is not a single specific chemical compound. In simple terms, pectin is able to form gels with sugar solutions which have soluble solids in the range 60 – 70% and pH values of 3.0 – 3.4

The controlling factors –(I) pectin type and quantity, (II) sugar concentration and (III) pH must be balanced to obtain optimum gel conditions. (Broomfield, 1988)

2.2.4.1;Gelation: high methoxyl pectins.

High methoxyl pectins will gel only under specific conditions of sugar concentration and acidity. Lower sugar content requires for proper gelation at lower pH values, higher pH values are feasible with higher sugar content. If the sugar content remains constant, gels with lower pH ranges will be harder and more brittle, the same applies if the pH stays the same and the amount of sugar increases.

The optimal soluble solids content for jams is 60 – 65%. Replacing part of the sucrose with glucose syrup or the use of the optimal type of pectin may prevent the formation of brittle gels and the crystallization of sugar and dextrose. The lower limit for proper gelation of high methoxyl pectins is a soluble solids content of about 55%. With 55 – 58% soluble solids, high methoxyl pectins with a very high degree of esterification (above 75%) show the best results. High methoxyl pectins do not gel at very low solids contents, for this application low methoxyl pectins and calcium salts are used instead.

Setting time and setting temperature

High methoxyl pectins are commercially available within the range of 50 to approximately 80% degree of esterification. This group of pectins shows a quite specific gelling behaviour. Under virtually the same conditions, higher methoxyl pectins set faster and at higher temperatures than pectins with lower degrees of esterification. This explains the importance of setting time and setting temperature for the evaluation of high methoxyl pectins.

Based on the differences in setting time and setting temperature at which the gelation starts subsequent to gel manufacture in the following cooling period. There is no setting above this temperature, even though all criteria for gel formation are met. Gelation of extremely high methoxyl pectins, as shown in test gels, may already start at, for example, 90°C, that of less high methoxylated pectins at 60° C. The setting temperature also depends, beside the pectins degree of esterification, on the sugar content and the product's pH as well as the amount of buffer salts added and the cooling rate. The faster the products are cooled down, the lower the resulting setting temperature.

The setting time is defined as the period in which a fruit preparation after terminating the cooking process starts to gel at a defined constant temperature. The definition for a rapid set pectin might be that under defined condition setting requires 10 minutes at 90^0 C and slow setting pectins need for example 20 minutes at 65^0 C.

2.2.4.2:Gelation: low methoxyl pectins.

Low methoxyl pectins form gels by reaction with calcium ions. When small amounts of calcium ions are added, the pectin chains start to bond over calcium bridges. With increasing calcium ion concentration, gelation sets in. in case of excess dosage of calcium ions, calcium pectinate will precipitate under the given gel forming conditions, which is also referred to as 'pre –gelling'. The amount of the calcium dosage does not only control the strength of the gel, but also its rheological and sensorial properties. With a relatively low calcium concentration in relation to the pectin content the gels are slightly gelled; they are soft and spreadable with a low tendency to syneresis. The gels melt in the mouth; the fruity, sweet taste is pronounced, with increasing calcium concentration the gels become firmer, more elastic. With very high calcium concentration gels become brittle with tendency to syneresis The gels do not melt in the mouth, they feel rough. (Kratz, 1993)

2.2.5:Sugar

Sugar is chemically known as sucrose. Which is a sweet carbohydrate. It is also classified as a disaccharide i.e. when hydrolyzed by an enzyme or acid, it will yield one molecule each of glucose and fructose.

Sugar is an essential ingredient in our diet and is an important source of energy. One gram of carbohydrate will yield four kcal of energy. Sucrose is mainly obtained from sugar cane or sugar beet. It is found in the market in different grades ranging from icing sugar to granulated sugars and in colour from white to dark brown

2.2.5.1:Types of sugar

<u>Type 1: Brown sugar / Raw sugar.</u>

This is produced by simple defaecation or a modified defaecation process Defaecation is the sedimentation of the insoluble and some of the soluble non –sugar components in sugar by adding lime, (calcium oxide) to the juice at pH 8.0 – 8.4 and heating it. Sugar manufactured in this manner will have a characteristic flavour, sweetness and a wide range of colour from light brown to dark brown. The variation in colour is due to the molasses layer surrounding it.

Type 2: Plantation white sugar / mill white sugar.

When defaecated sugar is further decolourized by sulphitation or carbonation it gives an off white crystalline product known as plantation white sugar / mill white sugar.

Type 3: Refined white sugar.

This has undergone further purification with the aid of animal charcoal or bone charcoal in order to produce a white odourless sugar. Charcoal removes the gummy substances and the colouring matter.

Type 4: Icing sugar.

This is the pulverized white sugar with or without the addition of starch or anti caking agent.

Type 5: Mineral water sugar.

This is sugar refined specially to a very low concentration of ash and colour to be used in the mineral (aerated) water industry.

Type 6. Canner's sugar.

Canner's sugar should have a low microbiological count and low SO_2 content. The latter is to prevent blackening of the tin plate used in the canning industry.

In the food industry sucrose is used as a sweetener, bulking agent, texture modifier, preservative, flavour enhancer and as a fermentative substrate (for alcohol and spirit manufacture). Such multifunctional properties of sugar are related to the physical, chemical, microbiological and sensory characteristics of sucrose. The fruit processing and beverage industries in Sri Lanka consume the largest quantity of sugar. In jams and jellies, sugar act as a preservative. The setting of jam depends on the correct pH, acidity, pectin and sugar contents. Brown sugar cannot be used in the manufacture of the jams due to its varying buffering action. (Selvarajah 1990)

2.2.5.3:Effect of sugars in jam manufacture

During the boiling process some of the sucrose is converted to invert sugar, a mixture of dextrose and fructose This conversion is accelerated by increasing in temperature and by decrease in pH Inversion is advantageous since a solution of sucrose is saturated at about 66% at 20°C and may crystallize at higher concentrations. The solubility of a mixture of sucrose and invert sugar is higher, although an excess of dextrose will produce dextrose crystallization. In general, an invert level of 20 – 35% of the sugars will avoid either type of crystallization in products up to 72% total soluble solids (Broomfield, 1988).

2.2.6:Citric acid

The history of the commercial citric acid production can be traced back to the mid 19th century in the UK, when The Atlas Chemical Works in London started manufacturing the acid from lemon juice, imported from Italy.

It is not only lemon or citrus fruits (from which it derives its name), which contain citric acid Many other fruits, plants and even milk contain it too. Although originally citric was extracted from citrus fruits alone, by the early 1900's, mounting pressure of demand made this process uneconomical. Consequently, large-scale fermentation was commercialized in 1923 using the microorganism *Aspergillus niger*. Today the main raw materials for citric acid production are carbohydrates such as molasses and starches Production involves fermentation techniques with microorganisms converting the sugars into citric acid The citric acid broth produced from this fermentation is purified, concentrated and crystallized into either the anhydrous or monohydrate form, depending on the temperature The acid is then sieved into fine, medium or coarse granules or powders. Salts of citric acid are produced by neutralization with the appropriate alkali; the most widely used salt being trisodium citrate

2.2.6.1:Scope of applications

Citric and its citrates offer numerous processing attributed which make them an important tool for a range of products, from soft drinks to sauces, from canned fruits and vegetables to cheese and meats

Citric fulfills a variety of functions, imparting flavour, prolonging shelf life and contributing to ease of processing Citric acid, sodium and potassium citrates can be

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Citric fulfills a variety of functions, imparting flavour, prolonging shelf life and contributing to ease of processing Citric acid, sodium and potassium citrates can be used as independent ingredients, in conjunction with each other, or with other types of food additives, such as preservatives or antioxidants, to extend their performance.

As citric acid is a natural component of most fruit juices, its character blends well with the types of flavour systems commonly used. Also, its ability to chelate trace minerals allows antioxidants to function more effectively in retarding product deterioration.

Citric acid with sodium citrate provides precise pH control to stabilize the product. The most important single application for citric acid is in soft drink manufacture. The second main application area for citric is in confectionery and sweet fruit products such as jellies and jams. Citric is added to these products primarily for flavour, but it also increases the solubility and stability of artificially –sweetened products. As in soft drinks its compatibility with all fruit flavours makes citric a suitable acidulant to impart tartness. (From delicate berry flavours to strong sour products)

Citric has an important role to play in the processing of vegetables and all types of fruits It reduces heat –processing requirements by lowering pH below 4.6. Inhibition of microbial growth is a function of pH and heat treatment. Higher heat exposure and lower pH resulting in greater inhibition. As the heat requirement is minimized, so the integrity of the fruit or vegetable is better preserved.

Oxidative browning in most fruits and vegetables is catalyzed by polyphenol oxidase, which is naturally present. The enzyme activity is strongly dependent on pH and so if citric is used to lower pH to below three, the browning effect of the enzyme activity will be prevented.

The citric also optimizes flavour and, when used in conjunction with antioxidants such as ascorbic acid, it inhibits colour and flavour deterioration which can be caused by metal –catalyzed enzymic oxidation

2.2.6.2: Safety

Citric acid is accepted as a safe food additive. In the EU, citric acid and citrates (E330, 331 and 332) are approved for use "quantum satis" and the Acceptable Daily Intake (ADI) decided by the joint FAO/ WHO Export committee of Food Additives (JECFA) is 'not specified'. This means that in the levels required to create the desired effect in food products, citric acid and citrates are safe for human health.

2.2.7:Sodium metabisulfite

Sulfiting agents have a long history of use as food ingredients. The term sulfiting agents refer to suffer dioxide (SO_2) and several forms of inorganic sulfites that liberate SO_2 under the conditions of use. Sulfer dioxide (SO_2), potassium bisulfite ($KHSO_3$), potassium metabisulfite($K_2S_2O_5$), sodium bisulfite($NaHSO_3$), sodium metabisulfite($Na_2S_2O_5$) and sodium sulfite(Na_2SO_3) are listed in the Code of Federal Regulations (CFR) as GRAS provided that they are not used in meats or other foods recognized as a source of thiamin.

Sulfiting agents are added to foods for many important technical purposes, including the control of enzymetic and non enzymetic browning, antimicrobial action, antiioxidant and reducing agent uses, bleaching agent uses and a variety of processing aid uses. In many products, the sulfites serves more than one purpose Acceptable daily intake for sulfite is 42mg for a 60kg person. The carcinogenic mycotoxins, aflatoxins B_1 and G_1 can be degraded by bisulfite, although rather high levels are required. (Chichester, 1986)

2.2.8:Antioxidents

2.2.8.1:Lipid oxidation and rancidity

Rancidity caused by the lipid oxidation of fats and oils in food products is one of the major obstacles preventing long shelf life. Antioxidants capable of delaying the process of lipid oxidation and the development of rancidity are now widely use in the food industry. The oxidative resistance of food products is often high at first. But this resistance will be reduced, depending on factors such as the types of fat in the products concerned, temperature, light, amount of catalysts present (e.g. metal ions), degree of exposure to oxygen during processing, packaging, storage etc.

The process of lipid oxidation takes place in the fat phase, and is a reaction between oxygen and the fatty acid parts of the lipid molecules. The process is also called autoxidation, since it is an autocatalysed process occurring spontaneously. Lipid oxidation is a chain reaction resulting in the formation of free radicals and peroxides, which will reduce the quality of food products by leading to additional reactions and the onset of rancidity. This chain reaction results in the development of undesirable taste and smell and the loss of nutritional value

Effects of oxidation;

Unsaturated fat/oil

↓ oxidation

peroxides

↙ ↓ ↘

Further reactions with other compounds, e.g. vitamins, proteins.	Polymers	Smaller molecules, e.g. aldehydes, acids.
Affects;		
Texture	viscosity	smell/taste
Taste/smell	colour	cell damage.
	Nutritional value	

Delaying or preventing the onset of rancidity various solutions can be chosen such as;

The use of airtight packaging, gas packaging (e.g. using nitrogen), or the use of vacuum packaging or refrigeration. However these preventive methods are only capable of inhibiting the onset of rancidity to a certain extent. The addition of antioxidants, on the other hand, is an extremely efficient way of retarding the process of oxidation and thus prolonging the shelf life of food products.

2.2.8.2:Antioxidants

Antioxidants are substances, which are capable of retarding oxidation processes, and they also ensure consistent quality from a batch to batch, thereby providing a minimum of variation in the taste, odour, colour, and texture of finished products. Traditional antioxidants such ass BHA, BHT and gallates have found wide spread used, and they are still very important due to their high degree of efficiency (Lauridsen and Schultz, 1993)

There is, however, a growing demand for vitamin –based antioxidants such as vitamin C, vitamin E and carotenoids. The major effects of the antioxidant vitamins are as free radical scavengers. Vitamin C is a water-soluble antioxidant capable of regenerating vitamin E. Vitamin E and β -carotene are fat-soluble antioxidants. Vitamin E is efficient at high levels of oxygen pressure and β -carotene is efficient at low oxygen pressures. All work both singly and synergistically to prevent or delay oxidative reactions that lead over time to degenerative diseases, including cancer, cardiovascular diseases, cataracts and other diseases.

Most of the people are not consuming levels of the antioxidant vitamins needed because they do not eat enough fruits and vegetables and foods they do eat do not contain the levels needed. The best option to solve this problem is to fortify a variety of foods with the antioxidant vitamins. Which brings us to the concept of nutraceutical foods

A variety of commercial forms of the antioxidant vitamins are used in foods and beverages. Dry forms of β-carotene are commonly used because they are easily water dispersible and are available as a 10%, 7% or 1% cold-water soluble form or an insoluble colourless version. Vitamin C is offered as powdered or granulated ascorbic acid or in coated forms. Sodium ascorbate and coated version are offered, as is calcium sorbate. Vitamin E acetate is offered in cold-water soluble forms. Oil-soluble products, including 30% β-carotene (in corn oil) and α-tocopherol, its acetate, and mixed tocopherol are also offered and may be incorporated in to flavour emulsions.

Flavour problems which may be encountered while using commercial forms of the antioxidant vitamins and the suggested solutions are presented in table 2.c. Primary factors which affect stability of the antioxidant vitamins in foods and beverages are listed in table 2.d. Both vitamin C and β-carotene are sensitive to heat and oxidation, but vitamin E in its acetate form is quite stable

Processing methods are selected to minimize conditions that result in thee greatest losses and to compensate for the losses that do occur by adding overages. To reduce oxidation damage, it is best to use stainless steel, aluminum or plastic equipment avoiding contamination with copper, iron, brass or bronze. Removing air from the product also helps, as does using filling equipment that minimizes headspace and fills at a constant rate. Heat processing should be fast and the product should be protected from radiant energy. Glass or plastic containers should be of types that reduce permeability. The main objective is to minimize contact with oxygen or prooxidant metals during processing and to minimize oxygen transfer in the packaging. (Elliott, 1999)

Table 2.c.: Flavour problems and suggested solutions

Antioxidant vitamin	Potential problem	Suggested solution
β -carotene Vitamin E	Dry product forms Cloud in clear (transparent) beverages.	Add more juice to make opaque. (Natural juices are often cloudy) Add 30% β -carotene or tocopheryl acetate (oily form) to flavour emulsion.
Vitamin C	Taste too tart at higher levels of ascorbic acid	Use part or all of requirement as of sodium ascorbate. Calcium ascorbate is - bitter and not-recommended for most food uses.
β -carotene	Yellow to orange colour not desirable	Use β -carotene 10% B in products except beverages

Source: Elliott, (1999)

Table 2 d Primary factors, which affect stability of the antioxidant vitamins in foods and beverages

Antioxidant vitamin	Factor
β -carotene	1. Exposure to oxygen 2. Heat above 45°C for extended period of time. 3. Packaging in oxygen permeable or clear packages. 4. Oxidation catalyzed by metal ions, light and heat.
Vitamin C	1. Very stable in dry form 2. Very sensitive to oxygen and heat in solution. 3. Oxidation catalyzed by metal ions and heat
Vitamin E	1. d1-(α)-tocopheryl acetate very stable except at pH extremes 2 d1-(α)-tocopherol sensitive to oxidation which is catalyzed by heat and metal ions

Source: Elliott, (1999)

2.2.9:Sodium bensoate:

This is a salt of benzoic acid and is used in the preservation of fruit juices, squashes and jams. Benzoic acid is the effective agent. As it is sparingly soluble in water, its sodium salt, which is water-soluble, is generally used. Chemically, pure sodium benzoate is practically tasteless and odour less.

The preservative action of benzoic acid increases in the presence of CO_2. A typical example is that of *Bacillus subtilis* which cannot survive in benzoic avid solution in the presence of CO_2. Benzoic acid more effective against yeast than against moulds (Giridhari, 1960)

2.3: Jam Processing Methods

There are two major methods of jam processing.

1. The traditional open pan system.
2. Vacuum boiling process.

The boiling process, in addition to removing excess water, also has other effects, in particular partial inversion of sucrose, development of characteristic flavour, textural changes in the fruit and destruction of yeast and moulds. The boiling may be carried out at atmospheric pressure (traditional open pan system) or at reduced pressure (vacuum boiling).

2.3.1: Traditional open pan system (atmospheric pressure boiling)

When boiling at atmospheric pressure the product reaches about 105°C at completion and this process gives the characteristic flavour of traditional jam. This traditional method of jam boiling is use steam heated open pans normally capable of holding batches of 75 –100kg. Steam at 4 – 5 bar is supplied to a jacket or to internal coils for faster boiling.

Pans are used in sets of between four and eight so that a continuous supply of product can be obtained. Pans, which are discharged through bottom outlet valves, are more convenient (and safer) in use than tipping pans. Each pan supplied with a hood connected to an exhaust system for removal of water vapour. The pans are loaded by gravity or by blowing or pumping from a pre-mixing vessel. Once loaded, the steam supply is turned on and the mix boiled to the required solids level. This may be determined by refractometer or by temperature, which will need to be corrected for changes in atmospheric pressure.

2.3.2: Vacuum boiling

With vacuum boiling where the bulk of excess water removed at 50°C – 60°C, the flavour changes are less marked, with a reduced level of caramalization. Which flavour characteristics are preferred is a matter of opinion. Vacuum boiling also restricts the degree of sugar inversion and removal of suffer dioxide and these factors must be considered when formulating the product. Continuous operation has obvious production advantages if the required out put is sufficient to warrant it.

2.3.2.1:Batch vacuum boiling

Vacuum boiling vessels are available to take charges of 500 – 2000kg. The vessel made of stainless steel, is provided with heating coils, a vacuum pump or ejector system, a means of sampling or a built in refractometer, entry points and an inspection window.

The mode of operation is to prepare a premix in a stirred heated vessel. The premix is drawn in to the process vessel by vacuum. When charged, the pressure in the vessel is controlled such that evaporation takes place at 50°C – 60°C until the required solids level is reached. When this is achieved, the vacuum is released and the temperature is allowed to rise to about 90°C. This ensures that sterilization occurs and that conditions for formation of the pectin gel are achieved. The vessel is emptied by gravity, pump or air pressure

Since large batches of product are obtained, problems with presetting may occur and it is necessary therefore to add the acid and/or the pectin after the boiling is complete, making appropriate allowance in the solids level of the boil This later addition can be metering or by the use of two receiving vessels which are used alternatively

2.3.2.2:Continuous boiling

Continuous vacuum boiling may be carried out by two methods The APV system utilizes a plate evaporator whereas the Alfa – Level system makes use of scraped surface heat exchangers The former system is limited to handling jellies or sieved products whilst the latter can handle larger fruit pieces

When using continuous systems, it is necessary to control refractometric solids continuously and this is done either using a simple in -line unit or, preferably, an automatic unit with electrical feedback to control the evaporator (Broomfield, 1988)

2.3.3:Filling temperature

Product's setting temperature should be lower than the filling temperature This prevents pregelling, which would weaken the gel and exert a negative influence on the texture The height on the filling temperature is determined by the machines and systems employed in the process as well as the size of the packing containers used Containers, which cool more quickly, allow a filling at high temperatures of 85° C to

95^{0} C. Rapid set pectins in this temperature range provide good gelation. Containers, which pass through a long cooling phase, on the other hand, require low filling temperatures of e.g. 70^{0}C to 75^{0}C, since otherwise the consistency of the product might suffer by heat related damage affecting the center. For this purpose slow set pectins are used that do not tend to pre –gel in the temperature range in which they are applied

2.3.4: Consistency

Consistency is a very important parameter for sensorial acceptance and depends largely on the composition of raw materials such as the type of fruit, fruit quantity and sugars used, but also on the selected type of pectin. Pectins with a very high degree of esterification in firm gels, which are characterized by the rheological parameter 'highly elastic with an important viscous phase'.

For the purpose of spreading jam on slices of bread or sweet rolls, it should be noted that jellies with greater elastic and a very low viscous phase are more difficult to spread. In the extreme case, this implies that jellies spread on with a knife will just break up from a large lump in to many smaller pieces. Gels with an important viscous phase, on the other hand, will spread on easily and form coherent jelly layer on the bread The proper selection of the right type will thus to be a great help in controlling the desired rheological parameters of these products

The edible acid originally present in the fruits or added to the product tends to suppress the dissociation of free carboxyl groups in pectins If the acid content is too high (pH value under 2.8) the gel elasticity will be increased and the gels become hard and brittle If the acid content is low (pH value above 3.3) the gel structures become very soft. When exceeding a certain pH limit, gelation is no longer possible (Kratz, 1993)

2.4:Types of jams

(i) Presence of soluble solids of higher than 60% (conventional jams)

(ii) Reduced sugar jams of soluble solids of between 45% - 60%

(iii) Low sugar jams with a soluble solid content of less than 45%

(iv) No added sugar product typically of 60% soluble solids or less, where concentrated fruit juice replaces the sugar

2.4.1: Jam related products

(1) Extra jam

Extra jam is a term introduced via the EC preserves directive 79/693/EEC. All extra jams are jams but not all jams are extra jams, as the latter require higher fruit content. Basically 45g per 100g compared with 35g per 100g for jams (although there are some exceptions to these general levels).

Extra jams have to be made from 'fruit pulp' which is defined as the sliced or crushed edible part of the fruit' with or without peel, skin, seeds or pips but which has not been reduced to a puree. Extra jams cannot be made from puree and, so, legally it is not possible to make a 'seedless raspberry extra jam' as the fruit will here to be sieved before use. It is of course, quite permissible to make a 'seedless raspberry jam' with fruit content of 45g per 100g or more.

The definition of 'fruit' has been increased recently by amending legislation and now includes, for example, carrots, carrot jam being delicacy of the Portuguese. In addition their differing limits for residual sulfur dioxide content for the two classes of product

Sorbates or benzoates are permitted in extra jams,added colours are not permitted. Under the present legislation, there are no such products as, 'extra reduced sugar jam' or 'extra marmalade', as such products are not defined (Broomfield, 1988).

(2) Reduced sugar jam

Although still pectin/sugar gels, the low sugar contents permitted for reduced sugar jams means that normal high methoxyl (HM) pectins are ineffective, and so it is necessary to use the calcium / low methoxyl (LM) pectin gelling system. The texture of the low sugar content gel may be modified by the incorporation of additional stabilizers and/or gelling agents, many of which are listed in the UK regulations. The low sugar content also has two other effects. First, there is no chance of crystallization and second, the sugar content is insufficient to provide a preservative effect (hence the reason for the permitted use of preservatives)

(3) Jam for diabetics

Diabetics are intolerant to the sugars normally present in jams and marmalades, but they are unaffected by sorbitol a polyhydric alcohol derived from glucose. Specially prepared jams and marmalades are therefore manufactured for diabetics in which sorbitol is used as a direct replacement for sucrose and glucose. The same manufacturing methods are used but it is necessary to increase the quantities of pectin, as pectin/sorbitol gels are weaker than comparable sugar based gels.

Sorbitol based products do not have low energy value since the sorbitol is metabolized. The daily intake of sorbitol should be limited since it has a laxative effect.

(4) No-added-sugar fruit spreads.
In these products, the source of added sugar is fruit juice and not one of the sweetening agents, listed in the jam and similar product regulations 1981. Because of this, they do not have to conform to the legal requirements for reduced sugar jam.

(5) Marmalades:
Marmalades are effectively jams or jellies made from citrus fruits. Orange marmalade is by far the largest sector of the market. Bitter oranges, grapefruit, lemons, limes, mandarins and sweet oranges used in marmalade manufacture.

Various styles of marmalade are manufactured, the differences being in the size and manner of cutting the peel and the proportions of peel to center which are used. The usual styles of marmalade are 'coarse cut' with the peel in strips about 5mm wide, and 'medium' and 'fine' cut with strips of about 3mm and 1.5mm wide, respectively. In each of these cases the peel includes the albedo. The white portion lying beneath the skin. Legislation requires marmalade to contain minimum of 20g of citrus fruit per 100g, of which 7.5g (99atleast) shall be from the epicarp(center).

(6) Jelly Jams and marmalades:
Jelly jams and marmalades are prepared from the juice of the selected fruit and do not contain any of the insoluble fibrous material, except that jelly marmalade may contain small pieces of peel. The juice is obtained from the fruit either by mechanical pressing or by aqueous extraction. Jelly is formulated and manufactured in the same way as jam. In the production of jelly marmalade, clarified juice or aqueous extract from the dummy is used in the preparation of the jelly (the pulped centers are known as 'dummy') Where peel is added, this is in the form of finely cut 'chips' without albedo. The product requirements for a good jelly are good colour, clarity and flavour (Broomfield, 1988)

CHAPTER 3

3.0: materials and methods

3.1:Materials

3.1.1: Materials for preparation of tender coconut jam

- **Consumable**

1. Tender coconut kernel from 9 months and 10 months old nuts, picked up according to the method given in table 2.a.
2. Water
3. White Sugar
4. Medium setting pectin.
5. Sodium metabisulphite
6. Sodium benzoate.
7. Citric acid
8. Vitamin C
9. Vitamin E
10. Emulsifier

- **Equipment and tools**

11. pH meter
12. Thermometer
13. Refractometer (Brix 45~82% and Brix 0~32%)
14. Electric balance
15. Blender
16. Knives
17. Spoons
18. Sauce pan
19. Gas cooker
20. Glass ware
21. Packing materials (Plastic cups, lids)

3.1.2: Materials for sensory evaluation

1. Prepared tender coconut jam
2. Spoons
3. Water glasses
4. Serviettes
5. Cream cracker biscuits
6. Plates
7. Pen and Ballet sheets

3.1.3: Materials for determination of pH value

1. pH meter
2. Prepared tender coconut jam
3. Water
4. Tissue papers

3.1.4: Materials for determination of Brix value

1. Refractometer (Brix 45~82%)
2. Water
3. Tissue papers
4. Prepared tender coconut jam

3.2: Location

This experiment was conducted at the quality control laboratory of the 'Vasmee', Midigama Fruit Farms (Pvt.) Ltd., Midigama, Ahangama.

3.3:Methods

3.3.1: Preparation of samples

This experiment was done to develop an innovative jam from tender coconut for the dynamic market

In the case of jam manufacture four major variables were taken into account with two levels -low and high, and samples were prepared with respect to the treatment combinations given below.

1. Maturity level
   - 9 months old –a_0
   - 10 months old –a_1
2. Sugar level
   - Low level (60g /100g) – b_0
   - High level (66.13g/100g) – b_1
3. pH level
   - High pH level (0.6g/100g -citric acid) –c_0
   - Low pH level (0.8g/100g -citric acid) –c_1
4. Antioxidant
   - Weak antioxidant –d_0
   - Strong antioxidant –d_1

16 treatments were designed by combining the above variables as follows;

1) $a_0 b_0 c_0 d_0$ -9months / low sugar level/ high pH level/ weak antioxidant
2) $a_0 b_1 c_0 d_0$ -9months /high sugar level/ high pH level/ weak antioxidant
3) $a_0 b_0 c_1 d_0$ -9months /low sugar level/ low pH level/ weak antioxidant
4) $a_0 b_1 c_1 d_0$ -9months /high sugar level/ low pH level/ weak antioxidant
5) $a_0 b_0 c_0 d_1$ -9months /low sugar level/ high pH level/ strong antioxidant
6) $a_0 b_1 c_0 d_1$ -9months /high sugar level/ high pH level/ strong antioxidant
7) $a_0 b_0 c_1 d_1$ -9months / low sugar level/ low pH level/ strong antioxidant

8) $a_0 b_1 c_1 d_1$ -9months / high sugar level/ low pH level/ strong antioxidant
9) $a_1 b_0 c_0 d_0$ -10 months / low sugar level/ high pH level/ weak antioxidant
10) $a_1 b_1 c_0 d_0$ -10months /high sugar level/ high pH level/ weak antioxidant
11) $a_1 b_0 c_1 d_0$ -10 months / low sugar level/ low pH level/ weak antioxidant
12) $a_1 b_1 c_1 d_0$ -10 months /high sugar level/ low pH level/ weak antioxidant
13) $a_1 b_0 c_0 d_1$ - 10 months / low sugar level/ high pH level/strong antioxidant
14) $a_1 b_1 c_0 d_1$ - 10 months / high sugar level/ high pH level/ strong antioxidant
15) $a_1 b_0 c_1 d_1$ -10 months / low sugar level/ low pH level/ strong antioxidant
16) $a_1 b_1 c_1 d_1$ - 10 months / high sugar level/ low pH level/ strong antioxidant

3.3.1.1: Determination of maturity level

Development of coconut fruit from flower takes about one year duration. Soft endosperm begins to form after about 7 months from the fertilization. After 9 months there is mature '*kurumba*', jelly like kernel that covered entire cavity. After 10 months, very tender kernel called '*kalati*' is there (See table 2.a)

These two stages were selected as the most economical stages to prepare jam. Fat content is increase along with the maturity stage. Lower maturity levels were found not economical to prepare jam, as amount of kernel per nut is very low.

3.3.1.2: Preparation of pulp

Tender coconut nuts of 9 months old were harvested and dehusked. Nuts were opened and tender kernel was scooped. The parings were removed using a knife. It was blended while adding water in order to get the Brix value of 4% in the pulp. Same procedure was adopted for 10 months old nuts too

3.3.1.3: Preparation of samples with two levels of sugar

Two portions of blended coconut pulp was taken and incorporated with sucrose (sugar) 60g and 68.13g in order to prepare with two sugar levels (b_0 and b_1)

3.3.1.4: Preparation of samples with two levels of pH values

Two portions of blended coconut pulp were taken and incorporated with citric acid 0.6g and 0.8g in order to prepare samples with two pH levels (c_0 and c_1)

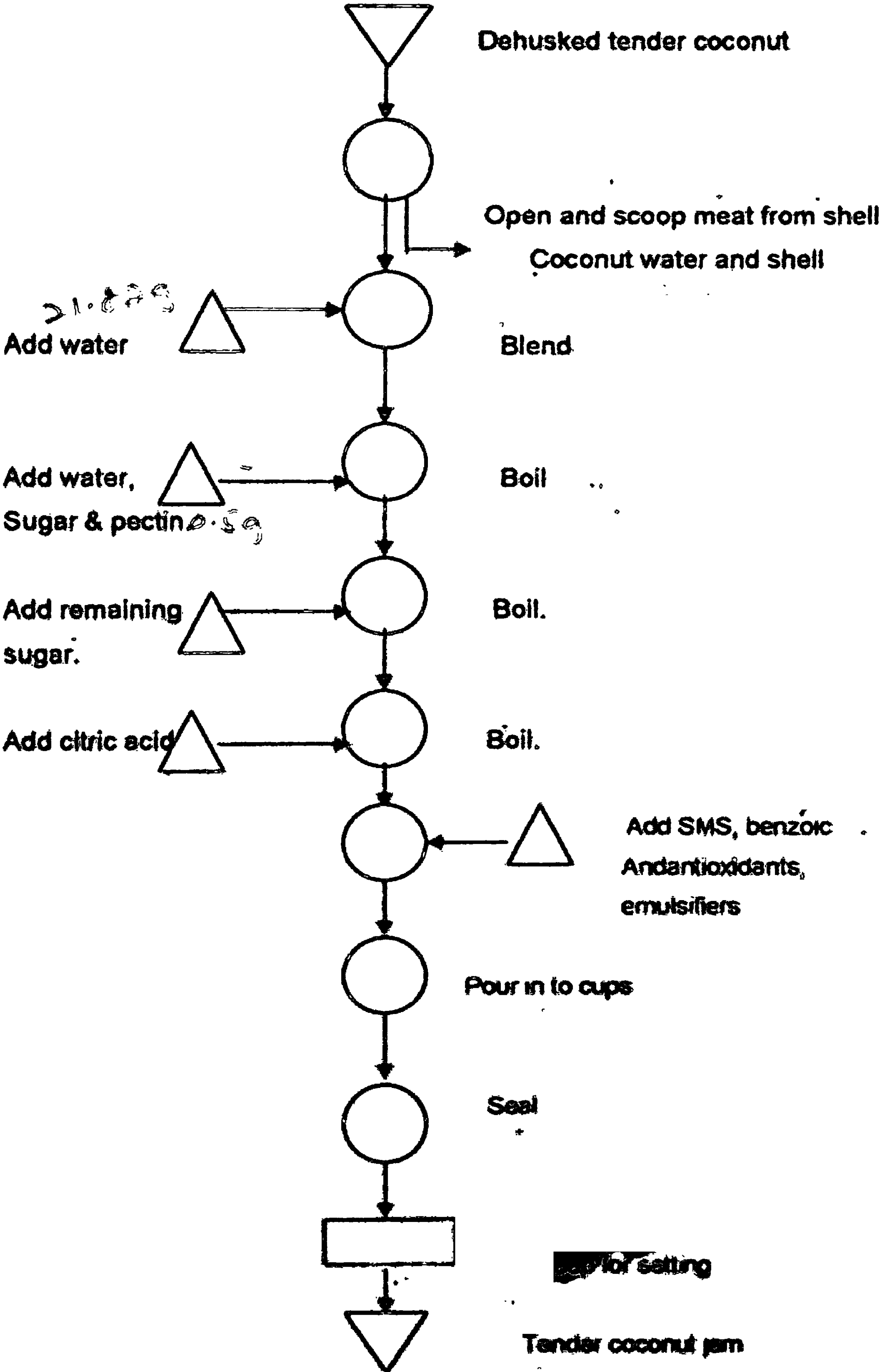

Figure. 3 a Common procedure for tender coconut jam processing

3.3.3: Determination of pH values

The pH value of a jam should be between 2.8 - 3.3. If pH value is lower than 2.8, the jam becomes hard and brittle and pH values higher than 3.3, it make the jam very soft. Therefore determination of pH value is very important. The pH of the product has a great influence on the inversion of sugar and setting of jam. The pH value is necessary to be optimal to produce a good firm setting pectin jelly.

3.3.3.1: Method of pH meter calibration

Before the beginning of the experiment, pH meter was calibrated by using buffer solutions of 4 and 7 and electrode was rinsed with distilled water and blotted with a soft tissue.

3.3.3.2: Method of pH determination

The pH meter was inserted to the sample and kept for one minute to stabilize the reading. Then the stabilized reading was recorded. Readings were taken after one month and after three months.

3.3.4: Determination of Brix value:

In jam manufacturing, the Brix value of jam should be maintained between 60 to 70%, in order to preserve the gelling behaviour. Hence measuring of the Brix value is important prerequisite in manufacturing the jam with right quality.

Very minute quantity of jam was placed on the Brix meter (refractometer) and read the value of Brix by degree of reflection of light.

3.3.5: Sensory evaluation

3.3.5.1: Selection of sensory panel

A sensory panel was selected to determine the gustatory sense of the 16 samples, as these characters are negligible

3.3.5.2: Method of selection of sensory panel

Twelve young persons who refrained from behaviours of biting chew beetles and smoking were selected and served 10 sucrose solutions representing from 0.1% to 1% of sucrose.

Persons who were responded for least sugar levels (absolute threshold level) were selected for the panel.

3.3.6.3: Sensory evaluation method:

Sensory evaluation was carried out to determine the best sample or samples out of 16 samples prepared in the study. Scoring test method was used for sensory evaluation.

The scoring test was conducted by giving a hedonic scale of 'like or dislike'. Dislike extremely to like extremely was numbered from 1 to 9 respectively (see appendix I) and given to the panel to state their scores in front of the code number given to each sample

Appearance, flavour, colour, odour, texture and overall acceptability of samples were tested at the sensory evaluation according to the above method Results obtained from the sensory evaluation for organoleptic properties were analyzed by ANOVA statistical method and were checked whether there were significant differences in 16 samp'es studied

CHAPTER 4

4.0: Results and Discussion

Study was carried out to evaluate the quality changes of jam by assessing pH, Brix and organoleptic properties of jam samples over 3 months.

4.1.1: Results of analysis of variance procedure for the sensory evaluation

Sensory evaluation was carried out twice. The first was conducted one month after preparation of tender coconut jam and the second was three months after preparation of tender coconut jam

Appearance, colour, smell, flavour, texture and overall acceptability of the samples were tested at the evaluation. The results of statistical analysis of the sensory evaluation are shown in the table 4 a

Table 4 a results of sensory evaluation

Attribute	After one month		After three months	
	F value	P value	F value	P value
Appearance	0 99	0 474	0 72	0 754
Colour	1 06	0 405	0.56	0 897
Smell	0 47	0 950	0.50	0 935
Flavour	0 72	0 761	0 81	0 664
Texture	0 94	0 523	0 86	0 612
Overall acceptability	0 80	0 675	0 73	0 749

Appearance:

According to the statistical analysis of ANOVA there were no significant differences among 16 treatment combinations for three months (See appendix III) Therefore the appearances of all samples were good for three months of period

Colour:

According to the statistical analysis of ANOVA there were no significant differences among 16 treatment combinations for three months (See appendix III) Therefore the colour of all samples was good to apply to the product for three months of period

Flavour:

According to the statistical analysis of ANOVA there were no significant differences among 16 treatment combinations for three months. (See appendix III) Therefore the flavour of all samples was good for three months of period. That means any level of sugar -low or high- can be added to the product as preferred.

Texture:

According to the statistical analysis of ANOVA there were no significant differences between 16 treatment combinations for three months. (See appendix III) Therefore it can be said that the texture of all samples was good for three months of period.

Smell:

According to the statistical analysis of ANOVA there were no significant differences among 16 treatment combinations for three months. (See appendix III) Therefore the smell of all the samples was good for three months of period. That means there is no auto oxidation in the product for three months of period, as the smell can be deteriorated by fat oxidation. Therefore any antioxidant -weak or strong- can be used in the product

Overall acceptability:

According to the statistical analysis of ANOVA there were no significant differences among 16 treatment combinations for three months (See appendix III) Therefore the overall acceptability of all the samples was same for three months of period

4.1.2:Results of analysis of pH values

Recorded pH values of the samples were analyzed by ANOVA statistical method and the results are given in the table 4 b. According to the results there is a significant difference between 16 samples at 5% significant level

Table 4 b results of pH analysis

After one month		After three months	
F value	Pr>F	F value	Pr>F
8.18	0.0001	12.60	0.0001

552, 578, 581, 452, 864 samples are similar with each other and different from the other samples 298, 347,403 samples are similar with each other and different from the other samples. 459, 756, 732 samples are similar with each other and different from the other samples. 721, 258, 135,276, 384 samples are similar with each other and different from the other samples.(See appendix II)

4.1.2.1: Change of mean pH of samples.

There were no significant differences of mean values of pH after three months. (See table4.c.)

Table 4.c. Change of means pH of samples.

Sample code	One month later	Three months later
578	3.1	3.2
298	3.0	3.1
452	3.0	3.2
347	3.1	3.1
384	2.9	2.9
756	3.0	3.0
276	2.9	2.9
258	3.0	3.0
403	3.1	3.1
552	3.2	3.2
581	3.2	3.2
864	3.2	3.2
135	2.9	2.9
721	3.0	3.0
459	2.9	3.0
732	3.0	3.0

No microbial oxidation and no auto oxidation so far may be the reasons for the pH value remains unchanged. But it should be tested for at least another 6 months.

According to the results the samples with high citric acid levels with or without Vitamin C had a pH value between 2.9 to 3.0. The pH values of 3.1 to 3.2 were found in the samples with low citric levels with or without vitamin C.

The pH value of a jam should be between 2 8 and 3 3. If it is lower than 2.8, the jam becomes hard and brittle If the pH value is higher than 3 3 of the jam, it becomes soft Therefore the pH range of this tender coconut jam is suitable in obtaining a good setting jam

These pH levels keep the product out of microbial deterioration, especially from bacteria. Therefore both levels are suitable for the product for three months.

4.1.3: Results of analysis of Brix value

According to the results analyzed by statistical method ANOVA there is a significant differences among 16 samples (See table 4 d)

Table 4 d results of analysis of Brix value

After one month		After three months	
F value	Pr>F	F value	Pr>F
5 15	0 0001	2.60	0 0113

581, 347 samples are similar with each other and different from the other samples 732, 452,864,258, 298,276,384,756,552,459 samples are similar with each other and different from the other samples 135,578,721,403 samples are similar with each other and different from the other samples (See appendix II)

There was not much difference after three months in the mean of the Brix value of the 16 samples The mean Brix value was 67° to 69°, in the samples that added low levels of sugar Brix value of 69° to 70°was recorded in the samples that were with high level of sugar

According to Broomfield, (1988), pectin is able to form gels with sugar solutions, which have soluble solids in the range 60 – 70% Therefore Brix values of the samples are within the safe range

Addition of sugar acts as a preservative also and helps to prevent microbial deterioration

The selected variety of coconut for the development of tender coconut jam was form Typica in variety *Typica* According to Pethiyagoda U (1980), it is the best type for commercial products

Tender coconut kernel consists of protein, fat and carbohydrates. Tender coconut consists of higher protein and sugar level than the matured coconuts. According to Thampan. (1993), it is gradually decline as the nut is matured Therefore the nutritional value is high in tender coconut jam than other jams

Unlike other fruits. tender coconut has fat at a substantial level in the kernel. Hence several antioxidants were tested, such as Lime, Vitamin C and Vitamin E Emulsifier also was played a major role preventing fat oxidation by stabilizing the fat content in the coconut pulp As the fat content can be caused the deterioration of this product, the best antioxidant and the best emulsifier should be find out.

0 5% of Medium setting pectin was used in all samples in order to obtain a good setting jam
As plastic cups were used as the containers, there were no photo oxidation problems occurred in this experiment.

There is a large trend to increase the demand for processed foods all over the world as all respective citizens contribute their time and strength to develop their countries with the concept of globalization

Jam takes an important place among the processed foods as it is preferred by majority of people in all age groups. Yet, consumers today are concerned with their health while expecting a better nutritional value from every product.

This innovative product can be help at the above situation as a nutritious processed food

CHAPTER 5

Conclusion

Jam from tender coconut can make by the same method adopted to prepare other jams, but have to add emulsifiers and antioxidants to prevent oxidation and stabilize the oil in water emulsion. The tender coconut jam is suitable for use for three months of period.

Recommendations for further studies:

- This experiment has to be continued at least another six months
- Suitable emulsifier without flavours should be tested
- The fat content and the protein content should be determined
- Microbiology accept on the product should be determined.
- Suitability of glass jars should be tested as the photo oxidation can be happened

Appendix I

ORGANOLEPTIC TESTING OF TENDER COCONUT JAM

Date ....

Name ....

- This is a tender coconut based Jam
- Please taste the 16 samples of Jam and indicate your score against the sample code.
- The rating for such samples are given in numeric values ranging from 9 (Like extremely) to 1(Dislike extremely) as given below.

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

Quality Character	578	298	452	347	384	758	276	258	403	552	581	864	135	721	459	732
Appearance																
Colour																
Smell																
Flavour																
Texture																
Overall acceptability																

Panel score

Comments

Thank You

Appendix II

One-Way Analysis of Variance for pH value

- <u>Results of analysis after three months</u>

Analysis of Variance Procedure
Class Level Information

Class	Levels	Values
SAMPLE	16	135 258 276 298 347 384 403 452 459 552 578 581 721 732 756 864

Number of observations in data set = 48

Analysis of Variance Procedure

Dependent Variable: pH

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	0 47250000	0 03150000	12.60	0 0001
Error	32	0.08000000	0 00250000		
Corrected Total	47	0 55250000			

R-Square	C V.	Root MSE	pH Mean
0.855204	1 619433	0.050000	3 087500

Analysis of Variance Procedure

Dependent Variable: pH

Source	DF	Anova SS	Mean Square	F Value	Pr > F
SAMPLE	15	0.47250000	0.03150000	12.60	0.0001

Analysis of Variance Procedure

T tests (LSD) for variable: pH

NOTE. This test controls the type I comparisonwise error rate not the experimentwise error rate

Alpha= 0.05 df= 32 MSE= 0.0025
Critical Value of T= 2.04
Least Significant Difference= 0.0832

Means with the same letter are not significantly different.

T Grouping	Mean	N	SAMPLE
A	3.23333	3	552
A	3.20000	3	578
A	3.20000	3	581
A	3.20000	3	452
A	3.20000	3	864
B	3.16667	3	298
B	3.13333	3	347
B	3.10000	3	403
C	3.03333	3	459
C	3.03333	3	756
C	3.03333	3	732
D	3.00000	3	721
D	3.00000	3	258
D	2.96667	3	135
D	2.96667	3	276
D	2.93333	3	384

One-Way Analysis of Variance for Brix value.

- **Results of analysis aftr three months**

Analysis of Variance Procedure
Class Level Information

Class	Levels	Values
SAMPLE	16	135 258 276 298 347 384 403 452 459 552 578 581 721 732 756 864

Number of observations in data set = 48

Analysis of Variance Procedure

Dependent Variable: BRIX

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	48.81250000	3.25416667	2.60	0.0113
Error	32	40.00000000	1.25000000		
Corrected Total	47	88.81250000			

R-Square	C.V.	Root MSE	BRIX Mean
0.549613	1.618873	1.118034	69.06250

Analysis of Variance Procedure

Dependent Variable: BRIX

Source	DF	Anova SS	Mean Square	F Value	Pr > F
SAMPLE	15	48.81250000	3.25416667	2.60	0.0113

Analysis of Variance Procedure

T tests (LSD) for variable: BRIX

NOTE: This test controls the type I comparisonwise error rate not the experimentwise error rate.

Alpha= 0.05 df= 32 MSE= 1.25
Critical Value of T= 2.04
Least Significant Difference= 1 8595

Means with the same letter are not significantly different

T Grouping	Mean	N	SAMPLE
A	70.6667	3	581
A	70.3333	3	347
B	70.0000	3	732
B	70 0000	3	452
B	70.0000	3	864
B	69 6667	3	258
B	69 6667	3	298
B	69.3333	3	276
B	69 0000	3	384
B	68 6667	3	756
B	68 6667	3	552
B	68 3333	3	459
C	67 6667	3	135
C	67 6667	3	578
C	67 6667	3	721
C	67 6667	3	403

Appendix III

One-Way Analysis of Variance for organoleptic properties

Appearance:

Results of Analysis of Variance after one month.

Source	DF	SS	MS	F	P
Sample	15	42.32	2.82	0.99	0.474
Error	80	228.17	2.85		
Total	95	270.49			

Level	N	Mean	StDev
135	6	6.333	1.506
258	6	7.000	0.632
276	6	6.833	1.329
298	6	7.333	1.366
347	6	5.500	2.429
384	6	7.500	1.378
403	6	5.167	2.714
452	6	7.333	0.816
459	6	6.333	1.633
552	6	6.500	1.517
578	6	6.333	2.251
581	6	7.500	1.225
721	6	7.167	1.722
732	6	7.167	1.835
756	6	7.167	1.329
864	6	6.667	1.966

Pooled StDev = 1.689

Results of Analysis of Variance after three months.

Source	DF	SS	MS	F	P
Sample	15	38.82	2.59	0.72	0.754
Error	80	286.17	3.58		
Total	95	324.99			

Level	N	Mean	StDev
135	6	5.167	1.941
258	6	6.500	1.378
276	6	6.167	1.941
298	6	5.333	1.633
347	6	5.167	2.041
384	6	5.333	2.160
403	6	7.000	0.632
452	6	5.667	2.422
459	6	6.000	1.789
552	6	6.667	2.160
578	6	5.333	1.633
581	6	6.333	1.366
721	6	6.333	2.338
732	6	6.500	1.871

756	6	7.000	0.894
864	6	5.333	2.805

Pooled StDev = 1.891

Colour:

<u>Results of Analysis of Variance after one month.</u>

Source	DF	SS	MS	F	P
Sample	15	43.63	2.91	1.06	0.405
Error	80	219.33	2.74		
Total	95	262.96			

Level	N	Mean	StDev
135	6	5.833	1.329
258	6	7.000	0.894
276	6	6.833	1.329
298	6	7.167	1.329
347	6	5.667	1.966
384	6	7.667	1.366
403	6	5.500	2.739
452	6	7.500	1.049
459	6	6.167	1.472
552	6	6.333	1.966
578	6	6.667	2.422
581	6	7.667	1.033
721	6	7.333	1.506
732	6	7.167	1.722
756	6	6.833	1.472
864	6	6.333	1.751

Pooled StDev = 1.656

<u>Results of Analysis of Variance after three months.</u>

Source	DF	SS	MS	F	P
Sample	15	37.91	2.53	0.56	0.897
Error	80	361.50	4.52		
Total	95	399.41			

Level	N	Mean	StDev
135	6	4.667	1.366
258	6	6.333	1.211
276	6	6.333	2.066
266	6	4.500	2.428
347	6	4.833	1.722
384	6	5.500	1.643
403	6	6.167	1.472
452	6	5.667	2.422
459	6	5.167	2.137
552	6	6.000	2.000
578	6	6.167	3.061
581	6	5.500	1.761

721	6	6.500	2.588
732	6	6.500	2.510
756	6	6.000	1.897
864	6	5.667	2.733

Pooled StDev = 2.126

Smell:

Results of Analysis of Variance after one month

Source	DF	SS	MS	F	P
Sample	15	10.63	0.71	0.47	0.950
Error	80	121.33	1.52		
Total	95	131.96			

Level	N	Mean	SlDev
135	6	6.333	1.366
258	6	5.667	1.633
276	6	6.000	1.414
298	6	5.667	1.033
347	6	5.667	0.816
384	6	6.333	1.366
403	6	6.333	1.211
452	6	6.000	0.632
459	6	6.167	1.602
552	6	6.167	1.169
578	6	5.167	0.753
581	6	6.333	1.033
721	6	6.333	1.633
732	6	6.333	1.366
756	6	6.000	1.095
864	6	5.833	0.983

Pooled StDev = 1.232

Results of Analysis of Variance after three months.

Source	DF	SS	MS	F	P
Sample	15	28.99	1.93	0.50	0.935
Error	80	310.17	3.88		
Total	95	339.16			

Level	N	Mean	SlDev
135	6	5.500	2.881
258	6	5.667	1.366
276	6	5.833	2.137
298	6	5.000	2.449
347	6	5.000	1.265
384	6	6.000	1.673
403	6	6.667	0.516
452	6	5.167	1.941
459	6	6.167	1.941
552	6	5.667	2.251
578	6	4.333	2.066

581	6	6.167	1.722
721	6	5.667	2.160
732	6	6.000	2.098
756	6	5.333	1.506
864	6	5.333	2.338

Pooled StDev = 1.969

Flavour:

Results of Analysis of Variance after one month.

Source	DF	SS	MS	F	P
Sample	15	31.16	2.08	0.72	0.761
Error	80	231.83	2.90		
Total	95	262.99			

Level	N	Mean	StDev
135	6	7.667	1.366
258	6	7.333	2.160
276	6	6.333	2.805
298	6	5.667	1.862
347	6	7.000	0.632
384	6	6.833	2.137
403	6	7.500	0.548
452	6	7.500	1.049
459	6	6.167	1.722
552	6	7.500	0.837
578	6	7.333	1.211
581	6	7.500	1.378
721	6	7.167	1.835
732	6	7.000	2.191
756	6	6.333	2.251
864	6	7.333	1.366

Pooled StDev = 1.702

Results of Analysis of Variance after one month.

Source	DF	SS	MS	F	P
Sample	15	33.74	2.25	0.81	0.664
Error	80	222.17	2.78		
Total	95	255.91			

Level	N	Mean	StDev
135	6	6.333	1.366
258	6	6.500	2.074
276	6	6.833	0.983
298	6	6.333	2.503
347	6	5.333	1.211
384	6	6.000	1.789
403	6	6.333	1.366
452	6	6.000	2.530
459	6	7.000	0.894

552	6	6 500	0 837
578	6	6.000	1.095
561	6	7.333	1.033
721	6	7.000	2.098
732	6	7.833	0.753
756	6	6.167	2.229
864	6	6 000	2.098

Pooled StDev = 1 666

Texture:

Results of Analysis of Variance after one month.

Source	DF	SS	MS	F	P
Sample	15	38 33	2.56	0.94	0.523
Error	80	217.00	2.71		
Total	95	255.33			

Level	N	Mean	StDev
135	6	7.333	0.816
258	6	6 833	1.941
276	6	7 500	1 378
298	6	7.167	1.169
347	6	5 500	2 429
384	6	8 500	0 548
403	6	7.833	1.472
452	6	6 833	2.563
459	6	7 333	1 211
552	6	7.167	0.753
578	6	6.333	2.338
581	6	7 333	1 211
721	6	7 333	1 633
732	6	7 500	1 378
756	6	6 833	2 401
891	6	7 333	1 211

Pooled StDev = 1 647

Results of Analysis of Variance after three months

Source	DF	SS	MS	F	P
Sample	15	42 41	2.83	0.86	0 613
Error	80	263 83	3 30		
Total	95	306 24			

Level	N	Mean	StDev
135	6	6 667	0 516
258	6	7 000	0 894
276	6	6 333	1 751
298	6	6 667	1 211
347	6	4 833	2 229
384	6	5 833	2 483
403	6	7 000	2 000
452	6	5 667	3 141

459	6	6.667	1.506
552	6	6.667	1.211
578	6	6.333	1.366
581	6	6.667	0.816
721	6	7.167	2.137
732	6	6.667	1.862
756	6	6.667	1.633
864	6	5.000	2.280

Pooled StDev = 1.816

Overall acceptability:

Results of Analysis of Variance after one month.

Source	DF	SS	MS	F	P
Sample	15	32.74	2.18	0.80	0.675
Error	80	218.50	2.73		
Total	95	251.24			

Level	N	Mean	StDev
135	6	6.833	1.329
258	6	6.500	1.643
276	6	6.500	2.429
298	6	6.333	0.816
347	6	5.000	2.449
384	6	7.333	2.160
403	6	7.000	0.894
452	6	7.667	0.816
459	6	6.833	0.983
552	6	6.833	0.983
578	6	7.000	0.894
581	6	7.333	1.211
721	6	6.833	2.563
732	6	7.333	1.506
756	6	6.500	2.345
864	6	7.000	1.414

Pooled StDev = 1.653

Results of Analysis of Variance after three months.

Source	DF	SS	MS	F	P
Sample	15	46.07	3.07	0.73	0.749
Error	80	337.17	4.21		
Total	95	383.24			

Level	N	Mean	StDev
135	6	5.667	1.366
258	6	6.167	1.835
276	6	5.833	2.137
298	6	6.500	2.074
347	6	4.167	1.472
384	6	6.333	0.816
403	6	6.167	2.639
452	6	4.833	2.483

459	6	6.167	1.941
552	6	5.667	2.251
578	6	5.333	1.633
581	6	6.500	0.837
721	6	6.167	2.858
732	6	6.833	1.472
756	6	5.667	2.658
864	6	4.833	2.787

Pooled StDev = 2.053