MANUFACTURE OF PEANUT BUTTER IN SMALL SCALE.

By

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DECLARATION

The work is described in this thesis was carried out by me at Cathy Rich Memorial Food Processing training Centre under the supervision of Mr C.Edirisinghe and Dr K.K.D.S.Ranaweera. 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

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Abstract

The peanut (*Arachis hypogea*) is one of the major oil seed crops of high economic value. Almost the entire local production of peanut is supplied to the domestic market as raw pods. In Sri Lanka yet no attention is given for manufacture a peanut based a value added products. Therefore the development of a value added product at small and medium scales would remedy several problems involved in both crop and food industry. Among the peanut based products, peanut butter represents a promising item as there is a big demand of the butter itself and there is a variety of other applications for peanut butter in the food industry. In the context of Sri Lanka peanut butter is yet imported and sold at an approximate of 150 Rs for a 200g block.

A study was carried out to establish a protocol for a low cost peanut butter formula containing locally available raw materials. The study also included a comparative physico chemical analysis of the butter formula and a sensory evaluation of the final product. As raw materials Red Spanish and pink coloured peanuts, potable water, and several other ingredients were used. As equipment a manually operated grinder and a locally invented gas oven were used. Peanut butter samples prepared were packed in jam bottles. Peanut butter preparation was done in seven steps viz. baking, immediate cooling, removing skin and germ, grinding, mixing with ingredients, packing and cooling to 10 ^{0}C. Preliminary studies were carried out to detecting proper baking temperature, finding out and quantifying stabilizers to prevent oil separation, determining the effect of germs and skins, and assessing the effect of immediate cooling after filling peanut butter in to containers.

The optimal combinations of temperature for roasting a 2 Kg batch of peanuts were 160 ^{0}C for 30 minutes and 150 ^{0}C for 40 minutes. As suitable stabilizer hydrogenated vegetable fat gave satisfactory results. Germ and skin of peanuts gave a bitter taste to the peanut butter. In addition the ground skins also, gave a small dark spotted appearance to the butter making it unattractive. Removal of both skin and germ can remedy the problems like bitter taste and unattractive appearance. Immediate cooling of peanut butter after the preparation prevents oil separation of the butter. According to the sensory evaluation the butter samples could be competitive to the imported counter parts.

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Chapter 01.

1.0 Introduction.

The peanut (*Arachis hypogea)* is one of the major oilseed crops of high economic value. Among the varieties cultivated in Sri Lanka, MI1, Red Spanish, No.45 and south China are predominant.

As far as the recent peanut production in Sri Lanka is concerned, in 89/90 11,120 tons of pods were produced with the average yield of 1019 kg/ha. Almost the entire local production is supplied to the domestic market as raw pods. Usually the market prices during the harvested seasons (Yala and Maha) are considerably less. The seasonal fluctuation of the prices makes this farming less profitable to the farmers. Mainly, the local population consumes peanut roasted. Despite the big potential of this crop for manufacture of value added products yet no attention is given. Therefore, the development of value added products at small and medium scales would remedy several problems involved in this husbandry. However, the products to be manufactured should be competitive with similar products imported to the local market in every aspect including quality and cost effectiveness.

Among the peanut-based products, peanut butter represents a promising item as there is a big industrial demand through out the world and there are a variety of other secondary applications for peanut butter in the food industry.

Peanut butter is by far the most important product made from peanuts in the United States. Despite many countries including Sri Lanka produce peanut in large quantities they hardly consume peanut in the form of butter and if they consume only imported varieties. In the context of Sri Lanka peanut butter is imported and sold at an approximate of 150 Rs per 200g blocks. This price includes unnecessarily costs for importing, long range transporting and so on and is not affordable to the majority of the local consumers. Hence, manufacture of a low cost peanut butter in small scale certainly has a benefit for both farmers and consumers.

Peanut butter is a cohesive, comminuted food product prepared from clean, sound shelled groundnut by grinding roasted, mature groundnut kernel from which the seed coat have been removed and to which salt is added as a seasoning agent (U.S standard for grades,

EDH. 1965). The fat content should not exceed 55% while the amount of groundnut must not be less than 90%.

There are seven major steps involved in the manufacture of peanut butter viz. shelling and cleaning, roasting, cooling, blanching, picking and inspecting, grinding and packaging (Woodroof *et.al. 1949*).

The main objective of this study was to develop a protocol for manufacturing a peanut butter formula suitable for small-scale producers. In this connection attempts were taken to use hand-operated simple machines and to utilize locally available raw materials.

Major constrains in the manufacture of peanut butter are problems connected with oil separation from the solid particles, rancidity, putrefaction of protein fraction caused by bacterial action and darkening of the product due to reactions between the protein and sugar (Peanut butter contains nearly 25% of protein).
In reality for the protein fraction –putrefaction and for the darkening requires considerable moisture, since peanut butter seldom contains more than one percent moisture they need not be feared as danger sources. The splitting of fat depends on moisture contents and on the presence of fat splitting enzymes (lipase enzymes). The second step is the oxidative rancidity, which develops readily and rapidly, in the unsaturated portion of oil when it is exposed to air.

Methods of prevention of oxidation should either prevent oxygen from contacting the oil product or incorporate an antioxidant in to the product, which act as an oxygen acceptor. Operations in oil separation include special grinding of roasted peanuts, heat treatment of peanut butter after packing and incorporation of various substances in to the peanut butter including water, honey, glycerine, mono and diglycerides, and hydrogenated vegetable fat with different degrees of hardness. In the case of US peanut butter industry hydrogenated peanut oil is being used to remedy these problems.

Since crystals of fat are not present in the natural oil of peanut butter at ordinary temperatures, hydrogenated peanut oil, which is crystalline at these temperatures, is mixed uniformly with the product to provide such crystals. Generally, this incorporation improves general properties. The melting point of the hydrogenated peanut oil is reached to ensure more complete and a successful dispersion of the hard fat with the natural oil and the entire mass comprising peanut butter. In a satisfactorily stabilised peanut butter, crystallisation of the added fat (hydrogenated peanut oil) takes place generally throughout the product before

product to ensure the presence of sufficient crystals at the room temperature to entrap the natural oil.

The effect of the skin is more detrimental to the appearance than to the flavour. The ground skins appear as small dark spots through out the butter, giving an unattractive appearance. (Peanut hearts are also objectionable because of dull grey colour).

Hearts and skins of peanuts lower the aroma and flavour of the peanut butter as they contain bitter substances. Peanut hearts contains at least four bitter principles, which possess the saponins (Dieckert and Morris 1958). The skins are bitter due to the catechol tannin and related compounds (Stansbury and Hoffpauir 1952).

Purified tannin represents about 7% of the weight of the skins and discolours the peanut butter (Stanbury *et al.* 1950). Skins represents 2,5% to 3.5% of peanut kernels.
Bright light, especially that with U.V rays, is detrimental to peanut butter. According to experiments, oil separation was greater by 31% than in dark.

The stability of peanut butter was unaffected by salt. (Freeman *et al;* 1954) The experiment conducted to study on rancidity after 30 and 90 days revealed that there is no apparent difference in rancidity as indicated by aroma, flavour, peroxide value, or percentage free acid.

Storage temperature also affects the shelf life. Studies on the effect of storage temperature on the shelf life of the peanut butter showed that the lower temperatures increase the shelf life probably due to the reduction of rancidity and oil separation by lower temperatures.

There are several standards set by relevant International Institutions. According to the US Federal regulations the peanut content should be 90% or more, salt content does not exceed 1.6%, stabilizer content should not exceed 6%. In peanut butter the colour should be ranged within 3 to 4 U.S.D. standard colour chips. Maximum oil leakage permitted is 0.5 ml. Aflatoxin level should be below than 20 ppm as set by the F.D.A
Therefore small scale or medium scale farmer has a dual responsibility; should meet several requirements to produce profitable (low cost) butter formula while maintaining the quality parameters similar to commercially available counterparts. In this connection the following requirements are to be met.

The peanut butter formula should be cost effective.
The formula should have sensory characteristics acceptable to the consumer.

The formula should have sensory characteristics acceptable to the consumer.
The shelf life of the product should be sufficient.

Objectives of the study.

In accordance with the above requirements the present study has the following objectives.

1. To study the feasibility of manufacturing of peanut butter in small scale.
2. To analyse physicochemical characteristics of peanut butter and compare it with imported peanut butter samples

Chapter 02.

2.0 Literature review.

2.1 Local availability of peanuts

In Sri Lanka groundnut is mainly grown in the dry zone: and to a limited extent in the intermediate zone under Coconut *(Cocos nucifera)* plantations particularly in the Kurunagala district. The main growing seasons are Maha and Yala. The Maha is the period of major rains (mid September to January) and the Yala is the period of minor rains (mid March to July). The main growing areas in Maha (80%) are Hambantota, Moneragala, Kurunegala and puttalam districts and they are the highest grown districts of peanuts.

Table 2.1: Cultivated extent of groundnuts 1989- 1998. (In hectares)

	1984	1990	1991	1992	1993	1994	1995	1996	1997	1998
Total	11,240	8,950	7,530	7,640	9,690	1,0430	9,890	8,800	9,180	10,110
Maha	7,330	5,470	5,070	5,560	6,580	7,340	7,390	6,630	6,460	7,290
Yala	3,910	3,480	2,460	2,080	3,110	3,090	2,500	2,170	2,720	2,820

Source: (Statistical abstract of the democratic republic of Sri Lanka 1999)

2.2 Cultivation of peanut in Sri Lanka.

Table 2.2: Major peanuts varieties cultivated in Sri Lanka.

Variety	Attributes
MI 1	Medium sized 2 seeded pods with pink testa.
Red Spanish	Large 3 seeded pods with dark pink testa.
No 45	High shelling (75%) , 2 seeded pods with pink testa.
South china	Medium bold pods with pink testa.

Source: Groundnut a global perspective 1991.

In Sri Lanka the recommended sowing time for Maha season is mid October to the end of October and April for Yala season. Commonly spacing for peanut is 24 x 15 cm for Spanish bunch and 24 x 30 cm for Virginia bunch is common. Recommended fertilizer doses in Sri Lanka include N: P: K 30: 65:45 Kg/ha in form of top dressing at the flowering stage. In noncalcic Lactosols and Regosols, 100kg/ha of Gypsum is recommended to apply to avoid "pops" (empty pods) in the produce.

The Maha season crop in Sri Lanka is rainfed, whereas the Yala season crop receives full irrigation. Irrigation at 50% moisture depletion in reddish brown soils.give optimum pod yield and water use efficiency.

2.2.1 Harvest, drying and storage.

The crop is mainly harvested manually. Plants are pulled out by hand at the time of maturity. Proper drying of groundnut is very important before storage. Moisture content should be reduced up to 8% or below because higher moisture levels in the produce are congenial for the production of aflatoxin by fungi *Aspergillus flavus* in particular.

2.3 Aflatoxin contamination.

The several members of genera *Aspergillus* produce a substance toxic to other biological systems including humans. Strains of *Aspergillus flavus* and *Aspergillus parasiticus* produce aflatoxins. *Aspergillus* are common contaminants of soils and organic materials.
This *Aspergillus* group of fungi invades groundnuts in the field and during post harvest handlings.

2.3.1 Biological effects of Aflatoxins.

Aflatoxins can cause damages in microorganisms, cell cultures, plants and animals. There may be chronic or acute effects depending upon the dosage and the frequency of exposure to the toxins. The effect of aflatoxin can be toxigenic, mutagenic, teratogenic or carcinogenic.

Group of aflatoxins consists mainly of the following members B1, B2, G1, G2, M1, M2. Among them aflatoxins B1 is the most abundant and considered to be most toxic form of the aflatoxins. Aflatoxins are found in commodities like corn, rice, groundnuts etc. Usually aflatoxins are thermostable and they can be destroyed only in high temperatures.

2.3.2 Condition for toxin production.

The ability of the fungus to produce and accumulate aflatoxins depends on environmental conditions, genetic potential and the duration of contact between fungus substrate.

Minimum RH required for growth of *Aspergillus flavus* is 80%. (However the minimum RH suitable for growth varies with the condition of peanut kernels)

Aspergillus is mesophilic having the optimum temperature ranging from 11 ^{0}C- 41 ^{0}C and at 44 ^{0}C-60 ^{0}C they may exhibit a 6-8% growth.

Substrate with high carbohydrate concentration favour aflatoxin production. Generally moulds are aerobic. So it might be expected that O_2 is needed for growth and aflatoxin production. Reduction of O_2 and increase of CO_2 decrease the production of aflatoxin.
Peanuts can be contaminated with the mould and subsequently can be produced aflatoxin during growth, harvesting or storage. Infection of peanuts with toxigenic fungi usually is associated with insect or mechanical damage to the shells before, during or after harvesting.

Peanuts harvested mechanically tend to be contaminated than hand-picked ones due to the mechanical injuries on the pods. After harvesting of the peanuts it is essential to decrease moisture content to 8% or lesser. Then peanuts should be stored under the conditions where the moisture content is not increased. It is evident that field crops can be carriers of aflatoxins to human food through processing.

Several genotypes with resistance to *in vitro* seed colonization by *Aspergillus flavus* have been known in the past. However, this form of resistance is effective only when the seed coat remains intact. Recently, genotypes that resist fungus invasion in the field and production of aflatoxin after fungus invasion has been identified. Breeding efforts are underway at ICRISAT and NRCG, Junagadh, India, to combine these forms of resistance with high pod yield. Proceedings of an international workshop on aflatoxin contamination of groundnut, held at ICRISAT centre in 1987, summarize the status of aflatoxin management research in the region and elsewhere (ICRISAT 1989).

2.3.3 Methods use for the identification.

The simplest test, which can be used to determine the presence of aflatoxin, is the scanning of grain or seed with long wave U.V light (365 nm). A bright greenish yellow or greenish gold fluorescence is correlated with the presence of aflatoxin. Infrequently, nonfluorescent samples contain aflatoxin, but usually only in small amounts (less than 30 µg/kg). The fluorescence is not due to the presence of aflatoxin, but rather to the fungal produced kojic acid. Over 90% of the strains of aflatoxin producing *Aspergilli* also form kojic acid.

To determine aflatoxin TLC can be used. Firstly aflatoxin should be extracted from the sample with an organic solvent. For the separation TLC is used. For the detection long wave UV light is used. (The aflatoxin is soluble in methanol, acetone and various other polar solvents and sparingly soluble in water). TLC is sensitive to 2-4 µg/kg of aflatoxin (Romer 1973).
Confirmation of the presence of aflatoxin can be accomplished chemically, or by mass spectral methods. (Haddon *et al* 1977).

In one system, a minicolumn or florisil tube is used for separation. A direct readout of aflatoxin concentration in the tube can be obtained with a Velasco fluorotoxin meter. Alternatively, the column can be obtained served with long wave UV light (Romer 1976; Shotwell *et al* 1977)

According to Stoloff (1976) high pressure liquid chromatography (HPLC) shows promise for separating aflatoxins.

2.3.4 Preventive measures for aflatoxin.

The fungi attack damaged seeds more readily than they attack sound seeds. Control of insects and using care in harvesting can reduce the number of damaged seeds. Removal of damaged seeds and foreign material will help control growth and aflatoxin in production.

Development of low moisture content in seeds and storage at low RH.

Lowering the O_2 and increasing the CO_2 content.

Soaking of peanuts in a solution of P amino benzoic acid reduced production of aflatoxin by 50%. Potassium Sulfite and KF inhibit aflatoxin production. (Davis and Diener, 1975)

Spores of *Aspergillus flavus* do not survive a 45 second treatment with Ultraviolet light (Bean and Rambo, 1975).

2.3.5 Inactivation of aflatoxin.

Either chemical or physical treatments can be used to inactivate or detoxify aflatoxin. Methods for detoxification were reviewed by Dollear (1969).

Sodium hypochlorite, or bleach, has been effective in inactivation of aflatoxin. According to Dollear (1969), the most promising reagents for detoxifying aflatoxin are ammonia, methylamine, sodium hydroxide and ozone.

The primary physical treatment used to reduce toxicity of aflatoxin is heat. Roasting of peanuts at 150 ^{0}C for half an hour reduces aflatoxin B1 about 80% and B2 about 60 % (Lee *et al* 1969)

2.4 Nutritional aspects of peanuts and peanut butter.

Table 2.3 Composition of edible dried groundnut per 100g.

Composition	Values
Moisture	3.0g
Energy	567KCl
Protein	25.3g
Fats	40.1g
Carbohydrates	26.1g

Source: Perera W.D. A, Table of food composition 1989.

Table 2.4: Vitamins and minerals of groundnut dry per 100g of edible portion.

Composition	Values
Calcium	90(mg)
Phosphorus	350(mg)
Iron	2.8(mg)
Carotene	37(µg)
Thiamine	900 (µg)
Riboflavin	130 (µg)
Niacin	19.9 (µg)

Source: Perera W.D.A, Table of food composition 1989

Table 2.5: Composition of groundnut roasted 100g of edible portion.

Composition	Values
Moisture	3.0(g)
Energy	567(Kcal)
Protein	26.2(g)
Fats	39.8(g)
Carbohydrates	26.7(g)

Source: Perera W.D.A, Table of food composition 1989.

Table 2.6: Vitamins and minerals of roasted groundnut 100g of edible portion.

Composition	Values
Calcium	77(mg)
Phosphorus	370(mg)
Iron	3.1(mg)
Carotene	00(µg)
Thiamine	390(µg)
Riboflavin	130(µg)
Niacin	22.1(mg)

Source: Perera W.D.A, Table of food composition 1989.

Table 2.7: Composition of peanut butter per 100g of edible portion.

Composition	Values
Energy	2637 kJ
Protein	23.1 g
Fat	52.5 g
Total carbohydrate	17.5 g
Sugars	8.2 g
Cholesterol	Nil
Sodium	629 mg
Potassium	487 mg

Source: Perera W.D.A, Table of food composition 1989.

2.4 History of peanut butter.

Peanut butter is the most important product made from peanuts in the United States. Even though large quantities of peanuts are grown in other countries, practically non-is consumed as peanut butter.

Dates from about 1890 it was discovered that a very palatable paste or butter could be obtained by grinding peanuts. It soon become known as peanut butter, and presumably was made from raw peanuts. A physician in St Louis, Mo was reportedly the first to manufacture peanut butter commercially (Beattie 1936). It was recommended invalids because of its high nutritional value. It was said to be used in sanitariums elsewhere, especially at battle Creek, Mich., due to its high protein content, low carbohydrate content and palatability.

Due to limited sale at first and lack of adequate equipment for manufacture, the price was too high for general use.

The first product was shelled roasted peanuts chopped, ground, or beaten in to a pulp in a cloth bag with salt added.

About 1900, it was learned in the South America that the peanuts could be ground in to paste butter in the home. Soon it became a staple food and commercial production was greatly stimulated. Its first general use was for sandwiches served at outdoor parties and picnics; soon it was served in combination dishes, then in candies, cookies, ice cream, and other ways in the home, at schools, and in public eating-places.

Until World war II, peanut butter was made in many small plants. More recently plants have become fewer and larger. Some plants now have a capacity in excess of 5 tons/hr or more than 120 tons in a 24hr period.

Peanut butter and the method and equipment for manufacturing it are continuously changing. The popular brands on the market are quiet deferent from those ten or twenty years ago.
Peanut butter can be made from any variety of peanuts. However in the context of USA a blend of two parts Spanish or Runner peanuts with one part Virginia peanuts are considered to be the best to achieve the consistency desirable for peanut butter.

Some peanut butters have a heavy - roast colour and flavour where as, others possess light - roast characteristics. In an attempt to make peanut butters that are different in colour, flavour, and texture, some manufacturers include large pieces of peanuts, others add flavours such as malt, orange, ham, and cheese.

According to Woodroof and co-workers (1949) there are seven different major operations required in the manufacture of peanut butter; shelling and cleaning roasting, cooling, blanching, picking and inspecting, grinding and cooling.

2.6 Manufacture of peanut butter.

2.6.1 Roasting.

Peanuts used in the manufacture of peanut butter are dry roasted. Batch or continuous methods are used for dry roasting of peanuts. According to the opinion of some operators, batch roasters have many advantages over the continuous roasters.

Different varieties must be roasted separately. Moreover, peanuts frequently come in lots of different moisture content, which need special attention during roasting. This can be done more satisfactorily in batch roasters than in continuous ones. In the batch method, peanuts

are heated to 320F (Beattie 1936) and held at this temperature for 40- 60 min to obtain a satisfactory roast.
The nuts in the batch must be uniformly roasted. There should be even and complete development of colour from the centre to the surface of each kernel, without scorching, excessive oiliness, or decomposition of surface fats.

Roasting is used to rapidly dry the nuts and during this operation moisture content is reduced from a normal of about 5- 0.5% (Woodroof *et al* 1949). The drying is followed by the development of oily translucent spots on the surface of cotyledons, called "steam blisters" caused by oozing of oil from the cytoplasm as free oil. Change in colour is due to the cell walls becoming wet with oil. This stage is referred to as "white roast". The skins too become wet with oil, and darker in colour. The final stage of roasting is the development of a brown colour at which time the peanuts are done or "brown roasted" (Woodroof and Leathy 1940). Colour and flavour of the peanut butter is dependent on the extent to which brown roasting is allowed to proceed. High roasting temperatures are undesirable. They breakdown the oils, scorch the surface of the peanuts and char the broken pieces of loose skin. Soot and smoke caused by burning chaff within the cylinder also result from these high temperatures.

Willich et al (1952) found that the time of roasting peanuts is the most important variable affecting the colour of the roasted product. The moisture content is proportionately lower as the darkness increases; and the efficiency in blanching is not related to the degree of roasting.

Studies on effect of different roasting conditions on the content of thiamine in peanut butter showed that the content of thiamine diminishes with increase of roasting while the roasted peanuts darken.
Morris and Freeman (1954) determined that butter made from medium - roasted peanuts exhibits the most desirable flavour and its retention, as compared with butter from light roasted or dark roasted peanuts.

Morris *et al* (1953) found that roasted peanut kernel have a higher oil content (47.9%). The difference results from loss of volatile components and moisture during roasting.

Sorted cotyledons remaining after elimination of germs, skins and objectionable material during blanching, screening, and sorting contain a higher, percentage of oil (49.5%) than the roasted kernels.

Separation of components of lower oil content is responsible for this difference. The Skins of raw peanuts contains very little oil, but when separated from roasted nuts they contain 27% oil. The skin absorbed oil from the cotyledons during roasting. The free fatty acids extracted from raw, roasted peanuts, sorted cotyledons, and peanut butters are uniformly law.

2.6.2 Cooling.

Cooling after roasting is necessary in order to stop cooking at a definite point and to produce a uniform product.

In the plant, the hot peanuts pass from the roaster discharge directly to a cooler box. The coolers are designed to distribute air in such a manner that the entire stuffs of peanuts get cool evenly.

2.6.3 Blanching.

Removal of skin and heart of peanuts are called as blanching in the manufacturing process of peanut butter, this operation is necessary as hearts of the peanuts give bitter taste if it remains in the final product.

2.6.4 Picking and Inspecting.

The blanched nuts are screened and inspected to remove scorched and rotten nuts, stones or other foreign or undesirable matter. This is done on a conveyer belt. Light nuts are removed by blowers, discoloured nuts by electric eye, and metal pates by magnets.

2.6.5 Grinding cooling and packing.

Grinding is one of the simplest, but one of the most delicate operation in the plant. Several deceives are used for grinding peanuts into butter are referred to as comminuters, attrition mills, homogenisers, disintegrates, hammer mills, or colloid mills.

Most of these can be adjusted over a wide range. This results in a considerable variation in the quantity of peanuts ground per hour, the fineness of the product and the amount of oil freed from the peanuts. The grinding mill should be easy to clean. Usually two grinding

operations are used to manufacture peanut butter. The first reduces the nuts to a medium grind and the second to a fine smooth texture.

In order to make "chunky " peanut butter, peanuts pieces are mixed with regular peanut butter. A specially designed plate is substituted for the regular grinding.

Ingredients what are used for peanut butter are fed into the grinder with peanuts. Heat is generated during grinding and this cause melting of hydrogenated fat an ingredient used for peanut butter. Over-heating is prevented by a water jacket. A constant pressure prevents formation of air bubbles in peanut butter during these operations.

A heavy screw feeds the peanuts into the grinders and may also be used to deliver the deaerated peanut butter in to containers in a continuous stream under even pressure. To ensure even and complete assimilation of all additives into the peanut butter as well as adding others, it is discharged in to mixing pump.

Subsequently the extent goes to the filling machine. Mixing is done with propeller-type blades with both forward and backward pitch.
Recommended temperature used during the blending of stabilizer added to peanut butter is 60^0C to 74^0C. But some mills run 10 to 15 degree higher. A second mill for texturing or homogenising is recommended. Recommended temperature for filling jars is 29 ^{0}C to 44 ^{0}C. Filled containers should be about 10 ^{0}C.

Recent studies have shown that the best heat generated by grinding and mixing should be removed immediately to ensure proper crystallization of the fats. Votators, a type of heat exchanger, are used to cool peanut butter from about 49^0C to 76^0C or less before it is packaged.

2.7 Uses of peanut butter.

Peanut butter is used by most families in some manner. Children eat most of it, although women use a considerable amount. Very little is eaten by babies, men (of any age), elderly women, or by the obese or diabetics. One of its greatest assests is that almost every one likes the flavour. The high protein and fat renders it especially suitable for combining with carbohydrate foods, and the flavour is compatible with sweets.

In America 94% families reported that they used peanut butter as a spread. Peanut butter is a favourite item in school lunches in many countries. Characteristics that render it favourable for use in school lunches are,

1. It is an excellent protein supplement and very high in total energy value.
2. Fair source of calcium, iron, thiamine, riboflavin and niacin.
3. Children like its flavour.
4. Peanut butter may be held in unopened containers for several months without deterioration.

The use of peanut butter in sandwiches for school lunches, picnics and in the home has tended to level off since about 1969 in favour of more convenient and "less messy" ways of serving peanut butter. To satisfy this trend there has been a marked increase in commercially made peanut butter sandwiches, cookies, wafers, patties, bars, and other snacks.

A few recently introduced peanut butter products are the following:

Peanut butter cream cookies, Peanut crunch sandwiches, Nut sundae cookies, Nutty bars, Chocolate peanut bars etc.

2.8 Drawbacks of peanut butter.

1. Oil separation from the paste.
2. Rancidity.
3. Aflatoxin.
4. Loss of flavour during roasting.

2.9 Solutions for drawbacks.

1. To prevent oil separation hydrogenated fat, dextrose and powdered sugar are used.

2. The first step of this is the formation of free acid through the splitting of oil molecules. This depends on moisture and on the presence of fat splitting enzymes. The second is oxidative rancidity which develops rapidly when O_2 present. Methods of preventing oxidation are to keep O_2 away from the product, or place in the product an antioxidant, which act as an O_2 acceptor. The raw peanuts contain rather effective

amounts of naturally occurring antioxidants. But these cannot survive the heat and exposure of roasting and grinding. So the adding of antioxidant is the solution for this. Not only antioxidants but also refrigeration of peanut butter also protect against rancidity.

3. A great deal of the best flavour and aroma are unavoidably lost during roasting and cooling. Upon standing, specially when exposed to air at high humidity the flavours continue to be lost. This is to be avoided by rapid and continuous processing , and by promptly and properly packaging the product.

4. The fungi attack damaged seeds more readily than they attack sound seeds. Control of insects and using care in harvesting can reduce the number of damaged seeds. Removal of damaged seeds before manufacturing process is started is a one solution to reduce aflatoxin. For the identification of aflatoxin in peanuts the simplest test, which can be used, is the scanning of grain or seed with long wave U.V light (365 nm). A bright greenish yellow or greenish gold fluorescence is correlated with the presence of aflatoxin. In frequently nonfluorescent samples contain aflatoxin, but usually only in small amounts (less than 30 μg/kg). (Fennell *et.al.* 1973)

2.10 Sensory evaluation.

For the consumer preference quality of the food item is mainly affected. The quality attributes depend on the sensory characteristics of the product. Instrumental measurements of these sensory properties are impossible. To measure sensory properties human beings are used. In sensory evaluations sensory capabilities of a group of individuals are utilized to assess one or several qualitative aspects of a food item. These aspects include aroma, flavour, texture, etc. It is common and growing practice to utilize sensory evaluation panels to check final products, products being developed and the product already in the distribution.

The sensory quality is an important parameter for both consumer and producer. In producers side it attracts consumers and in consumers side it satisfies their aesthetic and gustatory sense.

It is believed that carefully selected, well trained, professional sensory panellists serve as proxies for the much larger population in terms of determining what is acceptable quality in many food stuffs.

Sensory tests can be classified in several ways. Sensory specialists and food scientists classify tests as consumer oriented or as product oriented. Tests, which are used to evaluate the preference for food products, are termed as consumer oriented. Tests used to determine differences among products are termed as product oriented.

Chapter 03.

3.0 Materials and methods.

The experiment was carried out in the Cathy Rich Memorial Food processing training centre Embilipitiya.

3.1 Materials and equipment used.

3.1.1 Peanuts.

Red Spanish and pink colour skinned varieties were used to prepare the peanut butter samples. Peanuts were visually inspected to remove mould infected nuts. Peanuts were bought from the Embilipitiya town.

3.1.2 Water.

Potable water from centralised water system of Embilipitiya was used for all processing purposes. This water is usually chlorinated.

3.1.3 Packing materials.

As packing materials jam bottles were used. All the bottles were sterilized before using and lid was hermetically closed. The brimful capacity of those bottles was 360 ml. The height was 117.5mm. The neck finish diameter is 68mm.

3.1.4 Grinding equipment.

In order to grind peanuts to obtain homogenised pieces a locally invented hand operated grinder was used.

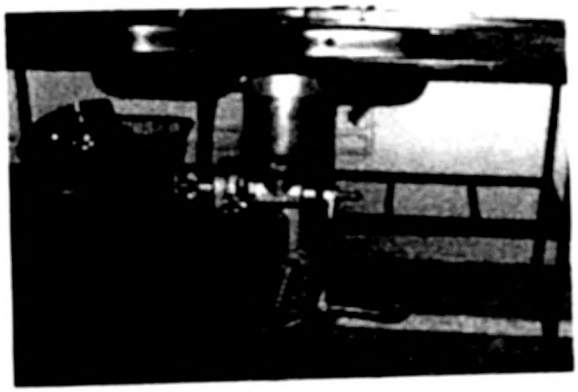

Plate 1: Manual grinder.

3.1.5 Apparatus for roasting.

For roasting the peanuts a gas oven and a paddy husk roaster were used

Plate: 02 Paddy husk roaster

3.1.6 Apparatus used for removal of skins of peanuts.

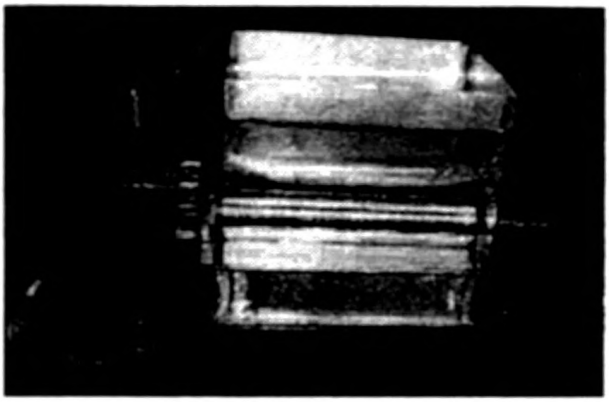

Plate 03: Peanut skin remover.

3.2 Preparation of peanut butter.

Usually, formula of the Peanut butter and accordingly the methods and equipment employed in manufacturing the butter are continuously being changed. As a result of that the popular brands on the present market are far different from those available in previous decades.

Geib (1941) described the peanut butter manufacture of in five steps; shelling, roasting, blanching and grinding and homogenising where as Woodroof et .al. (1949) described its manufacture involving steps; shelling and cleaning, roasting, cooling, blanching, picking and inspecting, grinding and packing.

The procedure followed in the present experiment is a different version (figure 3.1)

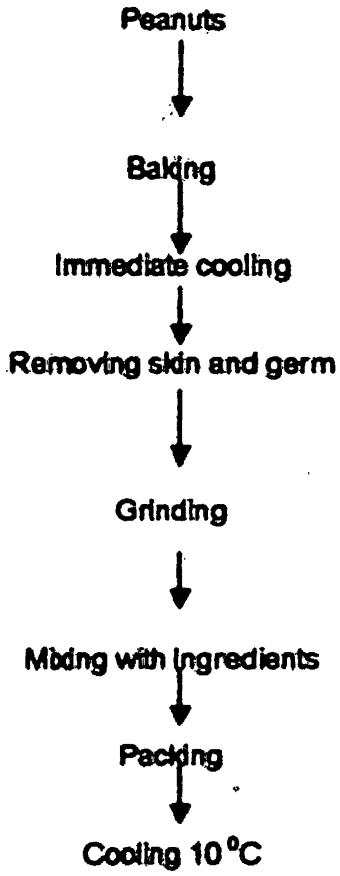

Figure 3.1 manufacturing procedure used to prepare peanut butter samples at Cathy Rich Memorial Food processing training centre.

3.3 Preliminary studies to determine baking temperature

A preliminary study was carried out to determine the baking temperature and its duration optimal for obtaining good quality peanuts. For this purpose, peanuts samples were baked at temperatures from 100 °C to 200 °C. It was found that peanuts were not properly baked at temperatures below 150 °C. However temperatures between 150 °C to 200 °C gave better results and time required for different temperatures to give successful results were also different.

Therefore, the next study was conducted to find the best combination of temperature and time by using a sensory evaluation. Ranking method was used as the sensory evaluation.

The ranks given by panellists were converted to scores according to the method of Fisher and Yates.

Table 3.1: Peanut butter prepared with peanuts roasted with different heat treatments.

Sample	Temperature	Time
987	180 °C	20 minutes
876	170 °C	25 minutes
765	160 °C	30 minutes
654	150 °C	40 minutes
543	Market sample	-

3.4 Studies to determine suitable stabilizer and the amount of stabilizers.

As stabilizers glycerine and dehydrogenated vegetable fat was used. Content of Glycerine remained constant whereas the quantity of dehydrogenated vegetable fat used was changed. Accordingly five samples with different amounts of the oil were prepared. (Table 3.2)

Table 3.2: peanut butter samples with different amounts of hydrogenated vegetable fat.

Sample	Dehydrogenated vegetable oil
S_1	0 g
S_2	1 g
S_3	2 g
S_5	3 g
S_6	4 g
S_7	5 g

After 30 days those samples were tested to determine whether there is oil separation. Another 5 samples were prepared by using vegetable oil instead of dehydrogenated vegetable fat.

Table 3.3: Peanut butter samples with different vegetable oil.

Sample	vegetable oil
V_1	1 g
V_2	2 g
V_3	3 g
V_4	4 g
V_5	5 g

After 30 days those samples were also tested to determine whether there is oil separation.

3.5 Preliminary studies to determine the effect of hearts and skins.

Three different types of samples were prepared to determine the effect of hearts and skins of peanuts on the quality of the peanut butter. The first sample was prepared without removing both skins and hearts. (Without blanching) The second sample was prepared removing only skins. The third sample was prepared with skins and removing hearts.

Table 3.4 peanut butter samples prepared with different impurities.

Sample name	way of preparation
R1	with both skin and heart
R_2	with heart
R_3	with skin

The samples were also tested to determine the quality.

3.6 Effect of cooling immediately after packing peanut butter into bottles on oil separation.

Two different types of samples were used for this purpose.

Immediately after preparation of peanut butter the first sample was placed in the refrigerator at 8 ^{0}C for 90 minutes. The second sample after the preparation was kept in the room temperature at 28 ^{0}C. After cooling the first sample was again brought to room temperature. Oil separation of both samples was assessed at regular intervals.

3.7 Chemical analysis

3.7.1 Moisture Determination

3.7.1.1 Equipments for moisture determination

1. Metal dishes, with lids.
2. Oven, maintained at 105 ± 2 ^{0}C.
3. Desiccators, with a suitable desiccant.

3.7.1.2 Determination of moisture.

The metal dishes were dried in the oven for 30 minutes and cooled in a desiccator and weighed to the nearest milligram (m_1). Then sample were put in dried dishes and got the weight of both (m_2). The samples were dried at 105 ^{0}C for 2 hours in an oven. Then they were cooled in a desiccator and were again weighed (m_3). This process of drying cooling and weighing of the oven dried samples were repeated at 30 minutes intervals until the difference between two successive weighs did not exceed 1 mg. (Three samples were used for the determination of moisture).

Note: These oven dried materials were kept for the determination of fat %

$$\text{Moisture, percent by mass} = \frac{(m_2 - m_1) - (m_3 - m_1)}{(m_2 - m_1)} \times 100$$

3.7.2 Determination of fat.

3.7.2.1 Apparatus.

1. Soxhlet extraction apparatus
2. Oven, maintained at 105± 2 ^{0}C.
3. Desiccator with a suitable desiccant.

3.7.2.2 Reagent.

Petroleum ether, boiling point ranges 40 ^{0}C to 60 ^{0}C.

3.7.2.3 Method.

The soxhlet flask was dried in the oven and cooled in a desicccator and weighed. The sample was weighed and transferred into a suitable thimble. The fat content in the thimble was extracted with the petroleum ether for 10 hours. Then the solvent was evaporated. The flask was dried in the oven, cooled in a descicator and weighed. This process of drying, cooling and weighing was repeated at 30 minutes interval until the difference between two successive weighing does not exceed 1 mg.

3.7.2.4 Calculation:

Fat, percent by mass = $((m_1-m_2) / (m_3)) \times 100$.
m_1 is the mass, in g of the flask with the fat
m_2 is the mass in g, of the empty flask
m_3 is the mass, in g, of the sample

3.7.3 Determination of the aflatoxin content in the peanut butter.

Determination of aflatoxin was conducted in collaboration with Thriposha Company by using HPLC method.

3.8 Sensory evaluation of prepared peanut butter.

Firstly ranking method was carried out for colour, aroma, and taste.

A trained sensory panel consisting 12 persons working as agricultural instructors at Uva province was used for this purpose.
For the sensory evaluation, panellists were assigned to individual booths was facilitated with drinking water to rinse mouth in between tasting, cream cracker biscuits to be taken in between tasting to avoid carrying over effects.

Each tasting booth was sufficiently illuminated and the panellists were served with a scorecard for the ranking test. It is shown in appendix 1.

The panellists were requested to score the samples according to the preference of colour, aroma and taste. This sensory evaluation method was carried out for the purpose of finding the suitable temperature for baking of peanuts.

3.8.1 Selecting a suitable peanut butter formula.

Another hedonic sensory evaluation was done to find the best formula for peanut butter making.

In this case five samples were used including market sample. For this purpose peanut butter samples were prepared changing the ingredient monosodium glutamate and vanilla. It is shown in the table 3.5. But the other ingredients and amounts are same.

All the test datum were analysed by SAS statistical computer software by using analysis of variance method (ANOVA) and least significant method (LSD) for Turkey test (Snedecor 1956) at 5% level.

Table 3.5. Special ingredients used for the preparation of samples.

Code no	765	654	543	432	321
Ingredients	No Vanilla or Monosodium glutamate	Vanilla and Monosodium glutamate	Vanilla	Monosodium glutamate	Market sample

Chapter 04.

4.0 Results and Discussion.

4.1 Selection of suitable time temperature combination for roasting of peanuts.

Results obtained from the sensory evaluation conducted to find out the optimal combination of temperature and time for roasting of peanuts revealed that the best time temperature combination for roasting of peanuts is 150 ^{0}C in 40 minutes.

Colour and flavour of peanut butter is dependent on the roasting process especially the quantity of heat and time of its exposure. Therefore, the sensory evaluation was conducted on the basis of colour aroma and taste. Preference for colour aroma and taste of four different samples were checked by a sensory evaluation. The baking temperature of peanuts of above mentioned samples were shown in the table 4.1. For the sensory evaluation a sample bought from the market was also used.

According to the analysis of variance procedure for aroma there is not significant different among samples. But according to the ANOVA procedure for taste there is significant different among samples. According to turkey test, sample 543 is significantly different from 987 and 876. But 876 and 987 are not significantly different. 543 654 and 765 are not significantly different. 543 is the market sample. So the 654 and 765 is not significantly different from the market sample. In the case of colour sample 543,654,765 and 987 are not significantly different. But 876 is significantly deferent from the other samples. So according to colour, aroma, and taste 654 and 765 are the most similar product to market sample. Therefore the best time temperature combination for roasting is the 150 ^{0}C 40 minutes and 160 ^{0}C 30 minutes.

Too many roasting of peanuts were resulted (190 ^{0}c and 200 ^{0}C) dark roasted colour and it may result loss of volatile components which is responsible for the typical peanut flavour.

Table 4.1: Baking temperatures used for roasting of peanuts.

Sample	Temperature	Time
987	180 ^{0}C	20 minutes
876	170 ^{0}C	25 minutes
765	160 ^{0}C	30 minutes
654	150 ^{0}C	40 minutes
543	Market sample	-

4.2 Results related for studies to determine the suitable stabilizer and the amount of stabilizers.

Oil separation could be seen in the samples, which were prepared by using vegetable oil. The amount of oil separation was increased with the amount of vegetable oil used. Oil separation was apparent in S_1 and S_2 sample, samples prepared with hydrogenated vegetable fat amounting 1 g and 2g respectively. There were not oil separation S_3, S4 and S_5 samples. Small amount of hydrogenated vegetable fat (including peanut oil) are the commonly used emulsifiers, which are added to prevent oil separation and to make the product easier to spread. The amount below 2 g of hydrogenated vegetable fat is not sufficient to prevent oil separation in 90 g of peanut butter. So that it could be seen oil separation of the samples, which were prepared by, using hydrogenated vegetable fat.

Since crystals of fat are not present in the natural oil of peanut butter at ordinary (room) temperatures, hydrogenated peanut fat that is capable of forming crystals at normal temperatures helps to provide such crystals. Therefore formation of such crystals in S_1 S_2 and S_3 samples possibly prevented oil separation. However hard fat needs to be sufficiently incorporated in the product in order to ensure the formation of sufficient crystals at room temperature for entrapping the natural oil.

4.3 Results related to the effect of hearts and skins.

Peanut butter, which was made by using nuts with hearts and skin, was found bitterer than other two samples, which contained either skins or hearts. Peanut butter, which was made using nuts with hearts, was bitter at a lesser degree. The other sample with no hearts and skins was not bitter. The ground skins gave a small dark spotted appearance to the butter, making it unattractive. Since the skins contain a great deal of dirt, which is hardly removed by the washing or brushing, they should be removed by other means in order to ensure hygienic conditions. Apart from that peanut hearts give a dull gray colour to peanut butter.

4.4 Results related to the effect of immediate cooling of peanut butter just after preparation.

Oil separation was not seen in the samples that were cooled immediately after preparation whereas oil separation was found in samples, which was not cooled.

Heat is generated during grinding of peanuts and mixing possibly makes hydrogenated fat melting. Those fats melted should be cooled for proper crystallization. Oil separation of peanut butter is largely determined by the nature and amount of crystals present. Due to the cooling of peanut butter just after preparation, fat crystals are formed and peanut oil is entrapped into those crystals thereby preventing oil separation.

4.5 Results obtain from the chemical analysis.

4.5.1 Results related to the moisture determination

Table4.2: Results related to the moisture determination

Weight of the crucible = 9.5095

Sample	Initial weight	final weight	Weight difference	moisture % in wet matter basis	Moisture % in dry matter basis
First	3.3688	3.3540	0.0148	0.439	0.441
Second	3.5090	3.4940	0.0150	0.427	0.429
Third	2.5050	2.4947	0.0103	0.41	0.419
Average				0.425	0.429

According to U. S. Food and Drug Administration the maximum allowable limits for moisture percentage in peanut butter is 4%.

The average moisture content of selected three samples was 0.425%. Water in the liquid state is essential for the existence of all living organisms. The cells of living organisms have a very high water content, i.e. more than 75%. This amount of water is required to maintain the cell in active state, and without liquid water living organisms, including microorganisms, will not grow or reproduce. Dormant cells, e.g. bacterial spores, have a much lower water content (15% in bacterial spores), which is insufficient to allow active metabolism. Normally in dried peanuts moisture content lies between 5-7%. To make peanut butter, roasting of peanuts at 150 ^{0}C for 40 minutes was done. Therefore, the remaining moisture content of peanuts also gets vaporised during roasting. More over in the normal manufacturing procedure, no water is added to the peanut butter formula. Therefore no a considerable amount of water is available in peanut butter. Accordingly it can be concluded that the growth of microorganisms in peanut butter is not possible under the above circumstances.

4.5.2Results related to fat percentage analysis

Weight of the rounded bottom flask = 187.3843 g
Weight of the initial sample =3.509 g
Weight of sample and rounded bottom flask =190.8783 g (after determination of moisture)
Weight of fat and rounded bottom flak =189.1313 g
Fat % = 1.747/3.509 x 100 = 49.78 %

According to the results the fat content of the butter formula is = 49.78%
This value is almost similar to that of the market sample, which is. (52.3)
According to Food and Drug Administration, the total oil content of finished food should not exceed 55%.

4.5.3 Results related to the determination of aflatoxin.

Examined aflatoxin amount was 15 ppb.
According to recommendation of the maximum level of aflatoxin content in peanut butter in U.S.A. is 20 ppb.
According to the SLS standards fresh unshelled groundnuts shall not contain more than 30 ppb.

4.6 Results related to the selecting of suitable formula for peanut butter preparation.

According to ANOVA procedure for colour and aroma, there is no significant difference was found in samples. As far as spredibility is concerned there is no significant difference between the samples coding No 432 and 321. Samples 543 and 765 are not significantly different from other samples. Code No 321 is the market sample. Therefore the sample coding No 432 mostly resemble with the sample which was purchased from the market sample. In the case of overall acceptability samples cording 432 543 and 765 are not significantly different from the market sample. Therefore all these formulas can be recommended for the preparation of the peanut butter.

Chapter 05

5.0 Conclusion.

5.1 Conclusions.

1. The results of the study revealed that the baking stuff of 2 Kg of peanuts at 150 ^{0}C for 40 minutes or at 160 ^{0}C for 30 minutes could satisfactory and efficiently roast the raw material.
2. As stabilizers for the prevention of oil separation from peanut butter, hydrogenated vegetable fat can be used as a replacement as gave better result than vegetable oil did.
3. Hearts and skins of peanuts contributed to a bitter taste in the peanut butter. And skins gave red colour spots through out the peanut butter making it rejectable by the consumers. Therefore it can be concluded that skin and hearts of the peanuts should be removed prior to grinding. To remove skins and hearts of peanuts a hand-operated equipment can be used. (See plate 3)
4. Immediate cooling of peanut butter just after preparation is needed to prevent oil separation.
5. For baking peanut a paddy husk roaster can be used in small-scale industries, as it is less expensive.
6. The product is remarkably cost effective compared with imported one. Therefore the butter formula can be introduced to the local market easily.
7. According to the results obtained it can be concluded that the samples produce have resembles with the market product in terms of sensory characteristics. Therefore the product could be marketed with help of small and medium scale industries.
8. The final product contains aflatoxin 15 ppb which is below than the standard set by U.S. F. D. A. therefore it can be concluded that the butter formula develop is safe for consumption.

5.2 Suggestions and recommendations.

Peanut butter formula developed by current study can be recommended for the further development in order to introduce it for small and medium scale industries. However prior to this there is a range of necessary procedures to be followed. Some of these are the:

1. Microbiological tests should be carried out to find out the presence of microorganisms in peanut butter.
2. An investigation is recommended to conduct to identify the best variety among the locally available peanut varieties.
3. The storage stability of formulation should be accessed in terms of varying storage temperatures.
4. The formulation is recommended to trial for possible applications in to other products such as ice cream.
5. Tests must be carried out for the manufacture of secondary products from peanut butter formula. Peanut butter-cream cookies, Peanut crunch sandwiches, Nut sundae coolies, Nutty bars, Chocolate peanut bars etc.
6. As far as the aflatoxins content in the product is concerned it is below than the U. S. F. D. A. standards. To maintain this level it is recommend that the raw materials be selected in such a way that aflatoxin level would be minimal. It is also recommended that farmers should be instructed to reduce mechanical damages and infections.

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Appendices 1.0

1.1 Questionnaire for ranking.

Product - Peanut butter.

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

You are provided peanut butter samples. Please rank these samples for aroma, colour and taste of the products. Please rank those samples according to the intensity of the above characteristics.

Sample No:

Aroma	☐	☐	☐	☐	☐
Taste	☐	☐	☐	☐	☐
Colour	☐	☐	☐	☐	☐

1.2 Questionnaire for hedonic test.

Product - Peanut butter.

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

You are provided peanut butter samples. Please evaluate the appearance, aroma, flavour, colour, taste, spreadability and overall acceptability of the products. Please include your degree of like by putting appropriate marks under the samples against the characters.

Sample No:

Appearance					
Aroma					
Texture					
Taste					
Overall acceptability					

Comments:

Marks

1. Dislike a lot.
2. Dislike a little.
3. Neither likes nor dislike.
4. Like a little.
5. Like a lot.

Appendices 2

Data of sensory evaluation

Data of first sensory evaluation conducted to determine suitable baking temperature

Table 2.1: Sensory score for taste

Panellists	987	876	765	654	543	Total
1	5	2	3	1	4	15
2	3	2	1	4	5	15
3	1	3	5	4	2	15
4	2	3	4	1	5	15
5	3	1	4	5	2	15
6	2	1	5	3	4	15
7	1	5	4	3	2	15
8	1	3	4	2	5	15
9	1	2	3	4	5	15
10	4	1	2	3	5	15
11	4	2	3	5	1	15
12	4	1	2	5	3	15
Total	31	26	40	40	43	180

The ranks were converted to scores according to the method of Fisher and Yates (1942) First=1.16, second = 0.05, Third = 0, fourth = -0.5, fifth = -1.16.

Table 2.2: Analysis of variance for taste.

Dependent Variable: SCORE

Source	DF	ANOVA SS	Mean Square	F Value	Pr > F
JUDGES	11	0.00000000	0.00000000	0.00	1.0000
SAMPLES	4	20.83333333	5.20833333	2.31	0.0726

Table 2.3: Turkey test for taste

T Grouping	Mean	N	SAMPLE
A	3.833	12	543
A			
B A	3.500	12	654
B A			
B A	2.917	12	765
B			
B	2.417	12	987
B			
B	2.333	12	876

Table 2.4: sensory score for aroma.

Panellists	987	876	765	654	543	Total
1	3	2	4	1	5	15
2	2	3	4	5	1	15
3	2	4	5	1	3	15
4	5	1	2	4	3	15
5	4	5	3	2	1	15
6	2	3	5	1	4	15
7	2	4	1	3	5	15
8	4	2	3	1	5	15
9	3	2	1	4	5	15
10	5	3	4	2	1	15
11	3	1	2	4	5	15
12	3	4	5	2	1	15
Total	38	34	39	30	39	180

Table 2.5: Analysis of variance for aroma

Dependent Variable: SCORE

Source	DF	ANOVA SS	Mean Square	F Value	Pr > F
JUDGES	11	0.00000000	0.00000000	0.00	1.0000
SAMPLES	4	2.83333333	0.70833333	0.27	0.8982

Table 2.6: Results of turkey test for aroma.

Least Significant Difference= 1.3426

Grouping	Mean	N	SAMPLES
A	3.250	12	543
A			
A	3.167	12	987
A			
A	3.083	12	765
A			
A	2.833	12	876
A			
A	2.667	12	654

Table 2.7: Sensory score for colour.

Panellists	987	876	765	654	543	Total
1	1	3	4	2	5	15
2	1	3	4	2	5	15
3	4	5	1	3	2	15
4	4	2	3	5	1	15
5	3	2	4	5	1	15
6	1	2	3	4	5	15
7	1	4	3	2	5	15
8	1	2	3	5	4	15
9	1	2	3	5	4	15
10	4	1	3	2	5	15
11	3	1	2	4	5	15
12	5	1	2	4	3	15
Total	29	28	35	43	46	

Table 2.8: Analysis of variance for colour.

Dependent Variable: SCORE

Source	DF	ANOVA SS	Mean Square	F Value	Pr > F
JUDGES	11	0.00000000	0.00000000	0.00	1.0000
SAMPLES	4	9.128733333	2.282183333	2.31	0.0726

Table 2.9:Results of turkey test for colour.

Least Significant Difference= 1.2578

T Grouping	Mean	N	SAMPLES
A	3.583	12	543
A			
B A	3.333	12	654
B A			
B A	3.333	12	765
B A			
B A	2.583	12	987
B			
B	2.167	12	876

Data of second sensory evaluation conducted to determine a best formulation.

Table 2.10: Sensory score for Colour.

Panellist	765	654	543	432	321	Total
1	4	3	5	4	5	21
2	3	4	3	4	3	18
3	4	4	4	3	5	20
4	4	4	4	4	4	19
5	4	3	3	5	2	18
6	3	4	4	4	5	17
7	2	3	3	4	5	16
Total	24	25	26	28	29	132

Table 2.11: Analysis of Variance Procedure for colour.

Dependent Variable: SCORE

Source	DF	ANOVA SS	Mean Square	F Value	Pr > F
JUDGES	6	3.71764706	0.61960784	0.89	0.5177
SAMPLE	4	2.40336134	0.60084034	0.86	0.5003

Table 2.12:Results of turkey test for colour.

T grouping	Mean	N	SAMPLE
A	4.429	7	321
A			
A	4.143	7	432
A			
B A	3.571	7	543
B			
B	3.000	7	654
B			
B	2.857	7	765

Table 2 .13: Sensory score for Aroma.

Panellist	765	654	543	432	321	Total
1	4	3	5	4	5	21
2	4	4	4	4	2	18
3	4	5	4	5	2	20
4	3	4	4	4	4	19
5	4	4	4	3	3	18
6	2	5	5	4	1	17
7	2	3	2	4	5	16
Total	23	28	28	28	22	129

Table 2.14: Analysis of Variance Procedure for aroma.

Dependent Variable: SCORE

Source	DF	ANOVA SS	Mean Square	F Value	Pr > F
JUDGES	6	3.54285714	0.59047619	0.49	0.8071
SAMPLE	4	5.25714286	1.31428571	1.10	0.3804

Table .2.15: Results of turkey test for aroma.

Least Significant Difference= 1.2073

T grouping	Mean	N	SAMPLE
A	4.000	7	543
A			
A	4.000	7	432
A			
A	4.000	7	654
A			
A	3.286	7	765
A			
A	3.143	7	321

Table 2.16: Sensory score for Taste.

Panellists	765	654	543	432	321	Total
1	3	3	4	5	5	20
2	3	4	2	4	3	14
3	3	5	4	5	5	22
4	2	3	4	5	4	18
5	4	4	4	5	3	20
6	3	4	5	4	4	20
7	2	3	2	4	5	16
Total	20	26	25	32	29	130

Table 2.17: Analysis of Variance Procedure for taste.

Dependent Variable: SCORE

Source	DF	ANOVA SS	Mean Square	F Value	Pr > F
JUDGES	6	6.17142857	1.02857143	1.71	0.1608
SAMPLE	4	11.60000000	2.90000000	4.83	0.0053

Table 2.18: Results of turkey test for taste.

T tests (LSD) for variable: SCORE

Least Significant Difference = 0.8545

T Grouping	Mean	N	SAMPLE
A	4.571	7	432
A			
B A	4.143	7	321
B			
B	3.714	7	654
B			
B C	3.571	7	543
C			
C	2.857	7	765

Table 2.19: Sensory score for Spredability.

Panellists	765	654	543	432	321	Total
1	3	3	4	5	5	20
2	3	4	2	4	3	14
3	3	5	4	5	5	22
4	2	3	4	5	4	18
5	4	4	4	5	3	20
6	3	4	5	4	4	20
7	2	3	2	4	5	16
Total	20	26	25	32	29	130

Table 2.20:Analysis of Variance Procedure for spreadibility.

Dependent Variable: SCORE

Source	DF	ANOVA SS	Mean Square	F Value	Pr > F
JUDGES	6	1.41197714	0.23532952	1.27	0.3097
SAMPLE	4	7.52304000	1.88076000	10.12	0.0001

Table 2.21: Results of turkey test of spreadibility.

T tests (LSD) for variable: SCORE

Least Significant Difference= 0.8426

T Grouping	Mean	N	SAMPLE
A	4.714	7	432
A			
A	4.571	7	321
B	3.714	7	543
B			
B	3.571	7	765
C	2.429	7	654

Table 2.22: Sensory score for Overall-acceptability.

Panellists	765	654	543	432	321	Total
1	4	3	4	5	5	21
2	4	4	4	4	3	19
3	3	3	4	5	5	20
4	4	4	5	5	4	22
5	4	3	4	5	2	17
6	2	2	5	4	4	17
7	4	2	3	3	5	17
Total	25	21	28	31	28	112

Table 2.23: Analysis of Variance Procedure for overall – acceptability.

Dependent Variable: SCORE

Source	DF	ANOVA SS	Mean Square	F Value	Pr > F
JUDGES	6	5.37142857	0.89523810	1.27	0.3078
SAMPLE	4	8.68571429	2.17142857	3.08	0.0351

Table 2.24: Results of turkey test.

Least Significant Difference= 0.9261

T Grouping	Mean	N	SAMPLE
A	4.429	7	432
A			
A	4.143	7	321
A			
A	4.000	7	543
A			
B	3.571	7	765
B			
B	3.000	7	654

Appendices 3.

F-table.

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	A
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	170	1 39
120	3 92	3 07	2 68	2 45	2 39	2 17	2 02	1 83	1 61	1 25
∞	3 84	2 99	2 60	2 37	2 21	2 09	1 94	1 75	1 52	1 00

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