DEVELOPMENT OF MIXED FRUIT SPREAD WITHOUT ADDED CANE SUGAR

By

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Thesis submitted in partial fulfillment of the requirements for the Degree of Bachelor of Science in Food Science and Technology of the Faculty of Applied Sciences, Sabaragamuwa University of Sri Lanka, Buttala, Sri Lanka.

December 2000

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DECLARATION

The work is described in this thesis was carried out by me at the Faculty of Applied Sciences under the supervision of Dr (Mrs.) S. F. Hussain and Mr. A. Sandanayake. A report on this has not been submitted to any other University for another degree.

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AFFECTIONATELY DEDICATED

TO MY EVERLOVING

PARENTS, SISTERS AND BROTHERS.

ACKNOWLEDGEMENT

Firstly I wish to express my sincere thanks to my project supervisors, Dr (Mrs), S.F Hussain, Research Officer, Food Research Unit, Department of Agriculture, Gannoruwa, Peradeniya and Mr A Sandanayake, lecturer, Faculty of Applied Sciences, University of Sabaragamuwa for their valuable advise, encouragement and guidance through out this study

I would like to thank Mr K Nadarajah and Mr M A J Wansapala, lecturer, Faculty of Applied Sciences University of Sabaragamuwa for providing me the grants and the opportunity to carry out this study at Department of Natural Resources

Thanks also extended to the sisters and brothers in our Faculty for their helpful encouragement and the staff of Natural Resources Departmental laboratory for their support

Finally I wish to express my gratitude to my mother, sisters and brothers for their advise, encouragement and guidance through out the real way of life

ABSTRACT

Health foods such as low - calorie, low - sugar or no - sugar and non - fat foods trends are increasing by consumer demand world - wide Therefore the objective of this study was to introduce a fruit spread with no added cane sugar for a health conscious target group
In manufacturing conventional jams, sugar is added to increase the sweetness of product A Total Soluble Solid (TSS) of conventional jam is 67 Brix In jams with end TSS of higher value like 67^{0} Brix High methoxy pectin is added to increase the naturally present pectin in the fruit in order to achieve the desired gel consistency

In manufacturing of fruit spread with no added cane sugar, sweetness is attained by cooking with unsweetened concentrated fruit juice Hence sugar content of fruit spread is greatly reduced (40 - 45^{0} Brix) compared to conventional jam Therefore in the production of this type fruit spread, low methoxy pectin is added to increase the desired gel consistency

Highly sweet tropical fruit varieties such as Mango, Pineapple, and Papaya were used for making the fruit spread Unsweetened, concentrated Apple juice/Grape juice was added This would be a high price commodity Different combinations of mango, pineapple and papaya fruit spread was prepared and evaluated organoleptically

Sensory evaluation rated that the combination of mango/pineapple/papaya 30/30/20 cooked in apple juice was the best This had a reasonable sweetness with good sugar/acid balance consistency and spread Sweetness measured as TSS was 41 6^{0} Brix and Acidity as citric acid was 4 99% and pH of 3 9

Combination of high sweetness fruits with intense colour and low astringency E g . Madan (*Syzygium cumini*) cooked with grape juice would mask the polyphenol oxidase activity naturally Such combination with low methoxy pectin included in the formulation and use of better techniques such as vacuum/double jacketed steam pan cooking could be recommended for a better end result and further development of fruit spread with no added cane sugar

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CHAPTER .1

INTRODUCTION

Health foods, such as low calorie, low sugar or none sugar and none fat foods trend are increasing by consumer demand worldwide In 1997, whole Earth Food Company in UK introduces jam like product in the market These types of products are made without sugar. But, sugar is replaced by concentrated fruit juice This type of products is termed as 'pure fruit spread'

In manufacturing jams and related products or like products, pectin is added to increase that naturally present in the fruit in order to achieve the desired gel consistency. Commercial pectins are classified into two main categories according to degree of methoxilation (DM). Low methoxy (LM) pectins have from 25 – 50% DM and will form a gel in the presence of divalent cations, e.g., Calcium High methoxy (HM) pectins with DM values from 50 to 80% form gels in the presence of sugar and acid and are most widely used for jam manufacture

Sugar content of fruit spread is greatly reduced compared with conventional jam Therefore, manufacturing of fruit spread, LM pectin is added to increase the desired gel consistency in the presence of Calcium ions (naturally occurring in fruit)

Lm pectin gel strength has been found to be mainly dependent on pectin concentration, degree of esterification, pH and Calcium ion concentration However, little study has been reported on the type of local varieties of fruits, concentrated fruit juice, and its effect on appearance, sweetness, flavour, and spreadability of fruit spread

The objective of the study was to investigate the use of fruit sugars only targeting a specific consumer group

CHAPTER .2

2. LITERATURE REVIEW

2.1. Jam

The general definition of jam is 1 1 ratio in fruit and cane sugar But following definition of fruit jams was issued by the Food and Drug Act (FDA) in 1936 "Preserve, fruit preserve jam, fruit jam is the product made by cooking suitable consistency property prepared fresh fruit, cold - pack fruit, canned fruit or a mixture of two or all of these, with sugar and dextrose, with or without water In its preparation not less than 45lb of fruits are used to each 55lb of sugar and dextrose A product in which the fruit is whole or in relatively large pieces of customarily designated a preserve rather than a jam" (Srivastava)

2.1.1. Types of jam

The jam can be separated into four distinct groups These are

Preserve of soluble solids of higher than 60% (conventional jams)
Reduced sugar jams of soluble solids of between 45 - 60%
Low sugar jams with a soluble solids content of less than 45%
No added sugar products typically of 60% soluble solids or less, where concentrated fruit juice replaces the sugar
(Indian food packer, 1996)

2.1.2. Jam related products

Jellies and marmalades are introduced in the market such as jam related products Primary structures of these products are similar to the jam The jellies made from sugar - acid - pectin systems, its possible to form pectinic acid gels by treatment with metal ions, with which lower soluble solids concentrations are required Marmalades are made from fruits, sugar, acid and pectin (Desrosier 1970)

2.1.3. Jam like products

Pure fruit spreads since, at least in the UK, these products fall outside the jam and similar products regulations (HMSO, 1981) This has nothing to do with the organic nature of such products, but reflects their origin in the UK health - food industry

Conventional jams are manufactured by dissolving sugar in water, adding fruit and pectin and boiling the resultant mix to a total solids content of about 66%, at which level of dissolving solids the jam becomes self - preserving In 1997, whole Earth Foods launched a 'jam' comprising apple juice, fruit, water and pectin The ingredients were mixed, heated to boiling and then filled hot into glass jars, which were lidded, labelled and packed whole earth foods eventually, termed this product a 'pure fruit spread'

Whole Earth launched the first range of pure fruit spreads made using fruit in 1987. Today there is a range of five flavours (orange marmalade, strawberry, cherry, apricot and rosheip). They are all made from fruit and apple juice concentrate, water and pectin, Under the EC (European Community) regulations the pectin need not to be organic compounds, and it is used at well below the 5%level permitted in the regulations

Pure fruit spreads are characterized by a very fruity flavour, thought to be caused in part by the high fructose content of the apple juice having synergistic flavour affect on the fruit juice another factor is that the process involves less heat than conventional jam production, (partially if processing under vacuum) so the fruit in a pure fruit spreads develops a less "cooked" not Sweetness is greatly reduce comparing with conventional jams, as it shelf - life after opening A conventional jam has a shelf life of several months ones open but because pure fruit have relatively low levels of dissolve solids, they will only keep for approximately three weeks after opening even if refrigerated beyond this time, yeast and moulds begin to spoil the pure fruit spreads, resulting in yeasty smells and visible mould colonies Against this pure fruit spreads have only half the calories of conventional jam, making them particularly suitable for diabetic and to consumers who wish reduce their energy intake (Wright 1994)

2.2. Ingredients

2.1. Fruits

Fruits act as very important rolls in the preparation of jam Different types of fruits are used for following,

Fresh fruits

Chilled or cold – stored fruits

Fruit pulp or fruit preserve by heat

Dried fruits

Jam is rich in fruity flavour, colour and more nutrients due to ripe fruits are used.

(Srivastava)

2.2.1.1. Pineapple

Pineapples are divided in major two types, such as Kew and Morish. In jam manufacturers are mostly used as morish, because it has more sweetness than another one.

Table2.1: Composition of ripe pineapple fruit flesh

Constituents	% fresh weight basis
Water	81.2 – 86 2
Sucrose	5 9 – 12 0
Glucose	1 0 – 3 2
Fructose	0 6 – 2 3
Cellulose	0 43 – 0 54
Pectin	0 06 – 0 16
Titrable acidity (as citric acid)	0 6 – 1 62
Citric acid	0 32 – 1 22
Malic acid	0 1 – 0 47
Ash	0 30 – 0 42
Fibre	0 30 – 0 61
Nitrogen	0 045 – 0 115

Source Dull (1971), Salunke and Desai (1984)

2.2.1.2. Mango

The most mango varieties are found in the Sri Lanka But jam manufacturers are commonly used in high sweetness varieties among them These are, Vellaicolomban, Betti, and Parrot/Gira.

Table 2.2: Composition of ripe mango fruit flesh

Constituents	% fresh weight basis
Moisture (g)	81.0
Protein (mg)	00 5
Fat (mg)	00 4
Carbohydrate (mg)	16 9
Calcium (mg)	14 0
Ferrous (mg)	16 0
Vitamin – A (mcg)	01 3
Caretenoids	465
Thiamine	90 0
Riboflavin	40 0
Niacin	00 4
Vitamin – C	42 0

Source Food value chart / Sri Lanka for medicinal use

2.2.1.3.Orange

Table 2.3: Composition of orange juice

Constituents	% fresh weight basis
Water (%)	87 6
Protein (mg)	00 7
Fat (mg)	00 2
Carbohydrate (mg)	10 9
Calcium (mg)	26 0
Ferrous (mg)	20 0
Vitamin – A (mcg)	00 3 – 1
Caretenoids	104
Vitamin – C	30 0

Source Food value chart / Sri Lanka for medicinal use

2.2.1.4. Papaw

Table 2.4: Composition of ripe papaw flesh

Constituents	% fresh weight basis
Moisture (g)	90 8
Proteins (g)	0 6
Fats (g)	0 1
Carbohydrates (g)	7 2
Calcium (mg)	17 0
Phosphorus (mg)	13 0
Iron (mg)	0 5
Carotene (mog)	666
Thiamine (mog)	40
Riboflavin (mog)	250
Niacin (mg)	0 2
Vitamin C (mg)	57

Source World Health Foundation of Ceylon (1979) M R I

2.2.2. Calcium salts

Table 2.5: Properties of Calcium salts

Calcium salts	Solubility (%,w/w)	Flavour profile
Calcium - L - lactate	9 0	Good/bland
Calcium - DL - lactate	4.5	Good/bland
Calcium gluconate	3 5	Flat/good
Calcium citrate	0 1	Sandy/sour
Calcium phosphate	<0 1	Milky/Sandy
Calcium carbonate	<0 1	Sandy/flat

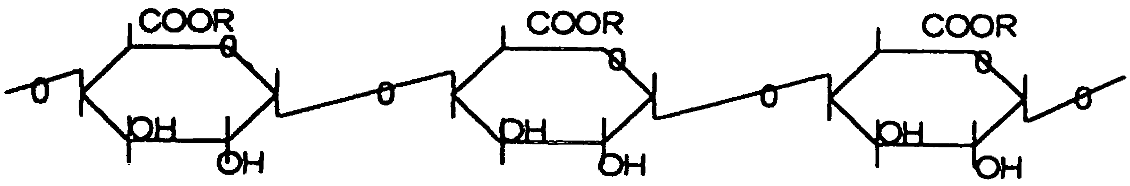
Note Solubility in water at 25 ^{0}C

Source Anon (1994) Ingredients and additives - Calcium fortification. Asia pacific Food Industry 1994 (August)

2.2.3.Pectin

2.2.3.1.General

Pectic substances are polymers composed mainly of (1 - 4) - α - D - Galacturonopyranosyl units, and they are found in the middle lamella of plants cells The acid groups can be esterified by methanol



R = H Low Methoxyl Pectin (LMP)

R = CH_3 High Methoxyl Pectin (HMP)

Figure 2.1: Representative structure of pectin

Protopectin is the pectic substances in the flesh of immature fruits and vegetables. It is highly esterified with methanol, is insoluble in water, and produces the hard texture of unripe fruits and vegetables Pectinic acid is less highly methylated pectic substances and is derived from protopectin by the action of protopectinase and pectin methyl esterase Depending on the degree of the polymerization (DP) and degree of methylation (DM), Pectinic acid may be colloidal or water - soluble Water - soluble pectinic acids are termed "Low - Methoxy Pectins"

Pectic enzymes contribute to the development of the desirable texture producing during ripening of plants During this period, protopectinase converts protopectin to colloidal pectin or water - soluble pectinic acids (Fennema, 1985)

2.2.3.2. Sources of pectin

Pectins are obtained in quantities from two agricultural waste products, citrus albedo and apple pomace. Waste from the processing of sugar beets contains pectin with a low – methoxyl content, but the presence of acetyl side chains limits its gel – forming capacity. Sunflower head waste has been analysed as a potential source of usable pectin. Pectin is extracted from albedo and pomace with hot water that contains acid. This pectin is available in dried form for commercial use in jellies, marmalade, and confections (Charley and Weaver, 1998)

2.2.3.3.Types of pectin

Pectins are divided into major two types such as High Methoxyl Pectin (HMP) and Low Methoxyl Pectin (LMP). Different types of low – methoxyl pectins are available. These are Purple ribbon pure, Genu LM 101 AS, Genu LM 102 AS, Genu LM 105 AS

Table 2.6: Pectins in the absence of externally provided Calcium ions

Type of pectin	Texture characteristics
Purple ribbon pure	Too slack gel, viscous
Genu LM 101 AS	Slack gel, viscous
Genu LM 102 AS	Slack gel, viscous
Genu LM 105 AS	Too slack gel
Purple ribbon D – 075	Sandy , gummy

Source, Copenhagen pectin factory Ltd. Denmark(1984)

2.2.4.Gel formation

In an acid fruit substrate, pectin is a negatively charged colloid the addition of sugar influences the pectin –water equilibrium established, and destabilizes the pectin. If conglomerates and establishes a network of fibres. This structure is able to support liquids. The continuity of the network formed by the pectin and the denseness of the formed fibres are established by the concentration of pectin. The higher concentration the more dense the fibres in the structure. The rigidity of the network is influenced by the sugar concentration and acidity. The higher concentration of sugar, the less water supported by the structure. The toughness of the fibres in the structure is controlled by the acidity of the substrate. Very acid conditions result in a tough gel structure or destroy the structure by action of hydrolysis of the pectin. Low acidity yields weak fibres unable to support the liquid, and the gel slumps

Gel formation occurs only within a narrow range of pH values. Optimum pH conditions are found near 3.2 for gel formation. Values below this point find gel strength decreasing slowly; values above 3.5 do not permit gel formation at the usual soluble solids range. The optimum solids range is slightly above 65%. It is possible to have gel formation at 60% solids, by increasing the pectin and acid levels. Too high a concentration of solids results in a gel with sticky characteristics (Desrosier, 1970).

Table 2.7: Effect of degree of esterification of pectin on gel formation

Degree of esterification (%)[a]	pH	Sugar (%)	Divalent ions	Rapidity of gel formation
> 70	2.8-3.4	65	No	Rapid
50-70	2.8-3.4	65	No	Slow
<50 (Low methoxy)	2.5-6.5	None	Yes	Rapid

[a] Degree of esterification = (number of esterified D – Galacturonic acid residues per total number of D – Galacturonic acid residues) *100

Source: Food Chemistry Fennema (1985)

2.2.4.1. High methoxyl gel formation

High methoxyl pectins produce optimum gels where the concentration of pectin is about 1%, although the concentration varies with the type of pectin. High gel strength correlates positively with high molecular-weight pectin molecules and extensive inter- molecular association. The effect of DE (Degree of Esterification) on gel setting time has been the subject of some study and much confusion. Generally, setting times increases for pectins with DE values increasing from 30-50. The methyl ester groups probably explain this as due to increased steric interference with intermolecular hydrogen bonding interaction. From DE 50-70 the setting time decrease and this may stem from increased hydrophobic interaction between pectin molecules due to the relatively high degree of methylation.

High methoxyl pectins, those with 55-80% of carboxyl groups present as methyl esters, from gels if the pH is 3.4 or less and if a cosolute such as sucrose or other polyol is present in sufficient

High methoxyl pectins, those with 55-80% of carboxyl groups present as methyl esters, from gels if the pH is 3.4 or less and if a cosolute such as sucrose or other polyol is present in sufficient concentration. Divalent ions make limited contribution to gelation of high methoxyl pectins (Fennema, 1985).

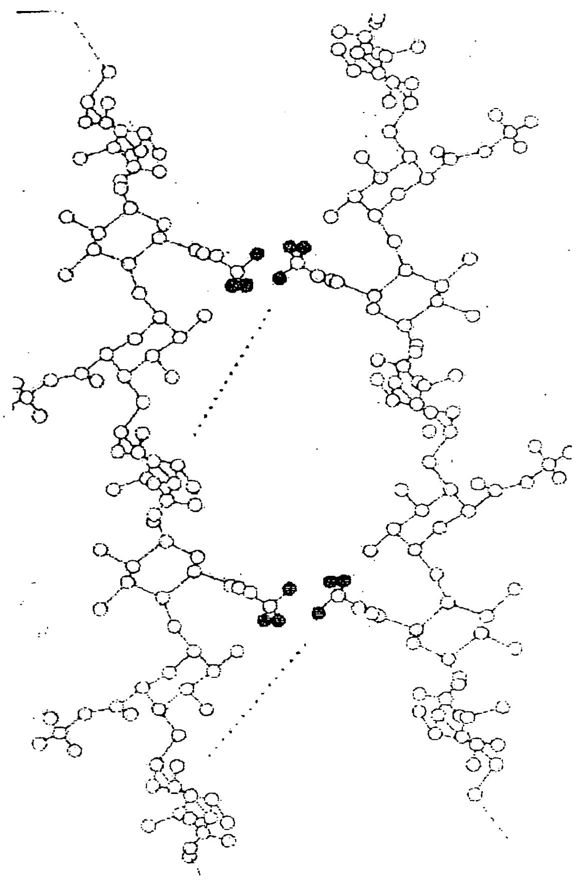


Figure2.2: Portion of junction zone in high methoxyl pectin

2.2.4.2. Low methoxyl gel formation

Low degree of esterification (DE) pectic substances (low methoxyl) can form stable gels in the absence of sugars but require the presence of divalent ions. Such as Calcium, which result in molecular cross-linking. Gels of this type are produced for sugar less or low-sugar dietetic jams and jellies. Low-methoxy pectin (LMP) is less sensitive to pH changes than are standard pectin gels. Low methoxy pectin gels may be formed in the pH range 2.5 to 6.5; normal pectin gels are limited to the pH range 2.7 to 3.5, with 3.2 optimal. Although LMP gels do not require sugar, the addition of 10-20% sucrose provides a gel with better textural properties Without the addition of sugar or some plasticizer, the LMP gels tend to be brittle and less elastic than those of normal pectins The gel forming action of Calcium ion is used in the preparation of dietetic jams and jellies with LMP (Fennema, 1985)

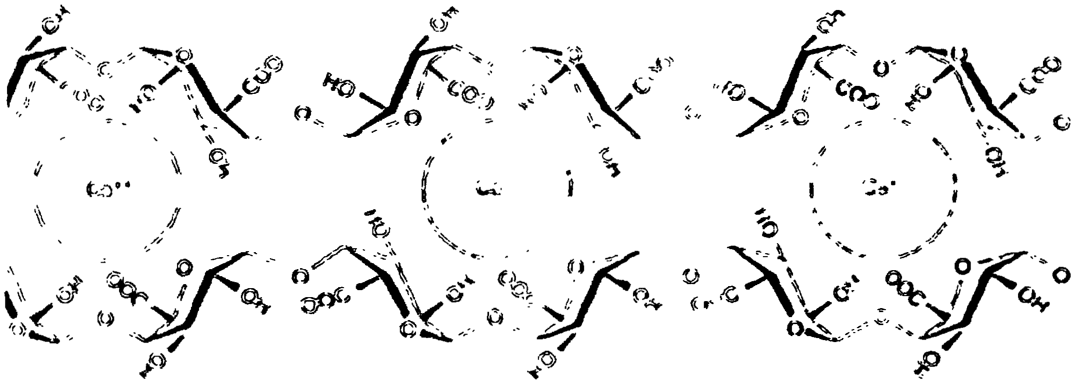


Figure 2.3: Junction zones in a Low-ester pectin gel shown as an egg – box model

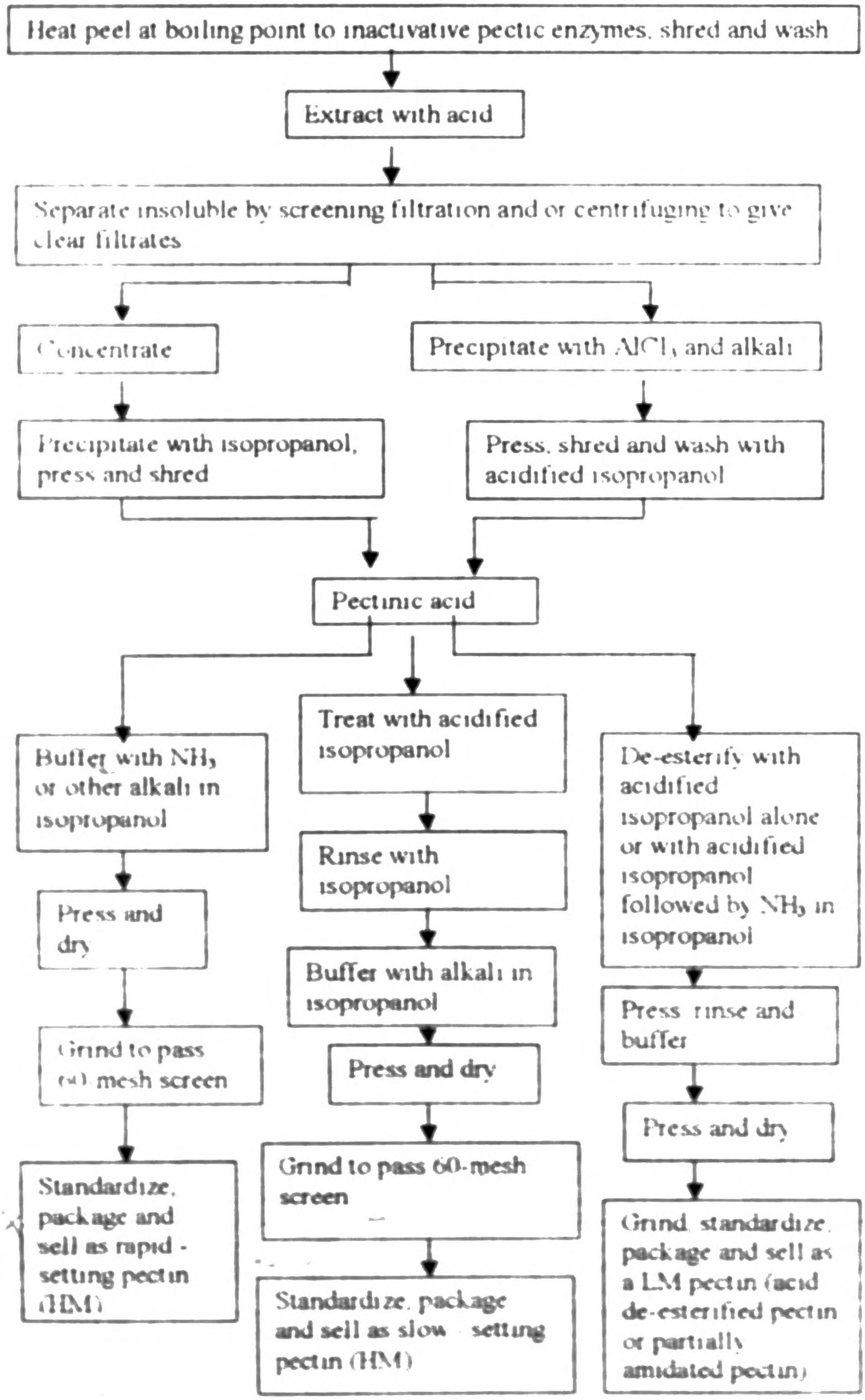
2.2.5. Properties of pectin

Table 2.8: Structure and properties of pectins

Origin	Structure	Solubility	Effects	Properties	Behaviour Rheology	Temperature	Mechanical	Freezing/Thawing	Storage environment	Applications
Pressed apple pulp citrus orange skin etc E 440	Polygalacturonic acid esterified to varying degrees by methanol High methoxyl pectin degree of esterification >50%	Soluble when hot in water or in milk	Gelling agent	Gel in acid sweet medium >60% Gel not heat reversible With rapid sets higher temperature and setting time shorter than with 'shorts sets'	Soft elastic gel	Swells and moves in to solutions when cold in absence of H^+ or Ca^{2+}	Broken gel	Depends on sugar content	Retrogradation possible	Acid preparations such as jam, confectionery Acid dairy products
	Low methoxyl pectin degree of esterification <50% may or may not be amided	Soluble when cold	Gelling agent	Gel in less acid media but requires the presence of Calcium Gel heat reversible Gel strength depends on pH and Ca content	Cohesiveness of gel depends on Calcium content					Milk desserts Jam with low dry extract content Pure fruit sugar

Source: New ingredients in food processing (1999)

2.2.6. Process of production of pectin



2.2.7. Preservation of jam

2.2.7.1. Preservation with Chemicals

The two important preservatives permitted in different part of the world These are,

(i) Benzoic acid (including benzoates)

(ii) Sulphur Dioxide (including sulphites)

(i) Sodium benzoate

It is salt of benzoic acid and is in used in the preservation of fruit juices and squashes Benzoic acid is the effective agent but since it is sparingly soluble in water, their sodium salt, which is water soluble, is used

The quantity of sodium benzoate required will depend on the extent and type of infection to be overcome and nature of the juice, particularly its acidity It has been found that in case of juices having pH 3 5 to 4 0, which is the range of most fruit juices, 0 06 – 0 10 % sodium benzoate is sufficient, but in less acid juices, such as those from ripe grapes, at least 0 3 % is necessary

Benzoic acids more effective against yeasts, it does not stop lactic acid and vinegar fermentation

(ii) Sulphur Dioxide

Potassium Meta – bisulphite is used as a source of sulphur dioxide Potassium Meta – bisulphite is a crystalline salt and is fairly stable in neutral or alkaline media It is, however, decomposed by weak acids like carbonic, citric, tartaric, and malic acids When it is added to fruit juice or squash, the potassium radicals react with the acid of juice forming the corresponding potassium salt and the sulphur dioxide, which is liberated forms sulphurous acid with the water of juice

The preservative affect of sulphurous acid depends not on its total quantity but on the available amount of sulphur dioxide It has been found that sulphurous acid has very little antiseptic value against microorganisms, 6000p p m of the combined form having less toxic action on yeast than 50 p p m of free sulphurous acid

Although sulphur dioxide can retard the development of yeast in the juices it cannot arrest their multiplication, once their number has reached a high value

Estimation of sulphur dioxide is very important when the jam has been made from pulp preserved with sulphur dioxide The residual sulphur dioxide should not be more than 40 p p m (Bhatia, 1997)

Table2.9: Concentration of Sulphur Dioxide (in parts per million) required preventing growth of organisms at different pH values

pH values	*Saccharomyces ellipsoideus* p.p.m of SO_2	*Mucor* Mould p.p.m of SO_2	*Penicillium* Mould p.p.m of SO_2	Mixed Bacteria p.p.m of SO_2
2 5	200	200	300	100
3 5	800	600	600	300
7 0	Above 5000	Above 5000	Above 5000	Above 1000

Source Small industry research institute – Delhi

2.3.Jam processing methods

2.3.1. General processing

Traditionally, jam boiling was carried out using open (atmosphere) copper boiling pans, but these days pans are now usually stainless steel. The pans are hemispherical, with a large lip extension to assist in the prevention of boil over The hemispherical part of the pan is steam jacketed, with high-pressure steam providing the heat source Extra heating may be provided by the use of internal steam coils. The capacity of the pans may range from a few kilograms up to 100 kilogram or more, but calculation should be carried out to balance the input and out put, the input should not be so large as to allow boiling over and consequent wastage While the output should not be so small as to allow burning of the jam on to the heated surface of the pan

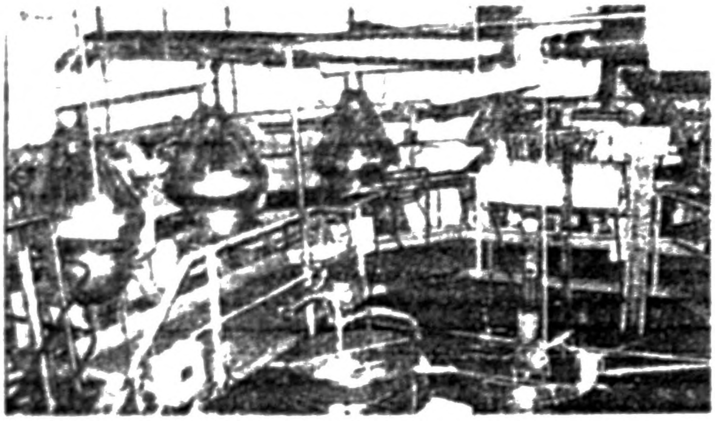


Fig 2.4: Atmospheric boiling pans.

2.3.2. Modern processing

Preserves may also be boiled under vacuum using either batch or continuous methods as well as by a combination of atmospheric pressure and vacuum The capacity of batch vacuum cookers also varies from a few kilograms up to several tonnes Puree type jams may be manufactured on a continuous basis using a plate evaporator while for products with defined fruit pieces, scrape surface heat exchangers operating both at atmospheric pressure and under vacuum are used as evaporators

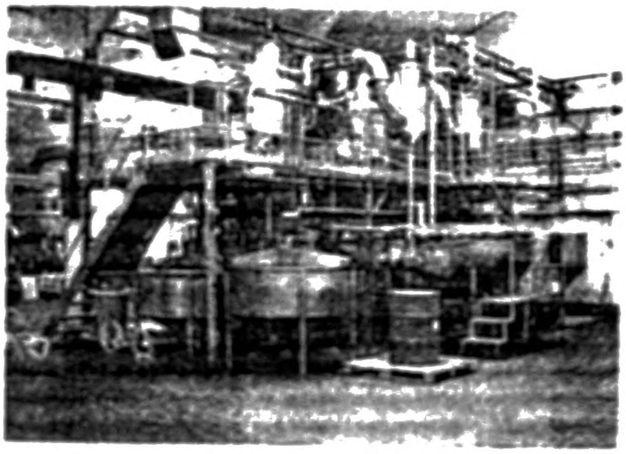


Fig 2.5: Batch vacuum boiling pans

CHAPTER .3

3. MATERIALS AND METHODS

3.1.Materials

Ripe fruits (Mango, Pineapple, and Papaw).

Concentrated fruit juice (Apple juice/Grape juice).

Pectin

Sodium meta - bisulphite (SMS)

Refractometer (Erma hand refractometer, Tokyo, Japan).

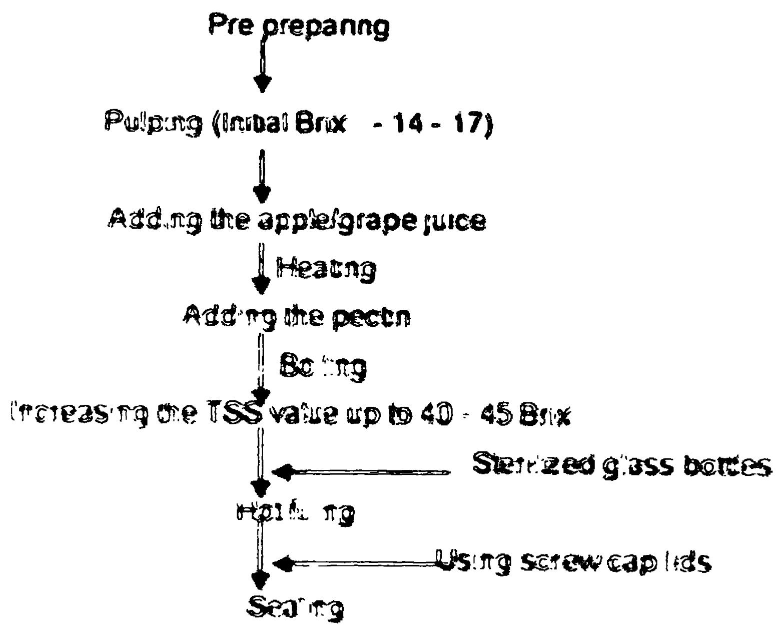
pH meter (Hanna instruments, 8519)

Stainless steel utensils

Laboratory equipment and analytical facilities.

3.2.Methods

Very ripe, sound fruits were collected. Those were washed with very dilute Sodium Meta - bisulphite (SMS) solution (about 10 p.p.m. SO_2). Fruits were prepared by using plastic chopping board and stainless steel utensils. Fruits were peeled and de – stoned. Pulped the prepared fruit in a blender. Concentrated fruit juice was added into the fruit pulp. It was checked for initial Total Soluble Solids (TSS). Pulp was heated by open pan heating. Pectin was added in towards final stage of fruit pulp. Citric acid was not added, because fruit pulp and juice had required acidity for final product. Mixture was heated up to 40 - 45 Brix° for spread consistency. Fruit spread was hot filled in to sterilized glass bottles with screw cap lids



3.2.1. Preparation of samples

Samples were prepared according to the following formulas in the table In all, 6 types of samples were prepared which differed only in amount of ingredients All remaining components were kept the same

Table 3.1:

Ingredients (%)	**Sample number**					
	218	**509**	**413**	**342**	**815**	**168**
Mango	20	25	30	30	40	40
Pineapple	25	25	30	30	15	10
Papaw	20	10	20	-	-	-
Grape juice	-	-	-	25	30	30
Apple juice	20	25	20	-	-	10
Water	14	14	-	14	14	9
Pectin	1	1	1	1	1	1

3.2.2. Method of sensory evaluation

In all, using ranking test under four parameters ranked 6 types of samples

3.2.2.1. Ranking

The panelist receives three or more coded samples and he asked to rank them for the intensity of some specific characteristics

The ranking method is rapid and allows the testing of several samples at once It is generally used to screen one or two of the best samples from a group of samples (Larmond, 1977)

3.2.2.2. Method

Nineteen judges were ranked the six types of fruit spreads using the score sheet in Appendix on page 29 Then ranks were given the samples by the judges were shown below (Table 3.2)

Table 3.2:

Judges	Samples					
	815	**342**	**168**	**509**	**218**	**413**
1	3	4	5	1	6	2
2	2	4	1	6	5	3
3	2	3	6	1	5	4
4	4	5	6	2	1	3
5	2	3	4	5	6	1
6	4	5	6	3	1	2
7	5	4	6	3	2	1
8	5	4	6	2	1	3
9	5	3	6	4	2	1
10	5	2	4	1	6	3
11	4	5	6	3	1	2
12	3	5	6	4	2	1
13	4	5	6	2	3	1
14	4	3	6	5	1	2
15	5	1	6	3	4	2
16	5	4	6	2	1	3
17	4	5	6	2	3	1
18	4	5	6	3	1	2
19	5	3	6	4	1	2
Total	75	73	104	56	52	39

3.2.2.3. Statistical analysis

The rank totals were compared with the values in chart 2 of the Appendix on page 43 (Kramer et al.1974). When there were six treatments and nineteen judges, the tabular entries were 49 - 84 the lowest insignificant rank sum was 49 and the highest insignificant rank sum was 84. If one or more rank sums were lower than the upper left value in the block (49) or higher than the upper right value in the block (84), statistical significance at the 5% level of significance was indicated

3.2.3.Preperation of samples

Another three samples were prepared as following formula.

Table 3.3:

Ingredients (%)	Samples number		
	675	812 = 413	420
Mango	35	30	-
Pineapple	35	30	-
Papaw	20	20	-
Grape juice	-	-	20
Apple juice	10	20	-
Madan	-	-	80
Pectin	1	1	1

3.2.4.Method of sensory evaluation

In all three samples were scaled by descriptive sensory analysis for mainly examine flavour and texture profile

3.2.4.1.Descriptive sensory analysis

The most commonly known descriptive methods are the flavour profile (Caul, 1957) and the texture profile (Brandt et al 1963)

The flavour profile is the description of the flavour and aroma of a food product. The description names_the perceptible factors the intensity of each factor, the order in which the factors are perceived, aftertaste, and overall impression

The texture profile is the description of the textural characteristics perceived in a food product, the intensity of each factor, and the order in which they are perceived (Larmond, 1977)

3.2.4.2.Method

Eight judges were scaled the 3 types of fruit spreads using the score sheet in Appendix on page30 Then scales were given the samples by the judges were shown in appendix on page 31and32

3.2.4.3.Statistical analysis

Analysis of variance was conducted on the numerical values for each characteristic The statistical package was used the Minitab windows version (1996).

3.3.Methods for proximate analysis

3.3.1.Total soluble solids (TSS)

For each sample, TSS was tested by Erma hand type Refractometer (Brix^{0} meter)

3.3.2.pH

For each sample, pH was measured by Hanna instruments type pH meter

pH meter was calibrated using pH 7 and 4 standard buffer solution before use.

3.3.3.Titrable acidity

Titrable acidity was tested for each sample, according to the AOAC procedure (1996), clause 920 151

CHAPTER .4

4. RESULTS AND DISCUSSION

4.1 Results

4.1.1. Results of ranking

All of the rank sums were now compared to the lower pair of values in the block to determine which samples were significantly low (overall acceptability). Sample413, which received a rank sum of 39, was significantly high acceptability than sample 168, which received a rank sum of 104. Therefore, sample 413 was significantly better than sample 168. The order in enhancing acceptability was 218>509>342>815. Sample 413 was sweeter than other samples due to the fact that it contained high fruit content (80% of fruit pulp out of the 100% of mixture)

4.1.2. Results of proximate analysis

All six types of samples were analyzed for Total Soluble Solids (TSS), Titrable Acidity, and pH

Table 4.1:

Sample No:	218	509	413	342	815	168
Titrable acidity	3.07	4.22	4.99	3.3	3.45	3.3
pH	3.81	3.54	3.95	3.52	3.46	3.43
TSS (initial)	14.0	14.0	16.4	17.0	16.2	15.2
TSS (final)	36.5	37.5	41.6	42.0	40.0	39.5

Mean of the above value of characteristics are shown below

Table 4.2:

Total soluble solids	Titrable acidity	pH
39.52	3.72	3.62

Samples were analyzed for TSS, titrable acidity and pH

Table 4.3:

Sample No:	**812**	**675**	**420**
Titrable acidity	4 56	4 2	3.31
pH	3 89	3 62	3 42
TSS (initial)	15 4	15 2	10 4
TSS (final)	37 5	36 8	41 0

4.1.3. Results of descriptive analysis with scaling

Another three types of samples were analyzed by two-way analysis for characteristics of products such as appearance, aroma sweetness, and spreadability See the appendix on page 33,35,37,and39

Two characteristics out of the four characteristics were significantly different, but another two were not significantly different Each characteristics were analyzed by Tukey's test for difference of the above three types of samples See the appendix on page 34,36,38,40.

Sweetness of sample 812 was significantly different from sample 420 Spreadability of samples 812 and 675 were significantly different from sample 420. Appearance of sample 675 was significantly different from sample 420 Aroma of each sample was not significantly different Each characteristic was same between 675 and 812

4.2. Discussion

In 1997, Whole Earth launched a 'fruit spread' comprising apple juice, fruit, water and pectin. The ingredients were mixed, heated to boiling and then filled hot into glass jars, which were lidded labeled and packed whole earth foods eventually, termed this product a 'fruit spread' (Wright, 1994)

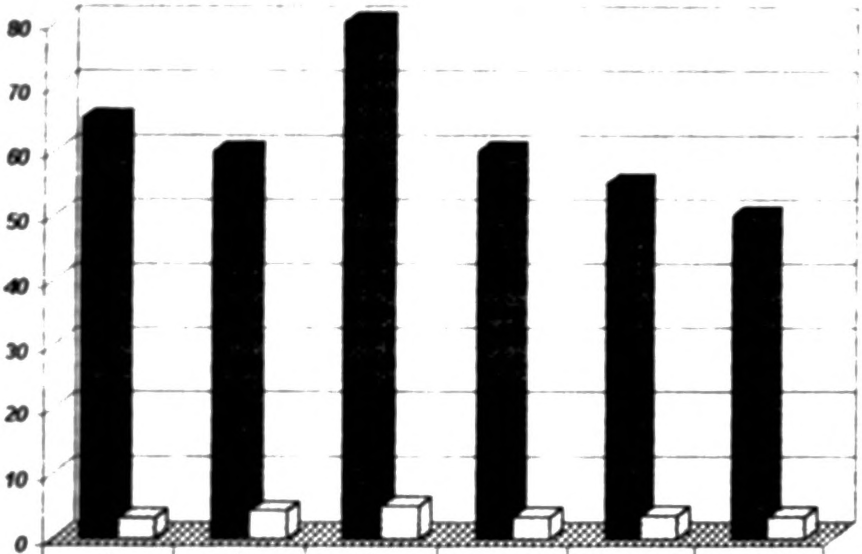
In preparing of fruit spread, sugar was not added Therefore sweetness of spread can be reduced But, Sri Lanka is tropical country Tropical fruits are high acidic than temperate fruits Thus, high sweetness fruit varieties should be collected But, many difficulties were faced for collecting to such fruits

Other problem is difficult to the concentration of fruit juice from open pan heating. Because when water evaporates continuously by open pan heating, juice tends to be burned. But, double-jacketed steam kettle or vacuum evaporator is not available in the laboratory.

Low methoxyl pectin can form stable gels in the absence of externally added sugar, but require the presence of divalent ions such as calcium which result in molecular cross – linking Gels of this type are produced for sugar less or low – sugar/ diet jams or jellies. (Fennema, 1985) But types of low methoxyl pectin are very expensive and not available in the laboratory. Therefore high methoxyl pectin was added into the fruit spread High methoxyl pectin can form stable gels if the pH is 3 4 Or less and if a cosolute such as sucrose or other polyols is present in sufficient concentration (65%) Divalent ions make limited contribution to gelation of high methoxyl pectins (Fennema, 1985) But, mean of the pH of fruit spread is more than 3 4 and it contains less sugar concentration than 65% Therefore fruit spread cannot be achieved to desired gel consistency

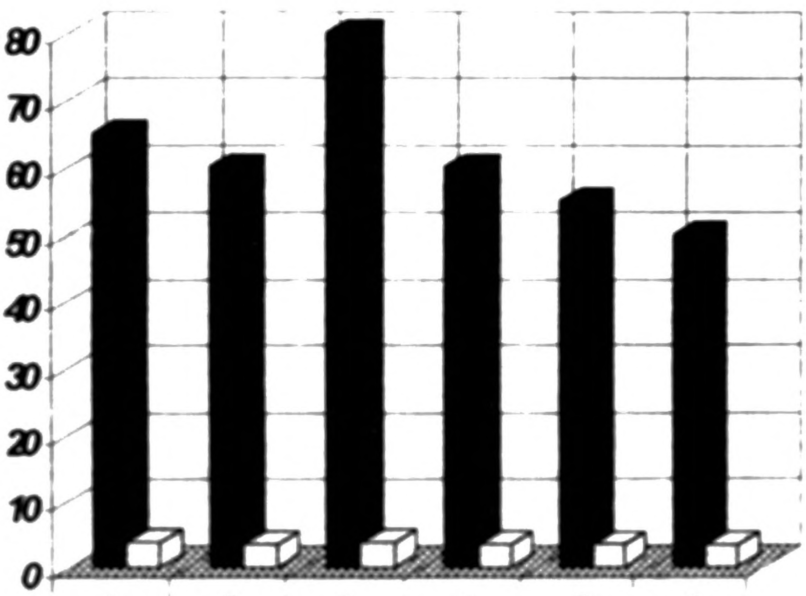
Fruit spread may also be boiled under vacuum using either batch or continuous method as well as by a combination of atmospheric pressure and vacuum At the laboratory level only the open pan method was available for the evaporation of the water from the fruit spread But this method cause burning of the fruit spread Therefore fruit spread cannot be achieved to desired gel consistency

Sample 413 was the best among all six types of samples This had a reasonable sweetness with good sugar/ acid balance , consistency and spread Sweetness measured as TSS was 41 6 Brix and acidity as citric acid was 4 98% and pH of 3 9 Fruit spread should have exceed 45 Brix If achieved the desired TSS value, low methoxy pectin should be included in the formulations and should be used of better techniques vacuum/double jacketed steam pan cooking



	1	2	3	4	5	6
■ Fruit content	65	60	80	60	55	50
□ Titrable acidity	3.07	4.22	4.99	3.3	3.45	3.3

Figure 4.1.



	1	2	3	4	5	6
■ Fruit content	65	60	80	60	55	50
□ pH	3.81	3.54	3.95	3.52	3.46	3.43

Figure 4.2.

According to the Figure 4.1, when increasing the fruit content titrable acidity also increases. When water is evaporated in spread, fruit sugars can be concentrated. If it is contained high amount of fruit, amount of natural fruit sugars also high. It preferably affects to the sugar/acid balance as well as pH value of the fruit spread (Figure 4 2).

In order to results of descriptive analysis sweetness of sample 420 was less than sample 812 Sample 420 was contained 'Madan' (***Syzygium cumini***) 'Madan' is less sweet than combination of mango/Pineapple/Papaya fruits Spreadability of sample 420 less than other two samples 'Madan' fruits are not fleshy fruits Therefore it pulp was not have good Spreadability.

CHAPTER .5

CONCLUSION

Combination of high sweetness fruits with intense colour and low astringency. E. g, Madan (***Syzygium cumini***) cooked with grape juice would mask the polyphenol oxidase activity naturally Such combination with low methoxyl pectin included in the formulation and use of better techniques such as vacuum / double jacketed steam pan cooking could be recommended for a better end result and further development of fruit spread with no added cane sugar

CHAPTER .6

REFERENCES

1. Arthey D., Ashurst P R, 1996, Fruit Processing, Blackie Academic & Professional an Imprint Of Chapman & Hall, London
2. Bennett H, 1965, The Chemical Formulary (vol vii), Chemical Publishing Co
3. Bennett H, 1990, The Chemical Formulary (vol Xxix), Chemical Publishing Co
4. Bhatia S C, Canning & Preservation Of Fruits & Vegetables (38th pub), Small Industry Research Institute, India
5. Charley H, Weaver C, 1998, Foods A Scientific Approach, Simon & Schester / A Viacom Co N J
6. Desrosier N W, 1970, The technology of food preservation, 3rd edition, The Avi Publishing Co LD
7. Dziezak J D, 1996, Sweeteners And Product Development, Food Techno Vol. 40.
8. Fennema O R, 1985, Food Chemistry, Marcel Dekker Inc
9. Gunderson F L, Gunderson H W, 1963. Food Standards And Definition In The United States, Academic press, USA
10. Hime A. C., 1971, The Biochemistry Of Fruits And Their Products, Academic press, USA
11. Koivistoinen P, Hyvonen L, 1980, Carbohydrate Sweeteners In Food And Nutrition, Academic Press USA
12. Linden G, Lorient D, 1999 New Ingredients In Food Processing Biochemistry & Agriculture Wood head publishing Ltd
13. Man C M D, Jones A.A., Shelf Life Evaluation Of Foods Blackie Academic & Professional an Imprint Of Chapman & Hall, London
14. Ranganna S, 1977, Hand Book Of Analysis And Quality Control For Fruit And Vegetable Products, Hill Publishing Co Ltd T M
15. Raphael ides S N, Ambatzidon A, and Petridis D 1996 Sugar Composition Effects On Textural Parameters Of peach Jam A Publication Of The Institute Of Food Technologist Sep - Oct
16. Somogyi L P Ramaswamy H S and Hui Y H 1996 Processing Fruits, Science And Technology (vol 1) Biology, Principles And Applications Technomic Publishing Co
17. Srivastava K. Small Medium And Large-Scale Industries Small Industry Research Institute
18. Wright S, 1994 Hand book Of Organic Food Processing And Production Blackie Academic & Professional an Imprint Of Chapman & Hall London

CHAPTER .7

APPENDIX

QUESTIONNAIRE FOR RANKING

Name ; .... **Date:** ....

Product : ....

INSTRUCTIONS

- Please check the appearance, aroma, sweetness, and Spreadability for each sample
- After that, rank the sample you like best as first and the sample you like least as last
- Taste the samples in the following order

815 342 168 509 218 413

First ☐

Second ☐

Third ☐

Fourth ☐

Fifth ☐

Sixth ☐

COMMENTS

QUESTIONNAIR FOR DESCRIPTIVE ANALYSIS WITH SCALING.

Name: ______________________ Date: ____________

Product: ______________________

INSTRUCTIONS

- Please evaluate the appearance, aroma, sweetness, and Spreadability of these samples of fruit spread.
- Mark vertical lines on the horizontal line to indicate your rating of the parameter of each sample Label each vertical line with the code number of the sample it represents.
- Please taste the samples in the following order
675 420 812

1 Appearance

|——————————————————————————|

Less attractive ... high attractive

2 Aroma

|——————————————————————————|

Less aroma ... high aroma

3 Sweetness

|——————————————————————————|

Less sweetness ... high-sweetness

4 Spreadability

|——————————————————————————|

Less Spreadability ... high-Spreadability

Comments:

Sweetness

Judges	Samples			
	675	420	812	Totals
1	3 55	1 05	6 4	11 0
2	4 20	2 65	8 6	15 45
3	9 0	3 7	7 95	20 65
4	10 0	8 3	3 4	21 7
5	6 3	1 6	6 15	14 05
6	9 4	7 05	8 95	25 4
7	6 0	4 55	9 75	20 3
8	9 6	8 7	10 8	29 1
Totals	58 05	37 6	62 0	157 65
Means	7 25	4 7	7 75	

Spreadability

Judges	Samples			
	675	420	812	Totals
1	3 6	1.1	6 6	11 3
2	10 9	2 8	10 2	23 9
3	9 55	8 6	10 65	28 8
4	11 7	2 45	9.6	23.75
5	6 2	0 25	6 5	12 95
6	11 45	3 2	10 2	24 85
7	8 05	5 6	9 5	23 15
8	7 3	3 7	10 85	21 85
Totals	68 75	27 7	74 1	170 55
Means	8 59	3 46	9 26	

Appearance

Judges	Samples			
	675	420	812	Totals
1	4.8	0.6	2 4	7 8
2	10 0	7.85	3 7	21 55
3	8 9	9 9	7 5	26 3
4	10 75	7 8	5 5	24 05
5	9 1	3.05	10 0	22 15
6	8 95	1 9	9 2	20 05
7	8 1	6 9	9 05	24 05
8	10 0	7 7	8 9	26 6
Totals	70 6	45 7	56 25	172 55
Means	8 82	5 71	7 03	

Aroma

Judges	Samples			
	675	420	812	Totals
1	6 65	0 6	3 1	10 35
2	3 3	11 7	6 4	21 4
3	6 55	7 9	5 4	19 85
4	10 8	3.8	6 85	21 45
5	10 4	3 15	9 5	23 05
6	10 4	2 6	10 1	23 1
7	7 5	4.8	7 5	19 8
8	9 15	10 5	8 0	27 65
Totals	64 75	45 05	56 85	166 65
Means	8 09	5 63	7 10	

Aroma.
Two-way Analysis of Variance

Analysis of Variance for samples

Source	DF	SS	MS	F value
C2	7	56.38	8.05	0.83
C3	2	24 57	12.29	1.26
Error	14	136 05	9 72	
Total	23	217 01		

```
              Individual 95% CI
C2          Mean  --+---------+---------+---------+---------
1           3 5  (-----------*-----------)
2           7 1          (-----------*-----------)
3           6 6         (-----------*-----------)
4           7 2          (-----------*-----------)
5           7 7            (-----------*-----------)
6           7 7            (-----------*-----------)
7           6 6         ( ----------*-----------)
8           9 2               (-----------*-----------)
                  -+---------+---------+---------+---------
                  0 0       3 5       7 0       10 5
```

```
              Individual 95% CI
C3          Mean  --+---------+---------+---------+---------
1           8 1            (-----------*-----------)
2           5 6  (-----------*-----------)
3           7 1        (-----------*-----------)
                  ---+---------+---------+---------+-----
                    4C        6O        8O        100
```

Tukey's test.

Root of error mean square = 1.1
Degree of freedom = 3.7
Least significant difference = 3.7 * 1.1 = 4.07

Sample scores	675	420	812	
	64.75	45.05	56.85	
	8.1	5.6	7.1	
Magnification of means		675	812	420
		8.1	7.1	5.6

675 - 420 = 8.1 - 5.6 = 2.5 < 4.07 not significant difference

Sweetness.

Two-way Analysis of Variance

Analysis of Variance for samples

Source	DF	SS	MS	F value
C2	7	83 93	11 99	2,63
C3	2	42 88	21 44	4.71
Error	14	63 75	4.55	
Total	23	190 56		

```
                 Individual 95% CI
C2         Mean  ------+---------+---------+---------+---
1          3 7  (---------*---------)
2          5 2      (---------*---------)
3          6 9          (---------*---------)
4          7 2           (---------*---------)
5          4 7     (---------*---------)
6          8 5              (---------*---------)
7          6 8          (---------*---------)
8          9 7                  (---------*---------)
                 ------+---------+---------+---------+---
                      3 0       6 0       9 0      12 0
```

```
                 Individual 95% CI
C3         Mean  ---------+---------+---------+---------+
1          7 26             (---------*---------)
2          4 70   (---------*---------)
3          7 75               (---------*---------)
                 ---------+---------+---------+---------+
                       4 50      6 00      7 50      9 00
```

Tukey's test

Root of square mean = 0 76
Degree of freedom = 3 7
Least significant difference = 3 7 * 0.76 = 2.8

Sample scores	675	420	812
	58 05	37 6	62 0
	7 26	4 7	7.75

Magnification of mean

812	675	420
7 75	7 26	4 7

812 - 420 = 7 75 - 4 7 = 3 05 > 2 8 significant difference
812 - 675 = 7 75 - 7 26 = 0 49 < 2 8 not significant difference
675 - 420 = 7 26 - 4 7 = 2 56 < 2 8 not significant difference

Spreadability.

Two-way Analysis of Variance

Analysis of Variance for samples

Source	DF	SS	MS	F value
C2	7	85.02	12 15	4 13
C3	2	161 11	80 56	27 40
Error	14	41 20	2 94	
Total	23	287 34		

```
                Individual 95% CI
C2         Mean  ----+---------+---------+---------+------
1          3 77  (---------*---------)
2          7 97                (---------*---------)
3          9 60                      (---------*---------)
4          7 92                (---------*---------)
5          4 32    (---------*---------)
6          8 28                  (---------*---------)
7          7 72               (---------*---------)
8          7 28              (---------*---------)
                ----+---------+---------+---------+------
                  2 50      5 00      7 50     10 00
```

```
                Individual 95% CI
C3         Mean  --+---------+---------+---------+--------
1          8 59              (-----*-----)
2          3 46  (-----*-----)
3          9 26                 (-----*-----)
                --+---------+---------+---------+--------
                2 50      5 00      7 50     10 00
```

Tukey's test

Root of square mean = 0.61

Degree of freedom = 3 7
Least significant difference = 3 7 * 0.61 = 2 26

Sample scores	675	420	812
	68 75	27 7	74 1
	8 59	3 46	9 26

Magnification of mean

812	675	420
9 26	8 59	3 46

812 - 420 = 9 26 - 3 46 = 5 8 > 2 26

812 - 675 = 9.26 - 8 59 = 0 67 < 2 26
812 significant differences from sample 420
812 not significant differences from 675
675 - 420 = 8 59 - 3 46 = 5.13 > 2 26
675 significant differences from 420

Appearance.

Two-way Analysis of Variance

Analysis of Variance for samples

Source	DF	SS	MS	F value
C2	7	84 08	12 01	2 24
C3	2	39 05	19 53	3 64
Error	14	74 99	5 36	
Total	23	198 12		

```
             Individual 95% CI
C2          Mean  -+---------+---------+---------+---------+
1           2.6  (---------*---------)
2           7 2            (---------*--------)
3           8.8                (---------*---------)
4           8 0              (---------*---------)
5           7 4             (---------*---------)
6           6 7           (---------*---------)
7           8 0              (---------*---------)
8           8 9                (---------*---------)
              -+---------+---------+---------+---------+
              0 0       3 0       6 0       9 0      12 0
```

```
             Individual 95% CI
C3          Mean  ------+---------+---------+---------+-----
1           8 82               (----------*----------)
2           5 71  (----------*----------)
3           7 03        (----------*----------)
                 ------+---------+---------+---------+-----
                      4 80      6 40      8 00      9 60
```

Tukey's test

Root of error mean square = 0 82
Degree of freedom = 3 7
Least significant difference = 3 7 * 0 82 = 3 03
Sample scores **675** **420** **812**
70 6 45 7 56 25
8 82 5 71 7 03
Magnification of means
675 **420** **812**
8 82 7 03 5 71
675 - 420 = 8 82 - 5 71 = 3 11 > 3 03 significant difference
675 - 812 = 8 82 - 7 03 = 1 79 < 3 03 not significant difference
812 - 420 = 7 03 - 5 71 = 1 32 < 3 03 not significant difference

Statistical chart 1

Significant studentized range at the 5% level.

Degrees of freedom f	Number of treatments 2	3	4	5
1	18 0	26 7	32 8	37 2
2	6 09	8 28	9 80	10 89
3	4 50	5 88	6 83	7 51
4	3 93	5 00	5 76	6 31
5	3 61	4 54	5 18	5 64
6	3 46	4 34	4 90	5 31
7	3 34	4 16	4 68	5 06
8	3 26	4 04	4 53	4 89
9	3 20	3 95	4.42	4 76
10	3 15	3 88	4.33	4 66
11	3 11	3 82	4 26	4 58
12	3 08	3 77	4.20	4 51
13	3 06	3 73	4 15	4 46
14	3 03	3 70	4 11	4 41
15	3 01	3 67	4 08	4 37
16	3 00	3 65	4 05	4 34
17	2 98	3 62	4 02	4 31
18	2 97	3 61	4.00	4 28
19	2 96	3 59	3 98	4 26
20	2 95	3 58	3 96	4 24
24	2 92	3 53	3 90	4 17
30	2 89	3 48	3 84	4 11
40	2 86	3 44	3 79	4 04
60	2 83	3 40	3 74	3 98
120	2 80	3 36	3.69	3 92
∞	2 77	3 32	3 63	3 86

Statistical Chart 2

Rank Totals

Rank totals required for significance at the 5% level (P<=0 05) The four figure blocks represent Lowest insignificant rank sum, any treatment-highest insignificant rank sum, any treatment Lowest insignificant rank sum, predetermined treatment-highest insignificant rank sum predetermined treatment

No of reps.	Number of treatments or samples 2	3	4	5	6	7	8	9	10	11
2	...	...			...	...	...	...	...	
	...	...		3-9	3-11	3-13	4-14	4-16	4-18	5-19
3	...	...		4-14	4-17	4-20	4-23	5-25	5-28	5-31
	...	4-8	4-11	5-13	6-15	6-18	7-20	8-22	8-25	9-27
4	...	5-11	5-15	6-18	6-22	7-25	7-29	8-32	8-36	8-40
	...	5-11	6-14	7-17	8-20	9-23	10-26	11-29	13-31	14-34
5		6-14	7-18	8-22	9-26	9-31	10-35	11-39	12-43	12-48
	6-9	7-13	8-17	10-20	11-24	13-27	14-31	15-35	17-78	18-42
6	7-11	8-16	9-21	10-26	11-31	12-36	13-41	14-46	15-51	17-55
	7-11	9-15	11-19	12-24	14-28	16-32	18-36	20-40	21-45	23-49
7	8-13	10-18	11-24	12-30	14-35	15-41	17-46	18-52	19-58	21-63
	8-13	10-18	13-22	15-27	17-32	19-38	22-41	24-46	26-51	28-58
8	9-15	11-21	13-27	15-33	17-39	18-46	20-52	22-58	24-64	25-71
	10-14	12-20	15-25	17-31	20-36	23-41	25-47	28-52	31-57	33-63
9	11-16	13-23	15-30	17-37	19-44	22-50	24-57	26-64	28-71	30-78
	11-16	14-22	17-28	20-34	23-40	26-46	29-52	32-58	35-64	38-70
10	12-18	15-25	17-33	20-40	22-48	25-55	27-63	30-70	32-78	34-86
	12-18	16-24	19-31	23-37	26-44	30-50	33-57	37-63	40-70	44-76
11	13-20	16-28	19-36	22-44	25-52	28-60	31-68	34-76	36-85	39-93
	14-19	18-26	21-34	25-41	29-48	30-55	37-62	41-69	45-76	49-83
12	15-21	18-30	21-39	25-47	28-56	31-65	34-74	38-82	41-91	44-100
	15-21	19-29	24-36	28-44	32-52	37-59	41-67	45-75	50-82	54-90
13	16-23	20-32	24-41	27-51	31-60	35-69	38-79	42-88	45-98	49-107
	17-22	21-31	26-39	31-48	35-56	40-64	45-72	55-80	54-89	59-97
14	17-25	22-34	26-44	30-54	34-64	38-74	42-84	46-94	50-104	54-114
	18-24	23-33	28-42	33-51	38-60	44-68	49-77	54-86	59-95	65-103
15	19-26	23-37	28-47	32-58	37-68	41-79	46-89	50-100	54-111	58-122
	19-26	25-35	30-45	36-54	42-63	47-73	53-82	59-91	64-101	70-110
16	20-28	25-39	30-50	35-61	40-72	45-83	49-95	54-106	59-117	63-129
	21-27	27-37	33-47	39-57	45-67	51-78	57-87	63-97	69-107	75-117
17	22-29	27-41	32-53	38-64	43-76	48-88	53-100	58-112	63-124	68-136
	22-29	28-40	35-50	41-61	48-71	54-82	61-92	67-103	74-113	81-123
18	23-31	29-43	34-56	40-68	46-80	51-93	57-105	62-118	68-130	73-143
	24-30	30-42	37-53	44-64	51-75	58-86	65-97	72-108	79-119	88-130
19	24-33	30-46	37-58	43-71	49-84	55-97	61-110	67-123	73-136	78-150
	25-32	32-44	39-56	47-67	54-79	62-90	69-102	76-114	84-125	91-137

Source Modified from Larmond, 1977

Statistical Chart 3

Variance ratio – 5 percent points for distribution of *F*
n_1 – Degree of freedom for numerator
n_2 – Degree of freedom for denominator

$n_2 \backslash n_1$	1	2	3	4	5	6	8	12	24	α
1	161.4	199.5	215.7	224.6	230.2	234.0	238.9	243.9	249.0	254.3
2	18.51	19.00	19.16	19.25	19.30	19.33	19.37	19.41	19.45	19.50
3	10.13	9.55	9.28	9.12	8.01	8.94	8.84	8.74	8.64	8.53
4	7.71	6.94	6.59	6.39	6.26	6.16	6.04	5.91	5.77	5.63
5	6.61	5.79	5.41	5.19	5.05	4.95	4.82	4.68	4.53	4.36
6	5.99	5.14	4.76	4.53	4.39	4.28	4.15	4.00	3.84	3.67
7	5.69	4.74	4.35	4.12	3.97	3.87	3.73	3.57	3.41	3.23
8	5.32	4.46	4.07	3.84	3.69	3.58	3.44	3.28	3.12	2.93
9	5.12	4.26	3.86	3.63	3.48	3.37	3.23	3.07	2.90	2.71
10	4.96	4.10	3.71	3.48	3.33	3.22	3.07	2.91	2.74	2.54
11	4.84	3.98	3.59	3.36	3.20	3.09	2.95	2.79	2.61	2.40
12	4.75	3.88	3.49	3.26	3.11	3.00	2.85	2.69	2.50	2.30
13	4.67	3.80	3.41	3.18	3.02	2.92	2.77	2.60	2.42	2.21
14	4.60	3.74	3.34	3.11	2.96	2.85	2.70	2.53	2.35	2.13
15	4.54	3.68	3.29	3.06	2.90	2.79	2.64	2.48	2.29	2.07
16	4.49	3.63	3.24	3.01	2.85	2.74	2.59	2.42	2.24	2.01
17	4.45	3.59	3.20	2.96	2.81	2.70	2.55	2.38	2.19	1.96
18	4.41	3.55	3.16	2.93	2.77	2.66	2.51	2.34	2.15	1.92
19	4.38	3.52	3.13	2.90	2.74	2.63	2.48	2.31	2.11	1.88
20	4.35	3.49	3.10	2.87	2.71	2.60	2.54	2.28	2.08	1.84
21	4.32	3.47	3.07	2.84	2.68	2.57	2.42	2.25	2.05	1.81
22	4.30	3.44	3.05	2.82	2.66	2.55	2.40	2.23	2.03	1.78
23	4.28	3.42	3.03	2.80	2.64	2.53	2.38	2.20	2.00	1.76
24	4.26	3.40	3.01	2.78	2.62	2.51	2.36	2.18	1.98	1.73
25	4.24	3.38	2.99	2.76	2.60	2.49	2.34	2.16	1.96	1.71
26	4.22	3.37	2.98	2.74	2.59	2.47	2.32	2.15	1.95	1.69
27	4.21	3.35	2.96	2.73	2.57	2.46	2.30	2.13	1.93	1.67
28	4.20	3.34	2.95	2.71	2.56	2.44	2.29	2.12	1.91	1.65
29	4.18	3.33	2.93	2.70	2.54	2.43	2.28	2.10	1.90	1.64
30	4.17	3.32	2.92	2.69	2.53	2.42	2.27	2.09	1.89	1.62
40	4.08	3.23	2.84	2.61	2.45	2.34	2.18	2.00	1.79	1.51
60	4.00	3.15	2.76	2.52	2.37	2.25	2.10	1.92	1.70	1.39
120	3.92	3.07	2.68	2.45	2.39	2.17	2.02	1.83	1.61	1.25
α	3.84	2.99	2.60	2.37	2.21	2.09	1.94	1.75	1.52	1.00

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