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PROCESS AND PRODUCT OPTIMIZATION AND STORAGE CHARACTERISTICS OF CANNED PEANUT SOUP BASE

BY

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(10221138)

THIS THESIS IS SUBMITTED TO THE DEPARTMENT OF NUTRITION AND FOOD SCIENCE, UNIVERSITY OF GHANA, LEGON IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF M.PHIL FOOD SCIENCE DEGREE.

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DECLARATION

This is to certify that this thesis is the result of research work undertaken by Genevieve Fremah Opoku under supervision in the Department of Nutrition and Food Science, University of Ghana, Legon.

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ABSTRACT

Peanut soup is very popular in Ghana and the entire West Africa region. It is largely prepared and consumed both at the domestic and commercial scales. Due to the long and tedious nature of preparing the soup, there was the need to develop a shelf stable condensed canned peanut soup-base which could be reconstituted to create convenience in peanut soup preparation. Previous work/studies done established a process flow chart for the canned peanut soup-base through selection of suitable peanut variety; ingredient formulation and evaluation of the thermal processes.

This study sought to optimize the production process of a canned peanut soup-base; conduct a shelf life study; determine proximate composition of product and to evaluate the canned peanut soup-base for consumer acceptance.

The central composite rotatable design for three variables (i.e. K=3) was used to optimize the processing variables of the peanut soup base. The variables and their levels were roast temperature (130˚C - 150˚C), roast time (30-60 minutes) and retort (thermal process) time (45-65 minutes). The canned peanut soup-base obtained from the 16 experimental runs was used to prepare peanut soup. The quality of soups after the canning were evaluated by a 20 member sensory panel using a balanced incomplete block design for b=20, t=16, λ=1, N=80. An accelerated shelf life test was used for the estimation of the product shelf life for a period of 8 weeks at storage temperatures of 27˚C and 55˚C. Product attributes evaluated during this study included pH; peroxide value; free fatty acids content and colour (L-Value). Proximate analyses of the product were also conducted. Fifty peanut soup consumers were randomly selected and were given the canned peanut soup to prepare and evaluate the product in their homes, using a pre-tested questionnaire.

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Results showed that the colour (L-value) of the peanut paste was affected by the roast temperature-time combinations for the peanuts. Roasted peanut colour was highly dependent on the roasting temperature and time. The higher and longer the roasting temperature and time, the darker the peanut roast colour. The total colour change (ΔE^*) of product after retorting showed significant differences ($p < 0.05$) with respect to the different retorting times. It ranged from 2.18 for 38 min retort time to 6.08 for 72 min.

Using the free fatty acid content of products after 5 weeks of storage as the cut-off spoilage indicator, the shelf life of the canned peanut soup base was estimated to be sixty-seven (67) weeks. The proximate analyses of the canned peanut soup base revealed that the product had moisture content of 64% with crude fat, crude protein, crude ash and carbohydrate been 21.81%, 6.54%, 2.27% and 5.48% respectively.

The results from the study indicate that an acceptable canned peanut soup-base could be obtained from roasting peanuts at 125˚C for 28 minutes to obtain a paste of light roast colour and retorting the product for 55 minutes. The canned peanut soup base product obtained would be stable on the shelf for more than a year, and would still be acceptable to consumers. This could be used to establish the shelf-life (best before date) for the product.

Also evaluation of canned peanut soup base revealed that close to 90% of consumers liked the product and are looking forward to seeing it on the market.

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DEDICATION

This research work is dedicated to God Almighty for His grace, provision, support and guidance. I also dedicate this research work to my entire family. Their support and prayers has brought me this far.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Peanuts

Peanuts/groundnuts are an inexpensive nutritionally complete food source for most individuals worldwide (Reese and Lehrer, 1999) including Ghana. They provide a wide range of nutrients from protein and fat to high levels of vitamin E, folic acid, and minerals (magnesium, copper, phosphorus, potassium and zinc**)** (Woodroof, 1983). The proteins range from 16.2 to 36% depending on the variety, and this may double in the defatted peanut meal. The proteins are relatively rich in acidic amino acids, with aspartic acid, glutamic acid and arginine accounting for about 45% of the amino acids. The digestibility of peanuts is very high (89%), with very little difference between raw and processed nuts (Woodroof, 1983). Despite being energy dense, peanuts have a high satiety value and chronic ingestion evokes strong dietary compensation and little change in energy balance (Alper and Mattes, 2002). Consequently regular consumption of peanuts is recommended for dietary weight control. In Ghana, peanuts are widely cultivated and consumed in almost every part of the country. Several food preparations incorporate groundnuts and related products to improve the protein level, taste and flavour. A fair amount is also processed into oil, cake, paste and other products**.**

Processing of peanuts in Ghana is still largely artisanal, based on simple traditional unit operations which include sun drying, hand sorting, roasting, and deskinning, milling and manual extraction of oil.

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1.2 Peanut paste

Peanut/groundnut paste is by far the most commercialized groundnut product in Ghanaian markets. The traditional production processes of groundnut paste are still cottage in nature and mainly done by women processors with little formal education. This causes a great deal of product quality variability between processors, and also between batches (Amaditor, 2010). The paste serves as the main ingredient in the preparation of peanut soup, though it is also used as bread spread.

Various studies conducted on peanut paste in different parts of the country revealed that there is no specific peanut variety known to be used in the processing of peanut paste. All the peanut varieties known to be available on the market are used in the processing of the paste. The most common varieties found on almost every market include the red (*sinkarzie*), *Chinese*, and the speckled *Manipintar* cultivars.

1.3 Peanut soup

Peanut/groundnut soup is a very popular soup in Ghana and the entire West Africa Region. Jolly *et al.* (2008) noted that most Ghanaians (90%) consume groundnut mostly as soup. In Ghana it is consumed together with starchy foods like fufu, banku, *omo-tuo* (rice ball), rice and kenkey amongst others. It is largely prepared and consumed on a domestic scale, but some restaurants and almost all chop bars prepare it on commercial basis.

The ingredients used in the preparation of peanut soup include peanut paste (main ingredient), meat and/or fish, tomatoes (fresh tomatoes and/or tomato paste), onion, ginger, pepper, salt, garlic and other seasonings.

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The colour of peanut soup has been determined to be a critical quality index for consumers and it is influenced by a number of factors, including the colour of the peanut paste. The colour as well as flavour and texture of the peanut are affected by the degree of roasting (Lee and Ressureccion, 2006). Roasting is a critical unit operation in the processing of peanuts. Roasting is key to colour, flavour and textural development through chemical reactions, heat transfer and drying which occur during process (Chiou *et al.*, 1991; Newell *et al.*, 1967; Saklar *et al.*, 2001; Simsek, 2007). Peanut characteristics (colour, flavour and texture) are affected by the time-temperature, duration to which the peanuts are subjected to during the roasting process. These different time-temperature combinations give rise to either desirable or undesirable features after the whole process.

1.4 Background work

Peanut soup preparation is known to be time consuming right from peanut paste preparation to the final soup making. Some studies conducted by Amaditor (2010) have shown that the safety aspects of Ghanaian peanut soup has become questionable due to

a. Adulteration and poor packaging of peanut paste on the Ghanaian market and

b. Aflatoxin contaminations of the peanuts

These issues raised concerns about the safety of peanuts on the Ghanaian market and their usage in processing of peanut products especially the peanut paste.

A study by Kotey (2010) on consumer perception and acceptability of canned peanut soup base through a cross sectional study design revealed a very positive response from consumers. Most

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of the consumers thought the introduction of canned peanut soup base would help protect them from adulterated and aflatoxin contaminated groundnut paste from the markets.

Based on that study, a prototype canned peanut soup base product was developed. This was achieved through preliminary survey on ingredient combinations (using extreme vertex design), selection of a peanut variety suitable for the product (in terms of physical and chemical properties) and selection of the appropriate product consistency. A process flow chart was developed for the canned peanut soup base as well as the optimization of the thermal process especially with respect to retort/process temperature.

However, the following research questions needed to be addressed:

a. How long would the product stay on the shelf before deteriorating?
b. What are consumers' perceptions about the product?
c. Does the product meet specifications and quality perceived by consumers?
d. What roasting conditions (roast temperature and roast time) would the peanuts/groundnuts have to be subjected to so as to produce a product with a desirable and an attractive colour?

1.5 Rationale

In product development, there is the need to optimize certain main procedures which form the core of product manufacturing, establish product's shelf life as well as finding out consumers views on the newly developed product. These factors put across the rationale for this research which seeks to answer the questions raised above by optimizing the roasting conditions of the

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peanuts/groundnuts, determining the shelf life of the canned peanut and conducting a consumer survey to obtain their views and comments about the newly developed canned peanut soup base.

A successful development of a canned peanut soup base will not only offer convenience by removing the tedium and time involved in peanut/groundnut soup preparation; it will also help protect consumers from the health hazards of adulterated and aflatoxin contaminated peanut butter obtained from the markets.

1.6 Main objective

The main objective of this study was to optimize the production process of canned peanut soup base and determine its storage stability.

1.7 Specific objectives

1. To optimize the roasting conditions of peanuts/groundnuts for the soup base
2. To conduct shelf-life studies on the canned peanut soup base
3. To determine the chemical composition (proximate analysis) of the canned peanut soup base
4. To evaluate consumer acceptability of the canned peanut soup base

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CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Peanuts

Peanut or groundnut (*Arachis hypogea* L.) is a major world oil seed crop. It is an annual herb of the leguminosae family with two subspecies (hypogaea and fastigata) grown commercially. The main varieties of great economic importance include runner, Virginia, Spanish and Valencia (Baker, 2003). According to Pattee (2005), India, China and the United States have been the major world peanut producers for some time now, contributing about 70% of the world crop production. Approximately 23.2 million tons of peanuts are harvested every year worldwide. According to (Cummins and Jackson, 1982), about 60% of peanuts are utilized in a variety of food products, and the rest approximately used in equal proportions for export as well as production of edible oil. Peanuts are known to have a unique, desirable flavour, aroma, taste and texture when they are freshly roasted.

2.2 Nutritional Composition of peanuts

Peanut kernels contain approximately 50-55% oil, 25-28% protein, 19-21% carbohydrates and 2.3-2.5% ashes (Grosso and Guzman, 1995). These oil and protein concentrations are influenced by the environment, genotype and the maturity level of the peanut (Holaday and Pearson, 1974). Due to their high oil content, peanuts are known to be rich in energy but are susceptible to rancidity and off-flavour development through lipid oxidation because of their rich composition in unsaturated fatty acid (approximately 80%), with 40-50% and 30-40% of the oil being oleic and linoleic acids respectively (Frankel, 2005). Although linoleic acid is known to be an essential component for human nutrition, it is susceptible to lipid oxidation (Nawar, 1996). Peanuts

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provide high levels of vitamin E, folic acid and minerals (magnesium, copper, phosphorus, potassium and zinc**)** (Woodroof, 1983).

2.3 Peanut made products

Peanut-containing foods have high consumer acceptance because of their unique roasted flavour (Riveros *et al.,* 2009). Peanuts according to Woodroof (1983) are continually applied for the preparation of new and improved food products because of this unique roasted flavour. A large proportion of peanut production in the world is directed to the processing of domestic foods such as peanut butter, snack products, confections and roasting peanut products shows positive results in relation to consumer acceptance as well as sensory and chemical stability (Nepote *et al.,* 2008). According to Ahmed and Young (1982), the rest of the peanut is used for making edible oil.

2.4 Peanut consumption in Ghana

In Ghana, peanut is a major cash crop cultivated in the Northern part of the country. It plays a significant role in the diet of Ghanaians serving as a major source of vegetable protein (Tsigbey *et al.,* 2003). Peanuts in Ghana are consumed in different forms including peanut paste/butter which is used extensively as an ingredient in peanut soup and also as a spread; roasted peanuts as a snack in combination especially with banana, roasted ripe plantain, roasted corn (Tsigbey *et al.,* 2003); *"nkatebolo/adarkwa"* (a snack made from peanut, spices and sugar); "*nkate cake*" and many other processed products like *Nkatie Burgar* and *Yankee nuts* (which are spiced coated roasted peanuts). The kernels are also used for vegetable oil extraction and the cake derived after the extraction is used in the manufacture of several local delicacies rich in protein (Tsigbey *et al.,*

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2003), such as khebab powder. A study conducted by Jolly *et al.* (2008) revealed that in Ghana, almost 90% of the citizens consume groundnut mostly as paste not for bread but for soup making.

2.4.1 Peanut soup

Peanut soup is common in most parts of Ghana. It is either prepared for domestic or commercial use. The ingredients used in the preparation of peanut soup include peanut paste (main ingredient), tomatoes (fresh tomatoes or tomato paste), onion, ginger, pepper, salt, sometimes garlic, other seasoning and meat/fish (Ghana recipes, 2006).

It is eaten with foods like banku, fufu, rice ball, konkonte, kenkey, gari and boiled rice. It is one soup preferred by most Ghanaians because it can be consumed together with different kinds of foods/dishes as mentioned above (Ghana recipes, 2006).

2.5 Roasting of nuts

Roasting is an important unit operation step involved in the nut manufacturing industry for the production of different nut products (Shakerardekani *et al.*, 2011). It is central to colour, flavour and textural development of the final product through several chemical reactions, heat transfer and drying which occur during the roasting (McDaniel *et al.*, 2012).

The development of roasted flavour and aroma not only depend on the type of nuts and techniques applied during the process but also on the temperature and time of roasting (Shakerardekani *et al.*, 2011). Birch *et al.* (2009) reported that the suitable roasting temperature and time for direct consumption of macadamia nuts were 135˚C and 20 minutes respectively.

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Kahyaoglu and Kaya (2006) have also reported that for the manufacturing of good paste from sesame, the seeds need to be roasted at temperatures of 155-170˚C for 40-60 minutes. The textural characteristic of the whole-kernel is affected by the roasting condition to some extent in that during roasting, the moisture content of most nuts is reduced to minimum levels (Emily *et al*., 2009) and the texture became more crumbly and fragile (less hard) (Vincent, 2004). Furthermore, roasting also dries the nuts and causes them to change colour (thus turn brown) as the peanut oil stains the cell walls.

The initial phase of roasting is characterized by a rapid lowering of the moisture content (MC) and water activity (aw) of the peanuts (deMan, 1999). Moisture content significantly decreases during the first 5-10 minutes of roasting and components such as total carbohydrates and glucose content have been found to be dependent on moisture content during this time (Chiou *et al.*, 1991). The presences of these components are known to have effect on the reactions that occur in subsequent roasting stages. After the initial rapid drying stage, colour development has been reported to occur rapidly (Saklar *et al.*, 1999).

Understanding of the roasting process is of interest because it is a critical processing step not only for peanuts, but many other food products such as coffee, cocoa, grains and other tree nuts as well as the colour of the final products made from them (Shakerardekani *et al.*, 2011).

According to Kita and Figiel (2007), nuts roasting are usually conducted within the range of temperatures from 100°C to 180°C and time from 5 to 60 minutes.

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Roasted nuts without any additives or spices have become popular snacks. They constitute a valuable raw material in industries like confectionery, bakery and others. Most often roasted nuts are peanuts, hazelnuts, almonds and pistachio nuts (Kita and Figiel, 2007).

Roasting is considered a critical control point in peanut processing. According to Chang *et al.* (2013), roasting times and temperatures are known to vary. This they explained is usually based on batch properties as well as the final product characteristics desired by the processor.

From this it implies that the roasting times and temperatures are varied in order to attain specific product attributes for a given market segment. Thus to obtain a suitable canned peanut soup base with desirable features especially the colour of the final product, there is the need to understand the time and temperature combinations to obtain the best final product characteristics.

2.5.1 Importance of roasting

The roasting process in nut production is important in:

- Increasing food safety by eliminating pathogens and enhancing quality parameters by creating a more desirable flavour and textural profile to the consumer (van Boekel *et al.*, 2010).
- Reduction in moisture content and modification of the internal microstructure of peanuts giving the characteristic crunchy and crispy roasted peanut texture (Lee and Resurreccion, 2006).
- Helps to enhance the flavour, colour, texture, the overall acceptability as well as the overall palatability of the nut product (Ozdemir and Devres 2000; Pittia *et al*., 2001; Sena *et al*., 2001).

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- Providing an increased bioavailability and functionality of certain nutritional components (van Boekel *et al.*, 2010).
- Increases polyphenolic content in peanuts and other foods by releasing compounds such as p-coumaric acid and hydroxybenzoic compounds which can serve as antioxidants (Talcott *et al.*, 2005).
- Reduces anti-nutritive factors and eliminates beany flavour

2.5.2 Types of peanut roasting

Two main distinguished roasting methods are used: roasting in oil and roasting in the air – so-called dry roasting (Kita and Figiel, 2007).

Roasting in oil

In this method of roasting, peanuts are immersed in a vegetable oil which is heated to an appropriate temperature (usually 140 °C). The nuts are then deep fat fried at a time interval of 3-10 minutes. In this method, peanuts are first of all subjected to blanching before roasting. When the roasting procedure is over, the oil is filtered off the peanuts.

Dry roasting

Dry roasting involves a convection and microwave method. In the convection method peanuts are heated by hot air at a given temperature, moisture and usually of determined air flow speed. This method is the most used peanut roasting in Ghana.

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2.6 Colour development in peanut process

Colour is an important quality indicator of the roasting process. Colour development is generally used as a way of measuring degree of roast because it is a quick, easy and nondestructive testing method (Manzocco *et al.*, 2000), as well as being an indicator of final peanut flavour (Smyth *et al.*,1998). Coffee producers also use roast colour as an indicator of final product quality (Baggenstoss *et al.*, 2008). Colour development depends on the initial composition of sugars, amino acids, as well as roasting time and temperature (Newell *et al.*, 1967, Rodriguez *et al.*, 1989).

Colour development in peanuts is dependent on the creation of brownish-coloured polymeric compounds known as melanoidins (Baker, 2003). "Melanoidins are water-insoluble, high molecular weight compounds formed through Maillard (carbonyl-amine) browning products that correspond directly to colour development in most food products" (Ames *et al.*, 1994). However according to Rizzi (1994) most of these melanoidin compounds do not necessarily contribute to flavour and aroma development in foods. Some factors are known to play major roles in the formation of these melanoidin compounds and Ames *et al.* (1994) states temperature, heating time, pH and moisture content as some of these factors. According to *Ames et al.* (1994) as the temperature of roasting increases (for a given time), the final colour appears darker due to the formation of higher molecular weight melanoidins formed during heating process.

Peanut roasting together with colour and flavour development in peanuts has been a topic of research for some time now especially on their influence on peanut products. Typically, roast colour is the most important quality control parameter in commercial processes (Sena *et al.*,

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2001). The roast colour in peanuts generally is measured by light reflectance in a colorimeter, giving an L-value in a range of 80 (very light or no roast) to 30 (very dark roasted). According to Sanders *et al.* (1989), the Hunter L-value of roasted peanuts used in high quality dry roasted peanuts and peanut butter falls in the range of 50-51. Peanut roasting researchers usually give a time-temperature protocol or refer to the degree of roast as light (53 ± 1), medium (48.5 ± 1) or dark (43 ± 1) with colour measurement (Buckholz *et al.*, 1980; Oupadissakoon and Young, 1984).

2.6.1 Maillard browning reaction

Four main types of non-enzymatic browning reactions occur in foods: Millard browning reaction, degradation of ascorbic acid, lipid peroxidation and caramelization (Davies and Labuza, 1997). In peanuts, the main non-enzymatic browning occurs in the form of Maillard Browning Reaction (MBR). The MBR is also the main form of non-enzymatic browning during roasting of other products such coffee, cocoa and grains (Saklar *et al.*, 2001).

MBR is a complex series of reactions (Figure 2.1) requiring both reducing sugars and amino acids to occur. The first step of the MBR is a condensation reaction between the carbonyl group from the sugar and the amine group from the protein. As the product loses water a Schiff base is formed which is then converted into an aldosylamine. The next step is the Amadori rearrangement, which can follow three major pathways: the formation of di-ketosamine, enolization, or Strecker degradation. The final step is polymerization, which creates melanoidins and heterocyclic compounds which make up the majority of the flavour and aroma compounds.

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Melanoidins produced by the polymerization reaction are characteristic of the brown colour and increase in molecular weight as browning increases.

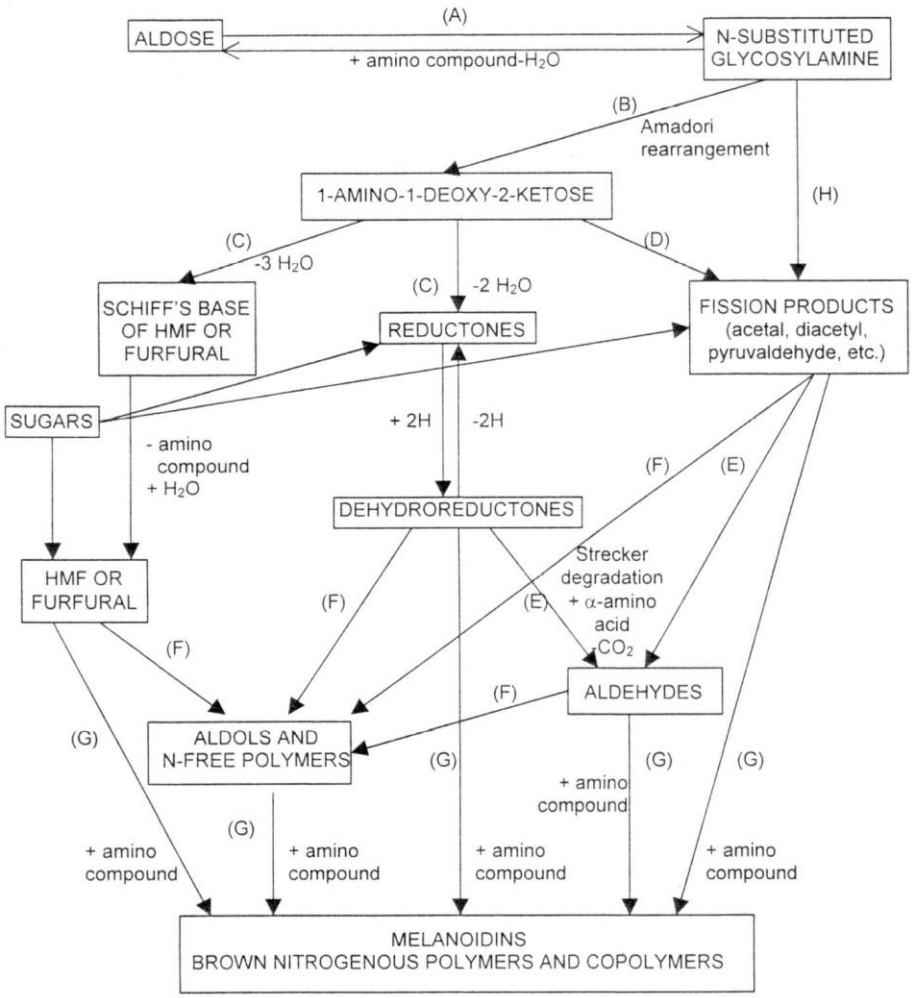

Figure 2.1 Maillard Reaction Pathway, taken from Fujimaki *et al.* 1985

2.7 Roasted peanut flavour

Peanut flavour is mainly developed during roasting and factors such as variety, growing, harvesting, maturity, curing and storage conditions all have been shown to influence roasted peanut flavour (Rodriguez *et al.*, 1989, Sanders *et al.*, 1989). Flavour development in roasted peanuts is known to be composed of a complex mixture of heterocyclic and other volatile

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compounds (Grosso *et al.*, 2008) and these compounds are formed during the process of peanut roasting as stated earlier through thermal degradation reactions such as the Maillard reactions which involves carbohydrates, free amino acids and proteins. Roasted peanutty is a desirable flavour in peanuts and is composed of a complex blend of heterocyclic compounds such as pyrazines, thiazoles, thiophenes and other volatile compounds formed during the roasting (Grosso *et al.*, 2008). In particular, this desirable flavour has been attributed to alkylpyrazines.

Mature peanuts have been found to have higher amounts of proteins which can break down into free amino acids during roasting, allowing for greater development of typical peanut flavour (Rodriguez *et al.*, 1989). Sucrose is the most abundant sugar in peanuts, and it's inversion to glucose and fructose has been reported to aid in the development of roasted peanut flavour through the development of Millard browning products (Newell *et al.*, 1967, Rodriguez *et al.*, 1989). The amino acids aspartic acid, glutamic acid, glutamine, histidine, asparagine, and phenylalanine have been reported to contribute to typical roasted peanut flavour (Newell *et al.*, 1967).

2.7.1 Pyrazine development in peanuts

According to Fors (1983), Maillard reaction products are grouped into three categories: simple sugar dehydration/fragmentation products, simple amino acid degradation products and volatiles produced by further interactions. Volatiles produced by further interactions include pyrroles, pyridines, imidazoles, pyrazines, oxazoles, and thiazoles.

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Pyrazines are volatile heterocyclic nitrogen containing compounds which are thought to be the major flavour compounds eliciting typical roasted peanut flavour (Warner *et al.*, 1996). Table 2.1 gives examples of pyrazine compounds found in peanuts.

Table 2.1 Pyrazine compounds found in peanuts

Pyrazine	Propylpyrazine
2-methylpyrazine	2-methylpropylpyrazine
2,3-dimethylpyrazine	2-methyl-6-propylpyrazine
2,5-dimethylpyrazine	Isopropylpyrazine
2,6-dimethylpyrazine	Methylisopropylpyrazine
Dimethylpyrazine	2-isopropenylpyrazine
Trimethylpyrazine	Methylpropenylpyrazine
2-ethylpyrazine	Vinylpyrazine
2-ethyl-3-methylpyrazine	2-methyl-5-vinylpyrazine
2-ethyl-5-methylpyrazine	2-methyl-6-vinylpyrazine
2-ethyl-6-methylpyrazine	Ethylvinylpyrazine
2-ethyl-3,5-dimethylpyrazine	Acetylpyrazine
2-ethyl-3,6-dimethylpyrazine	5-acetyl-2-methylpyrazine
3-ethyl-2,5-dimethylpyrazine	6-acetyl-2-methylpyrazine
3-ethyl-2,6-dimethylpyrazine	6-acetyl-2-ethylpyrazine
5-ethyl-2,3-dimethylpyrazine	6,7-dihydro-5H-cyclopentapyrazine
2,3-diethyl-3-methylpyrazine	2-methyl-6,7-dihydro-5H-cyclopentapyrazine
2,6-diethyl-3-methylpyrazine	
Diethylpyrazine	5-methyl-6,7-dihydro-5H-cyclopentapyrazine
Diethyldimethylpyrazine	
2,3-diethyl-5-methylpyrazine	2(3),5-dimethyl-6,7-dihydro-5H-cyclopentapyrazine
2-ethyl-3,5,6-trimethylpyrazine	

Source: Maga, 1982

In roasted foods, pyrazines or alkylpyrazines are formed through the Maillard reactions above 70°C and directly contribute to roasted or cooked flavours (Maga and Sizer, 1973). Formation of roasted flavour components in peanuts is especially apparent when peanut seeds are heated

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above 130°C (Landman, 1994). Pyrazines do not only play a role in the flavour when roasting peanuts but roasting of other products such as coffee beans, sesame seeds, barley and cocoa. Roasted flavour impact in peanuts is thought to come primarily from 2- methylpyrazine and isomers of dimethylpyrazine (Mason *et al.*, 1966; Warner *et al.*, 1996). Figure 2.2 is an example of mechanism for substituted pyrazines.

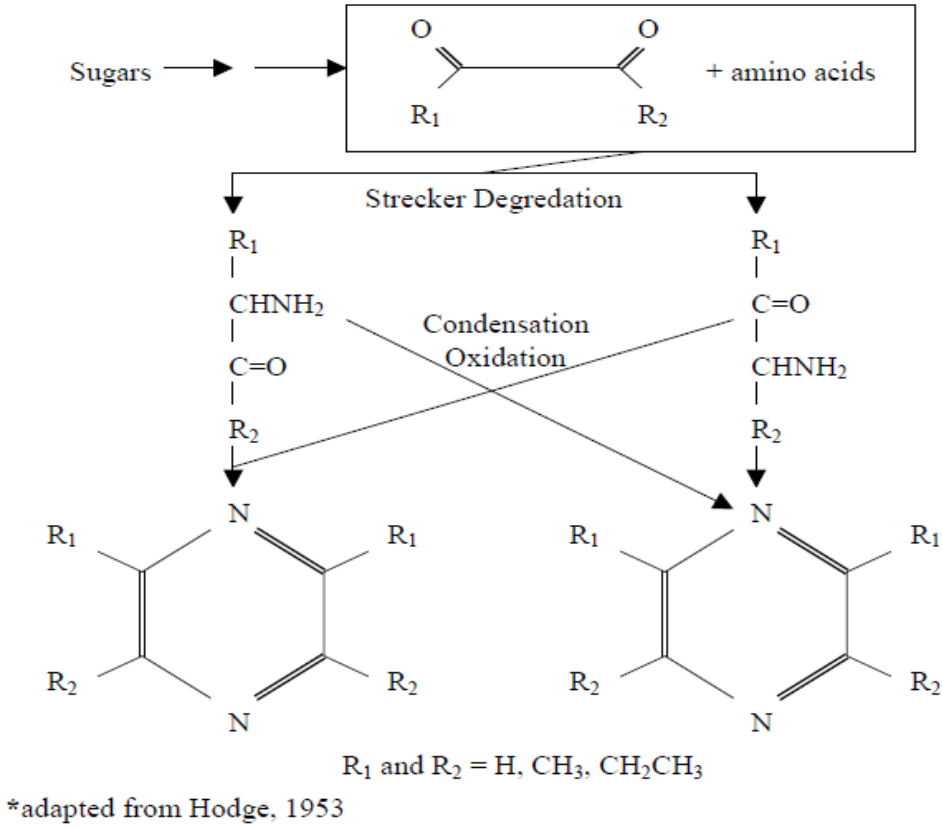

Figure 2.2 Mechanism of substituted pyrazine

2.7.2 Off-flavour in peanuts

Off-flavour developments in peanuts include lipid oxidation, induction of anaerobic respiration and external contamination with compounds such as limonene, antioxidants or insecticides (Ory *et al.*, 1992). Lipid oxidation is the main cause of flavour deterioration and of off-flavour

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formation in raw and roasted peanuts, due to a high content of unsaturated fatty acids (Reed *et al.,* 2002; Lee *et al.,* 2002). Lipid oxidation occurs during storage of peanut products and contributes to the development of undesirable flavours in them.

According to *Ory et al.* (1992) and Sanders *et al.* (1993), oxidation of the fatty acids in peanut oil can be caused by light, heat, air, metal contamination, micro-organisms, or enzymatic activity. Hydro-peroxides formed during lipid oxidation subsequently break down into alcohols, alkanes, ketones and aldehydes, which can be the source of off-flavours in the peanut (Schirack *et al.,* 2006). These aliphatic compounds are expressed as cardboard or painty flavours (Bett and Boylston, 1992). According to St. Angelo (1996), linoleic acid which forms about 30% of the total fat composition of peanuts becomes susceptible to rancid and off-flavour development as a result of this lipid oxidation.

2.8 Sterilization of processed food materials

In food processing, the term thermal processing refers to a technique involving the application of heat to help in preservation of food materials. The heat treatment can be done as a single preservation technique or it can be used as one step in conjunction with other preservation techniques. 'The sterilization of food products in commercial point of view aims at attaining commercial sterility rather than absolute sterility. This is because targeting a food that is completely void of microbes would render the product wholesomeness or inferior in quality' (Awuah *et al.,* 2007). Commercial sterility as defined by the United States Food and Drug Administration (FDA) refers to conditions achieved in a product by the application of heat to render the product free of microorganisms that are capable of reproducing in the food under normal non-refrigerated conditions of storage and distribution.

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The United States Food and Drug Administration (FDA) has classified foods in the federal register (21 CFR Part 114) as follows: (i) acid foods, (ii) acidified foods and (iii) low acid foods. Low-acid foods have been defined as foods, other than alcoholic beverages, with a finished equilibrium pH greater than 4.6 and a water activity greater than 0.85. During thermal processing of low acid foods, attention is given to *Clostridium botulinum* which can thrive comfortably under anaerobic condition resulting in the production of botulinum toxin (Awuah *et al.*, 2007). Brown (1991) reported that low acid foods must experience the minimum botulinum cook (F_o = 3 min) which is 12 D cycle reduction based on kinetic data for *C. botulinum.*

Scientific investigations according to Gavin and Wedding (1995) have revealed that spores of *Clostridium botulinum* will not germinate and grow in food below pH 4.8. To provide sufficient buffer, a pH of 4.6 has generally been accepted as the point below which *C. botulinum* will not grow to produce toxin. Commercial sterility is therefore achieved when *C. botulinum* spores are inactivated to satisfy regulatory requirements.

Traditionally, estimated kinetic data (using the classical first order equation) are linked to the time–temperature history at a pre-defined location (cold spot) within the product to evaluate the sterilizing value or otherwise "process lethality" (*F*o), which forms the basis for a sound thermal process (Hayakawa, 2007):

$$F_o = \int_0^t 10^{(T-T_o)/z} dt$$

Where t, z, T and T_o represent the time (min), temperature sensitivity of the target microorganism, temperature at any given time, and reference processing temperature,

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respectively. The reference temperature is conveniently chosen to be 121.1˚C (250˚F) for low acid foods. Two approaches could be used to evaluate the impact of time–temperature combinations on process lethality: (i) target lethality (*F*o) at the coldest spot of the product as defined by the equation above and (ii) an integrated lethality (*F*s) which represents the volume average of microbial survival (Stumbo, 1973). Low acid foods must experience the minimum "*botulinum* cook" (*F*o = 3 min) which is 12D cycle reduction based on kinetic data for *C. botulinum* (Brown, 1991).

2.9 Shelf-life of food products

Food is inherently perishable and depending on its physical and chemical properties and the storage conditions, there will come a point when either its quality will be unacceptable or it will become harmful to the consumer. At this point it is said to have reached the end of its shelf-life and the ability to predict this is of great value to the food industry. According to (NZFSA, 2005), shelf life of a product begins from the time the food is manufactured.

Most consumers on daily basis not only make demands as to how to obtain high quality foods but also have some expectations that such qualities obtained from these foods will be maintained at a high level during the period between purchase and consumption (Kilcast and Subramaniam, 2000).

Even though most food qualities decrease after some period of storage, there are some exceptions. For example, distilled spirits are known to develop desirable flavours during storage in wooden barrels; some wines also increase in flavour complexity in bottles and aging in cheese leads to formation of desirable flavours and textures (Robertson, 1993). For the majority of foods

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and beverages, however, a finite time occurs before the product becomes unacceptable and this time from production to unacceptability is usually designated as product shelf life.

2.9.1 Sensory characteristics of food products

Almost all food processing companies try diverse ways and means available to help predict the endpoint of storage life of a given food product under a given set of storage conditions.

Acceptable sensory characteristics most at times are defined by company policy as stated by Kilcast and Subramaniam (2000), but an understanding of how these characteristics change on storage can assist in defining the shelf life of food products. Thus with respect to the canned peanut soup base, a study concerning changes of some properties during storage just like any other new product becomes necessary.

Figure 2.3 shows the various categories of individuals who influence the shelf life of food products. Right from the farm (with respect to raw materials) through to processing, storage and distribution, the product shelf life is influenced by different individuals and groups before it finally gets to the consumer who also in a way influences the shelf life by means of storage and handling before usage.

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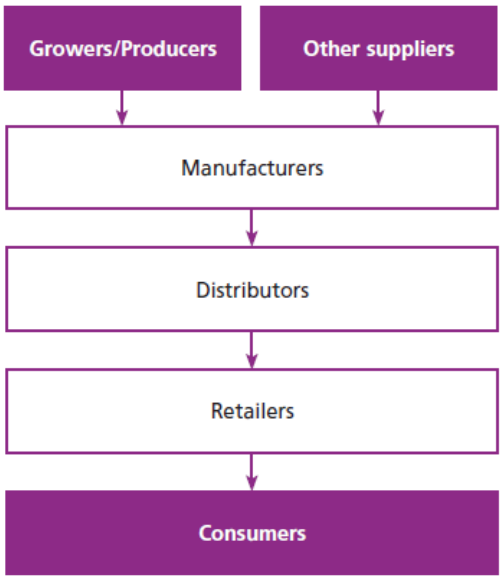

Figure 2.3 Categories of individuals who influence the shelf life of food.

Source (NZFSA, 2005)

2.9.2 Definition of shelf life

‘‘A product shelf life is defined as a verification of the stabilizing systems designed into any food product and usually, food manufactures will not or cannot release any new product into the market for consumers without any knowledge of how stable the product will be’’ (Fuller, 2005). IFST (1993) presents a more practical way of defining product shelf-life. It defines shelf life of a product as the time during which the product will:

(i) remain safe;

(ii) Be certain to retain desired sensory, chemical, physical and microbiological characteristics;

(iii) Comply with any label declaration of nutritional data, when stored under the recommended conditions.

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From the above definition the shelf life of the canned peanut soup base would be the time during which the product remains safe, retains its colour, flavour and aroma, have a stable peroxide value, free fatty acid content as well as be microbiologically stable and safe.

2.9.2.1 Factors controlling shelf life

Product shelf life is controlled by three main factors:

- product characteristics
- the environment to which the packaged product is exposed during distribution
- the properties of the package (Robertson, 1993)

Product characteristics

According to Robertson (1993), most foods fall into one of these three main classes; perishable (very short shelf life products), semi-perishable (short to medium shelf life products) and ambient temperature shelf stable (medium to long shelf life products). These are based on the different characteristics associated with different food products as well as the kind of changes that occur during their storage.

Ambient temperature shelf stable foods (nonperishable) include some ‘‘natural’’ foods (cereal grains and nuts and some confectionery products) and processed food products (canned foods, soft drinks, cake mixes), thus the canned peanut soup base falls into this category.

Distribution environment

Packaged foods may lose or gain moisture; they could also reflect the temperature of their environment because very few food packages are good thermal insulators. Thus, the distribution environment has an important influence on the rate of deterioration of packaged foods.

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According to IFST (1993), these factors that can influence/control the shelf-life of food products can be again grouped into intrinsic and extrinsic factors.

Intrinsic factors

Intrinsic factors are the properties of the final product which include water activity (*a*w); pH value and total acidity (type of acid); available oxygen; natural micro-flora and surviving microbiological counts; natural biochemistry of the product formulation (enzymes, chemical reactants) and the use of preservatives in product formulation (for example salt or sodium bicarbonate).

Extrinsic factors

These are factors which the final product encounters as it travels through the food chain. They include time–temperature profile during processing; temperature control during storage and distribution; environmental microbial counts during processing, storage and distribution and consumer handling.

2.9.3 Measuring of product shelf-life

2.9.3.1 Sensory panels

Sensory techniques are required in determinations of changes in food quality as they are subjected to storage (Kilcast and Subramaniam, 2000). They are quantitative quality measures which employ the use of either trained or untrained panels (depending on the kind of data needed). Though very useful, sensory techniques are very expensive and time consuming

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especially for the repeated measures needed for shelf-life assessment. Sometimes due to these challenges, instrumental methods are used as back-ups to these sensory techniques.

2.9.3.2 Physical measurements

Changes in colour and texture are the common physical measurements used to monitor changes in food product attributes during storage. Thus a change in product colour or texture can be used to detect whether the product has gone bad or is still in good condition for human consumption. These changes may be as result of some chemical reactions occurring in the product, such as those caused by interaction of ingredients or by environmental influences, such as moisture migration through the packaging and non-enzymatic reaction which may alter the colour of the product (Kilcast and Subramaniam, 2000).

2.9.3.3 Chemical measurements

Chemical analyses play a vital role in shelf-life testing. This is because they can be used either to measure the end points of chemical reactions occurring in food during storage, or to confirm the results obtained by the sensory panels (Kilcast and Subramaniam, 2000). Even though there are many chemical reactions occurring concurrently in any food product especially during storage, only the major ones influencing changes in the product quality are monitored and measured during shelf-life testing (Kilcast and Subramaniam, 2000).

Some chemical tests used in determining changes in a particular quality characteristic include free fatty acid and peroxide value measurements which serve as markers for the level of rancidity of products. These apply to the canned peanut soup base especially as it contains peanut oil.

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2.9.3.4 Microbiological stability determinations.

According to Kilcast and Subramaniam (2000), two important aspects considered in determining the microbiological stability of any given food (whether processed or fresh) product are

1. Microbial growth, which leads to the spoilage of a food product
2. The growth of microbial pathogens that affect the safety of the product

The water activity, storage temperature, time and pH are used to predict to a large extent the micro-organisms that are likely to grow in a given food product. The 'time to spoilage' is usually determined by storing the product at the appropriate temperature and measuring the microbial load at regular intervals. The time to reach a pre-determined level of microbial count (total count and level of individual microbes) is considered to be the end-point. Since it is advisable to leave a safety margin in setting the shelf-life, generally 70% of the time to spoilage is taken to be the storage life (Patrick, 2000).

2.9.4 Predicting shelf-life/shelf life testing

Introducing a new food product on the market usually does not take a day. Certain measures need to be established especially with the shelf life before finally certified to be put on the shelf for consumers to buy. Thus many countries require some form of date or labeling indicating when the product is likely to become unacceptable for consumption.

As stated by Kilcast and Subramaniam (2000), while this is feasible for short shelf-life products, products which may be expected to have a longer shelf life may require knowledge of their storage characteristics over the intended shelf-life period and this can introduce unacceptable delays in putting the product on the shelf.

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Generally the shelf life testing of food products falls into one of three categories (Gacula, 1975):

- experiments designed to determine the shelf life of existing products
- experiments designed to study the effect of specific factors and combinations of factors such as storage temperature, package materials, or food additives on product shelf life
- tests designed to determine the shelf life of prototype or newly developed products

The developed canned peanut soup base falls into the third category.

2.9.4.1 Selection criteria to assess shelf life

Every food product is associated with specific attributes either in their raw state or after certain conditions have been applied. Depending on the attributes, certain changes are noticed especially during storage and these changes help to detect if products have gone bad or not.

According to Fuller (2005), in the selection of criteria for shelf life assessment, two main steps are needed.

- First, changes that can be measured and appropriate for the product are selected. These criteria normally change gradually with time so the onset of the change can be measured. Example of such criteria include microbiological, nutritional change, undesirable change (loss or change of colour, textural changes like loss of crispness, staling) and change in a functional property.
- Second, there must be some decision made about how much loss of quality characteristics can be accepted. In other words, how much loss of a quality characteristic can be accepted before spoilage is declared

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2.9.5 Types of shelf life testing

According to (NZFSA, 2005), there are two main methods of shelf life studies:

2.9.5.1 *Direct method*:

This is the one most commonly used. It involves storing the product under the normal or pre-selected conditions for a period of time longer than the expected shelf life. The product is checked at regular intervals to see when it begins to spoil. The exact procedure is unique for each product. This method is usually referred to as real time studies.

2.9.5.2 *Indirect method*

The indirect has two types; the accelerated shelf life studies and predictive models.

Accelerated shelf life studies

This attempts to predict the shelf life of a product without running a full length storage trial. This type of study is usually used for product with a longer shelf life. Acceleration factors such as temperature are applied to the product to attempt to increase the rate of deterioration.

Predictive models

Predictive models are mathematical equations which uses information from a database to predict bacterial growth under certain defined conditions. They can be used to calculate the shelf life of a food with the help of information on the changes that occur in the product when it deteriorates, the properties of the product and packaging. Most predictive models are specific to particular types of organisms (NZFSA, 2005).

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Fuller (2005) also put across a third type of shelf life testing known as use/abuse tests. This type he explained is usually adopted by food technologists to assess the shelf life of a food product and its package as a unit. This type of shelf life testing is one in which the food product is cycled through environmental variables. For example, frozen food developers usually cycle new frozen foods through the temperature range of -10 to + 20°F.

Figure 2.4 shows the various steps involved in the determination of shelf life of a product using the direct method.

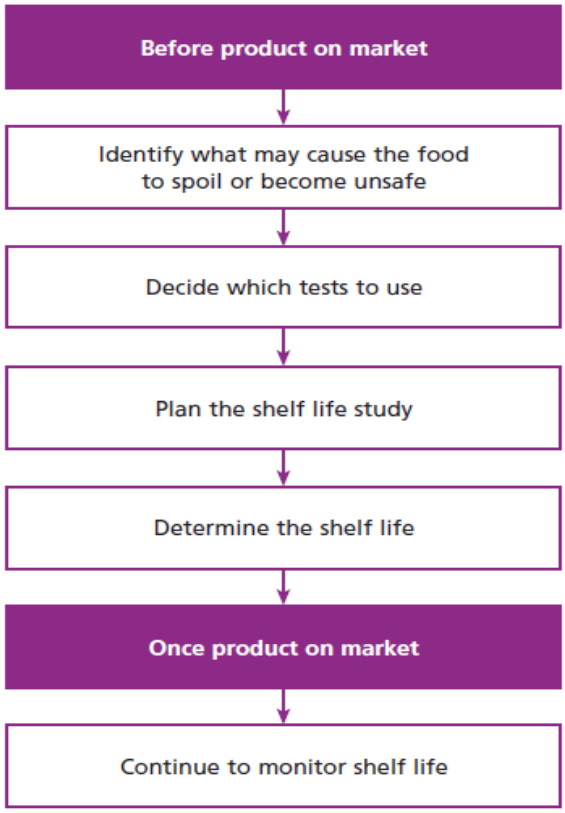

Figure 2.4 Steps involved in Calculating Shelf Life by the Direct Method

Source (NZFSA, 2005)

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2.9.6 Accelerated shelf life testing (ASLT)

The basic underlying principle of accelerated shelf life testing (ASLT) is that the principles of chemical kinetics can be applied to quantify the effects which extrinsic factors such as temperature, humidity, gas atmosphere and light have on the rate of deteriorative reactions (Robertson, 1993). By subjecting the food to controlled environments in which one or more of the extrinsic factors is set at a higher than normal level, the rates of deterioration is accelerated, resulting in a shorter than normal time for product failure and that a predictive shelf-life relationship related to ambient conditions can be defined. It is also often assumed that accelerated deterioration can be achieved by raising the storage temperature, using an Arrhenius equation (Labuza and Schmidl, 1985).

Because the effects of extrinsic factors on deterioration can be quantified, the magnitude of the acceleration can be calculated and the ‘‘true’’ shelf life of the product under normal conditions determined (Robertson, 1993).

One key importance of ASLT is the shorter time involved in predicting product shelf life. Many foods have shelf lives of one year and evaluating the effect on shelf life of a change in the product, the process, or the packaging would require shelf life trials lasting at least as long as the required shelf life of the product. Thus ASLT provides a shorter means by which shelf life of such products are determined.

One of the major determinants of product shelf life is the temperature to which the product is exposed during its lifetime. Without exception, food products are exposed to fluctuating temperature environments, and it is important, if an accurate prediction of shelf life is to be

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made, that the nature and extent of these temperature variations are known. If the major deteriorative reactions causing end of shelf life are known, expressions can be derived to predict the extent of deterioration as a function of available time-temperature storage conditions.

2.10 Peanut Stability and Oxidation

The term shelf life, in regard to peanuts, peanut oil or other peanut products, can be described as "the number of days before the onset of oxidative rancidity, a process which is generally induced in either the whole peanut or peanut oil by exposure to heat and air" (Mercer *et al.*, 1990). This definition implies that until the onset of oxidative rancidity, peanuts and peanut products are said to be shelf stable. Rancidity becomes the keyword in this context.

Rancid can be defined as "having the unpleasant taste or smell of oily substances that have begun to spoil" (Funk and Wagnall, 1997). Due to the high oil content in peanuts, the deterioration rate is known to be drastic as a result of lipid oxidation. This depends on some factors including the presence of oxygen, light, moisture and high temperatures (Lea, 1962). A factor of interest involves the content and structure of the fatty acid constituents in the oil. As the amount of double bonds increase in a fatty acid, it is more susceptible to oxidation.

In general, peanuts and peanut oil (about 50% of the peanut) tend to have greater shelf lives when compared to other high oil foods (O'Keefe *et al.*, 1993).

2.10.1 Deterioration of Oils and Fats

The reaction of fats and oils with water (hydrolysis) and the chemical reaction in which oxygen combines with another substance with the liberation of heat (oxidation) are the two basic

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processes that result in the deterioration of oils and fats (List, 2005). Oxidation is mostly responsible for much more of the deterioration of fats and oils than hydrolysis.

Moisture is known to promote the splitting of triacylglycerols to form free fatty acids, mono- and diacylglycerols (Figure 2.5) and these result in increase of refining losses directly related to the free fatty acid content of oils and fats.

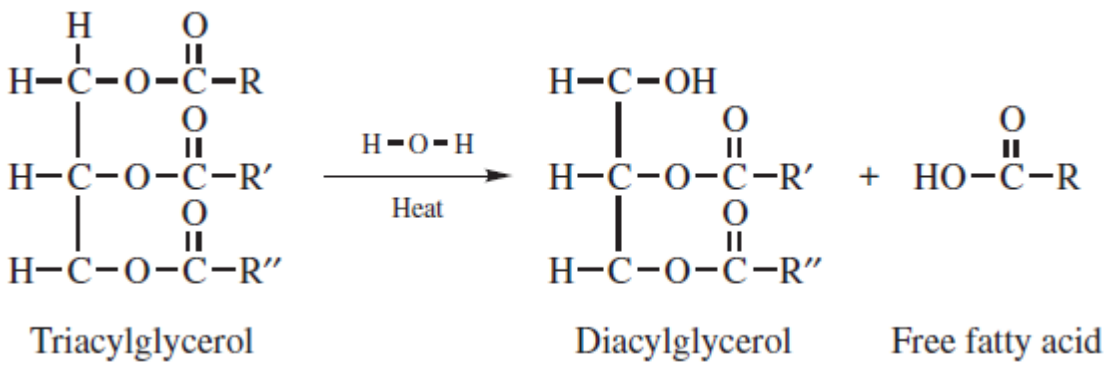

Figure 2.5 Hydrolysis of fats and oils

Essentially, hydrolysis is the reverse of making a fat molecule. This process typically requires a fat-soluble catalyst, high temperatures and long time (several hours). Partial hydrolysis of lipids typically occurs because of high moisture content, high temperature amongst others. The deterioration of a fat or oil in the presence of oxygen is termed oxidative rancidity. The initial step in the oxidation of an oil or fat is the addition of oxygen at or near the double bond of a fatty acid chain to form unstable compounds generally designated as peroxides (Figure 2.6).

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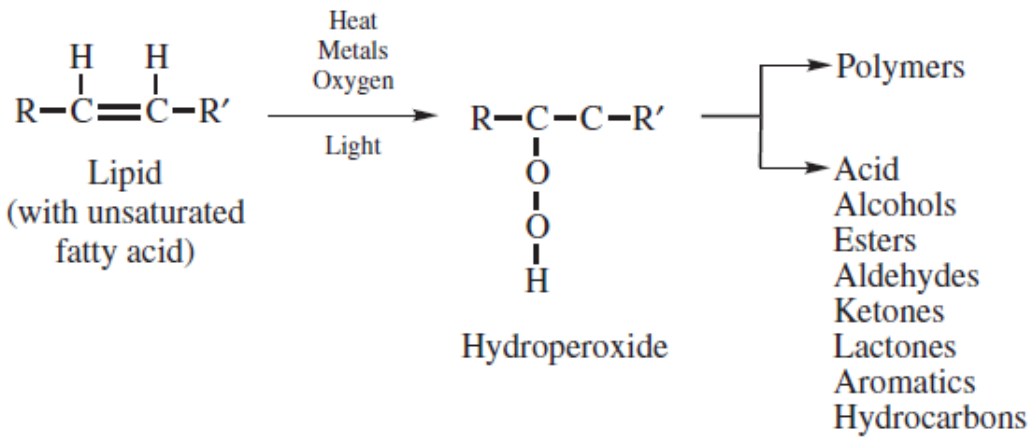

Figure 2.6 Oxidation of fats and oils

There are three types of lipid oxidation: autoxidation, photo-oxidation (or photo-oxygenation), and enzyme-catalyzed oxidation. Lipid autoxidation is a free radical chain reaction that involves the initiation, propagation, and termination steps.

2.11 Mechanisms of food deterioration

2.11.1 Reaction rate order

One simple technique used for accelerating the shelf-life testing is the 'initial rate approach' or reaction rate order (Kilcast and Subramaniam, 2000). In any food reaction analysis, it becomes necessary to evaluate how the rate of deterioration process behaves as a function of time and this in chemical reactions is provided by the order of reaction (n). The general equation of loss quality is given by

$$da/d\theta = kA^n$$

Where da/dθ = rate quality loss with respect to time, A = initial quality, k = A rate constant for a given temperature and water activity (Aw), n = reaction order (0, 1, 2, or fraction)

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Quality loss for most foods follows either a zero-order or first-order reaction (Seward and DeVries, 2008). The initial rate method assists in the provision of an ideal accelerated shelf-life testing technique. It has the advantage of obtaining, in a relatively short time, the kinetic data at the actual storage conditions.

2.11.2 Temperature coefficient (Q_{10})

Chemical deterioration reactions require a certain amount of energy, called the activation energy (*Ea)* to commence (Seward and DeVries, 2008). This activation energy is measured in kcal/mol. It is the average thermal energy required to initiate the rate-determining step of the reaction. Different chemical reactions have peculiar activation energy. Table 2.2 shows some activation energy range associated with some given chemical reactions

Table 2.2 Activation energy for different chemical reactions

Chemical reaction	Activation energy (kcal/mol)
Oxidative rancidity	10-25
Enzyme reactions	10-30
Vitamin losses	20-30
Non-enzymatic browning	25-50

Source: Seward and DeVries (2008)

According to Seward and DeVries (2008), higher activation energy for a given reaction indicates a greater acceleration with respect to increases in temperature and a simple way to express this acceleration is to use the temperature coefficient concept.

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Temperature coefficient (Q_{10}) is the factor by which the rate decreases or increases when there is a change in temperature. According to Seward and DeVries (2008), it is a unit less quantity which represents the factor by which the rate (*R*) of a reaction increases for every 10° C rise in the temperature (*T*), thus

$$Q_{10} = \left(\frac{R_2}{R_1}\right)^{\left(\frac{10}{T_2 - T_1}\right)}$$

Where Q_{10} = temperature coefficient, R_1 and R_2 are rate of reaction for temperatures T_1 and T_2, respectively.

Temperature coefficient according to Labuza (1982) is known to vary for different kinds of food materials. Table 2.3 gives an idea about Q_{10} values for various food preservation methods:

Table 2.3 Q_{10} values for various food preservation methods

Food preservation method	Q_{10} value
Thermally processed foods	1-4
Dehydrated foods	2-10
Frozen foods	3-40

Source: Labuza (1982)

2.11.3 The Arrhenius law

The expected shelf life of a product depends upon the potential environmental conditions of storage (Labuza and Schmidl 1985). One of the major environmental factors that result in

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decreased quality and nutrition for most food during storage is exposure to increased temperature. In order to predict the extent of food quality, and to be able to put a shelf-life date on a product, knowledge of the rate of deterioration as a function of storage condition, like temperature and time, is necessary (Labuza, 1982).

Chemical kinetics is known to be applied in food science for the prediction of the change in quality of a food as a function of time and environmental conditions (Labuza, 1984). The Arrhenius equation expresses the temperature dependence of the rate constant for an elementary chemical reaction

$$k = A\exp\left(-\frac{E_a}{RT}\right)$$

Where R = 8.31 $J \cdot mol^{-1} \cdot K^{-1}$ (universal gas constant), the parameter A is a constant which is taken as independent of temperature, k is the rate coefficient, T is the temperature and *Ea* is the Arrhenius activation energy.

In the process of preparation of food, it is certain that many chemical changes take place during the thermal procedure, for example oxidative rancidity, enzyme reactions and non-enzymatic browning amongst others.

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CHAPTER THREE

3.0 MATERIALS AND METHODOLOGY

The Chinese peanut variety was used for the entire work. This variety was selected because it is the most popular and easily obtainable variety in the markets. Furthermore, it was the variety used by Dongdem (2013) to start the work on the canned peanut based soup due to its chemical properties for the product formulation. Peanuts were obtained from the Madina Market in Accra, and transported to the Department of Nutrition and Food Science.

Plate 3.1: Chinese peanut variety used for the work

3.1 Peanut sample preparations

3.1.1 Sorting of peanuts to remove damaged kennels

Peanuts obtained from the market were weighed and manually sorted to remove shriveled and damaged ones from the lot. The presorted sound peanut kernels were transferred into aluminum trays and dry blanched at 140°C for 20 minutes in batches of 1kg in an Ariston electric cooker/oven (Ariston 60cm upright electric cooker with oven, Model: CX 67 SP6X) with stirring

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approximately every 10 minutes. The oven was preheated for about 10-15 minutes before introducing the peanuts. The peanuts were allowed to cool after the dry blanching, and manually dehulled (thus removing the skin). Dehulled peanut seeds were neatly packaged into zip lock bags.

The dehulled peanut seeds were manually sorted and only blanched peanuts with less than 50% discoloured, and clean peanuts with no discolouration were used (Dongdem, 2013). This was done to reduce aflatoxin levels in the peanuts.

3.2 Specific objective 1: Determination of optimum roasting conditions (roast temperature and roast time) for peanuts to be used for processing of the canned peanut soup base

3.2.1 Selection of optimization parameters for peanut soup base

Roasting temperature and time were the main factors considered since these parameters according to Rodriguez *et al.* (1989) are known to affect the final product colour and flavour from the very early stages of production. The third factor considered was the retort/process time because it also impacts some changes in the final characteristics of the product, especially colour.

3.2.2 Experimental design

The experiments followed a Central Composite Rotatable Design (CCRD) (Montgomery, 2001) for three independent variables (k=3). The independent variables were roasting temperature (X1), roasting time (X2) and retort time (X3). Maximum and minimum values were selected for the three factors based on previous work (Dongdem, 2013) and they are presented in Table 3.1.

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Based on the minimum and maximum levels of the variables, 16 runs were generated using the statistical software (Minitab 14) for CCRD for K=3 (Table 3.2). The dependent variables that were monitored included colour of roasted peanuts; peanut paste; soup base before retorting; soup base after retorting and soup prepared from the soup base after retorting.

Table 3.1 Minimum and maximum values for the 3 factors in the CCRD for K=3

Factors	Low	High
Roasting temperature (°C)	130	150
Roasting time (minutes)	30	60
Retort/Processing time (minutes)	45	65

Table 3.2 Design matrix for Central Composite Rotatable Design for 3 factors

Sample No.	Roasting temperature (°C)	Roasting time (minutes)	Retort/Processing time (minutes)
1	150	60	45
2	140	45	38.1821
3	140	45	55
4	130	60	65
5	140	19.7731	55
6	130	60	45
7	150	30	65
8	130	30	45
9	156.818	45	55
10	150	60	65
11	140	45	55
12	140	70.2269	55
13	140	45	71.8179
14	130	30	65
15	150	30	45
16	123.182	45	55

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3.2.2.1 Roasting of peanut seeds

850g of the dehulled colour sorted peanut seeds (for each of the 16 runs) was weighed into an aluminum tray and placed in the oven preheated to the desired temperature. The roast temperature was varied according to the experimental design, and monitored using a thermocouple attached to a temperature data logger. The peanuts were stirred approximately every ten (10) minutes to help obtain an almost uniform colour after roasting. At the end of the roasting time, as set by the experimental design, peanuts were taken out, air cooled, and packaged in zip lock bags.

3.2.2.2 Colour determination of roasted peanut seeds

The colour of the roasted peanut seeds for each temperature-time combination was determined, using a tristimulus chroma meter (CR-310, Minolta Camera Co. Ltd., Osaka, Japan). Roasted peanut seeds were filled into a clean-dried glass petri dish and covered with the lid. The chroma meter was calibrated using a white Minolta calibration plate No. 14333116 before measurements were taken. The L*a*b* colour space was selected. L*a*b* colour determination was done by taking measurements on three different parts of the lid covering the roasted peanut seeds.

3.2.2.3 Milling of roasted peanut seeds into paste

The roasted peanuts were milled using the dry section of the Master Chef blender (model No. MC-BL-1831) until an almost smooth peanut paste was obtained. Milled pastes were packaged into zip lock bags and labeled appropriately (with respect to roast temperature-time combination).

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3.2.2.4 Peanut paste colour determination

The colour of the peanut pasted was determined as described in section 3.2.2.2 using the Minolta Chroma meter. Peanut paste were filled into a clean-dried glass petri dish and covered with the lid. It was filled fully to prevent any air bubbles formation which might affect the reading.

3.2.2.5 Preparation of spice-mix extract

Onion, pepper and ginger were obtained from the market, cleaned and used to prepare the spice-mix extract. The spice mix extract was prepared by boiling weighed amounts of ginger, pepper and onions (10g, 12.3g and 100.8g respectively per 300g of peanut pastes.) in 200ml water for 15 minutes. The boiled spices were ground in a Master Chef blender (model No. MC-BL-1831) at low speed for 1 minute and maximum speed for 2 minutes and sieved. The residue was ground again in 100ml measured amount of water and sieved. The blender was rinsed with 100ml water and the content sieved. The filtrate obtained was used for the preparation of peanut soup base (Dongdem, 2013).

3.2.2.6 Processing of canned peanut soup base

Canned peanut soup base was prepared as shown in the flow diagram (Figure 3. 1) based on the method used by Dongdem (2013). The canned soup base was retorted in a vertical still retort at different retort times based on the design of experiments (Table 3.2) at a constant retort temperature of 122°C.

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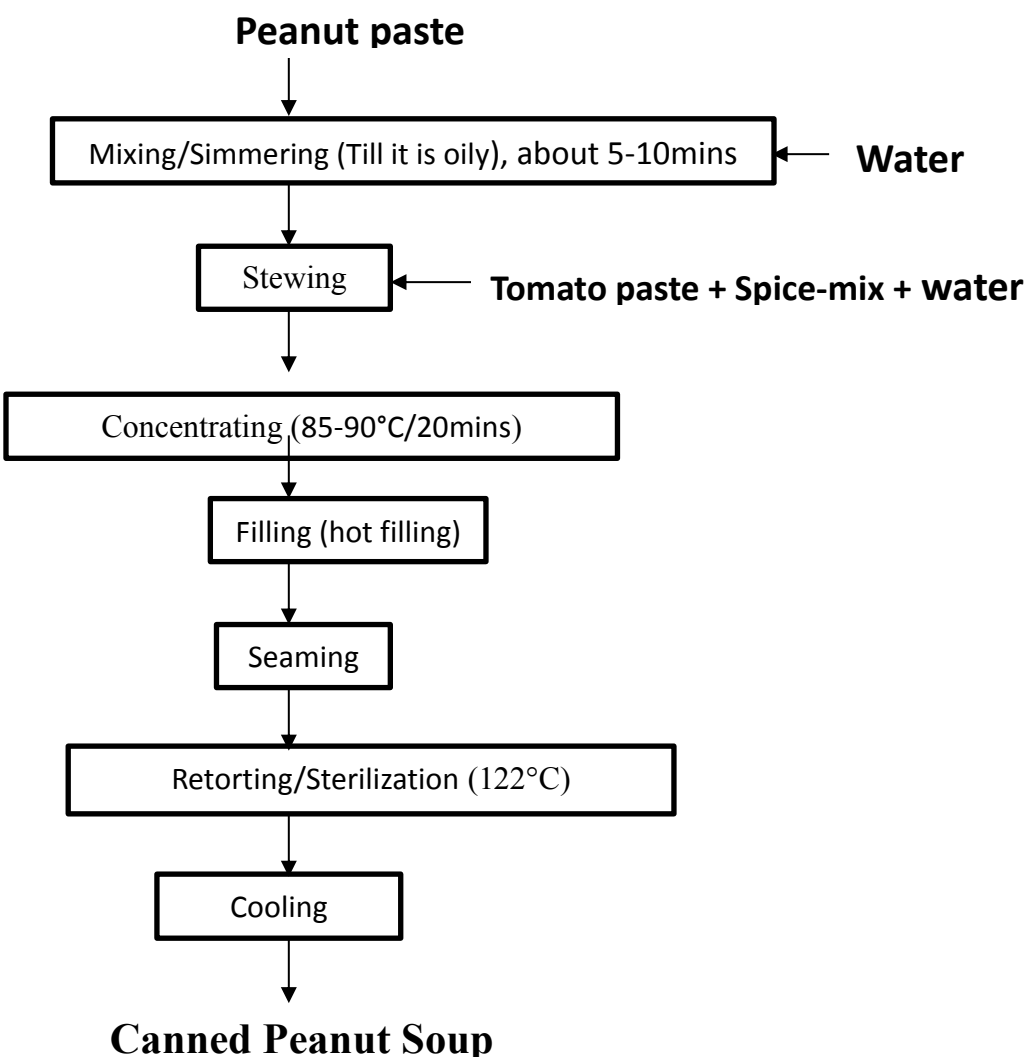

Figure 3.1 Flow chart for peanut soup base processing (Source: Dongdem, 2013)

3.2.2.7 Determination of colour and total colour difference of peanut soup base

The colour (L*a*b*) of the peanut soup base was determined before and after retorting using the combinations outlined in Table 3.2. The total colour difference (ΔE*) was calculated using equation below (Minolta, 1991):

$$\Delta E^* = \int [(L^* - L^*t)^2 + (a^* - a^*t)^2 + (b^* - b^*t)^2]$$

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Where ΔE* =total colour difference, L*t a*t b*t= colour of non-retorted peanut soup base and L* a* b* =colour of retorted canned peanut soup base.

3.2.3 Sensory evaluation of canned peanut soup bases

A balanced incomplete block design (Montgomery, 2001) was used for the attribute intensity and acceptability test conducted on the 16 different canned peanut soup bases obtained from Table 3.2.

A l0cm line scale and a 9-point hedonic scale for the attribute intensity and acceptability test respectively were used to evaluate the colour, aroma, flavour, taste, aftertaste and overall acceptability of the 16 different canned soup bases using 20 trained panelists (blocks). Attached appendix 7.1 is the sensory ballot sheet used for the evaluation. The criteria for selection of panelists were that they must be consumers of peanut soup. Peanut soups were warmed slightly and served approximately between temperatures of 35-40°C. Samples were coded using three digit numbers and the order of presentation to panelists randomized.

3.2.4 Determination of optimum roast temperature/ time region for the canned peanut soup base

Regression models of the sensory attributes and overall acceptability of peanut soups from the 16 different roast temperature and roast time combinations were used to generate contour plots. The contour plots for each sensory attribute and overall acceptability were superimposed based on the ranges of consumer intensity rating for each attribute and overall acceptability respectively. The region in which all contours satisfied the criteria of intensity rating and acceptability was considered as the optimum region for the roasting temperature and roasting time. These

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optimized roast temperature-roast time combinations were to be used for the processing of the canned peanut soup base which is a concentrated form of the peanut soup.

3.2.5 Validation of roast temperature-time combination in the optimum region

To validate the process, two roast temperature-time combinations within the optimum region and two outside the optimum region were selected. Four different peanut batches (850g for each batch) were roasted using the four different roast temperature-time combinations and their colour was measured. They were then milled separately into paste and again their colour was measured. Four canned peanut soup bases were processed (at 122˚C for 55 minutes) from them and used in making four peanut soups. These were served to 36 untrained panelists for sensory evaluation. Sensory attributes of the peanut soups that were made using roast temperature-time from the optimum region and from outside the region were compared with predicted attributes using the regression models. Sensory ballot is attached in appendix 7.1.

3.2.6 Determination of sterilization value (Fo) for products

F_o value for product retorted for 55minutes was determined. This was done because from the preliminary analysis done on the product with respect to the thermal processes (retort temperature and retort time) though optimized could still not produce an F_o value of 3 minutes (minimum acceptable F_o values for low acid canned foods according to Awuah *et al.* 2007). This was done using the trapezoidal integration method (Warne, 1988). The heat penetration data were collected at standard time interval of two minutes. The process lethal rates (L) product temperature (T) was calculated using a reference temperature of 121.1°C and a z value of 10°C

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given by equation (1). The *Fo* value was calculated as the product of the standard time interval (2 minutes) and the sum of the lethal rates (*L*) during the heating and cooling phases (equation 2).

$$\mathbf{L = Log^{-1}(T - 121.1/10)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{(1)}$$

$$\mathbf{F_o = 2\,\Sigma\, L} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{(2)}$$

Where *L* - lethal rate, *T* – product temperature at SHP and *Fo* – sterilizing value (Warne, 1988).

3.3 Specific objective 2: Shelf life testing

After the optimization and validation, the selected roast temperature-time was used for processing to estimate the shelf life of the canned peanut soup base.

3.3.1 Accelerated shelf life studies

Peanuts were roasted at a temperature of 125°C for 28 minutes (optimized roast temperature-time as obtained from sensory) using the Ariston electric cooker brand with oven. Milling of roasted peanuts was done using the attrition mill (due to the large quantity of paste needed). 50 peanut canned soup bases were processed as described in sections 3.2.2.5 and 3.2.2.6 above but this time all 50 were prepared as one lot (using optimized roast temperature-time) and subjected to the same thermal conditions (122˚C for 55 minutes). 24 canned peanut soup bases were stored in an incubator at a temperature of 55°C (as accelerated temperature) and another 24 were stored on the shelf at normal room temperature of about 27°C. Samples were stored for 8 weeks from which three (3) cans were randomly taken every week for analysis to determine the stability of the product at these two temperatures. Analysis conducted included sensory evaluation of the product; colour determination; pH; free fatty acid (FFA %) and peroxide value (PV). The product shelf life was estimated using the Arrhenius equation (stated below)

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$$k = A\exp\left(-\frac{E_a}{RT}\right)$$

Where R = 8.31 J·mol^{-1}·K^{-1} (universal gas constant), the parameter A is a constant which is taken as independent of temperature, k is the rate coefficient, T is the temperature and *Ea* is the Arrhenius activation energy.

3.3.1.1 Sensory evaluation of stored canned peanut soup base

The stored canned peanut soup bases were subjected to sensory analysis to help detect any changes in product colour, aroma, smoothness and consistency (thickness). 15 trained panelists were used for this study. A 10cm line scale was used to measure the intensities of the attributes mentioned above. Ballot sheet for shelf life sensory is attached in appendix 7.3.

3.3.1.2 Colour determination

Colour of the stored peanut soup base product was determined. The sample was filled into a clean-dry glass petri dish and covered with the lid. Colour determination was done using a tristimulus colour meter (CR-310, Minolta Camera Co. Ltd., Osaka, Japan). Colour meter was calibrated using a white Minolta calibration plate No. 14333116 before measurements were taken. The L*a*b* colour space was selected and colour determination was done by taking measurements on three different parts of the lid covering the peanut soup base.

3.3.1.3 pH determination

The pH of the two canned peanut soup bases was determined at 90% dilution with distilled water using a pre-calibrated pH meter.

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3.3.1.4 Free fatty acid (FFA %) and Peroxide value determination

Fat extraction

In order to determine free fatty acids (FFA %) and peroxide value (PV), the fat had to be extracted from the product and then used for the analysis. The chloroform-methanol fat extraction method was used according to Folch *et al.* (1957) with some modifications.

About 15-20g of the canned peanut soup base was weighed into a beaker and transferred into a 250ml separating funnel. 75ml chloroform-methanol mixture was prepared in a ratio of 2:1 (that is 50ml of chloroform to 25ml of methanol) and mixed thoroughly. The chloroform-methanol mixture was gently poured into the separating funnel containing the weighed peanut soup base. The separating funnel was agitated manually for about 60 seconds and clamp on a retort stand (Plate 3.2). The set up was left for about 2 days.

The lower region of the separating funnel was decanted into a beaker by opening the nub. This part contains the chloroform and the fat. The beaker was heated slightly to allow the chloroform evaporate leaving the oil/fat in the beaker. The fat obtained was used for the free fatty acid (FFA %) and peroxide value (PV) determination.

Free fatty acid (FFA %) determination

Free fatty acid for the canned peanut soup base was determined as described by AOAC method 940.28 with some modifications in the amount of sample weighed as well as reagents used.

Peroxide value (PV) determination

Peroxide value for the canned peanut soup base was determined as described by AOAO method 965.33.

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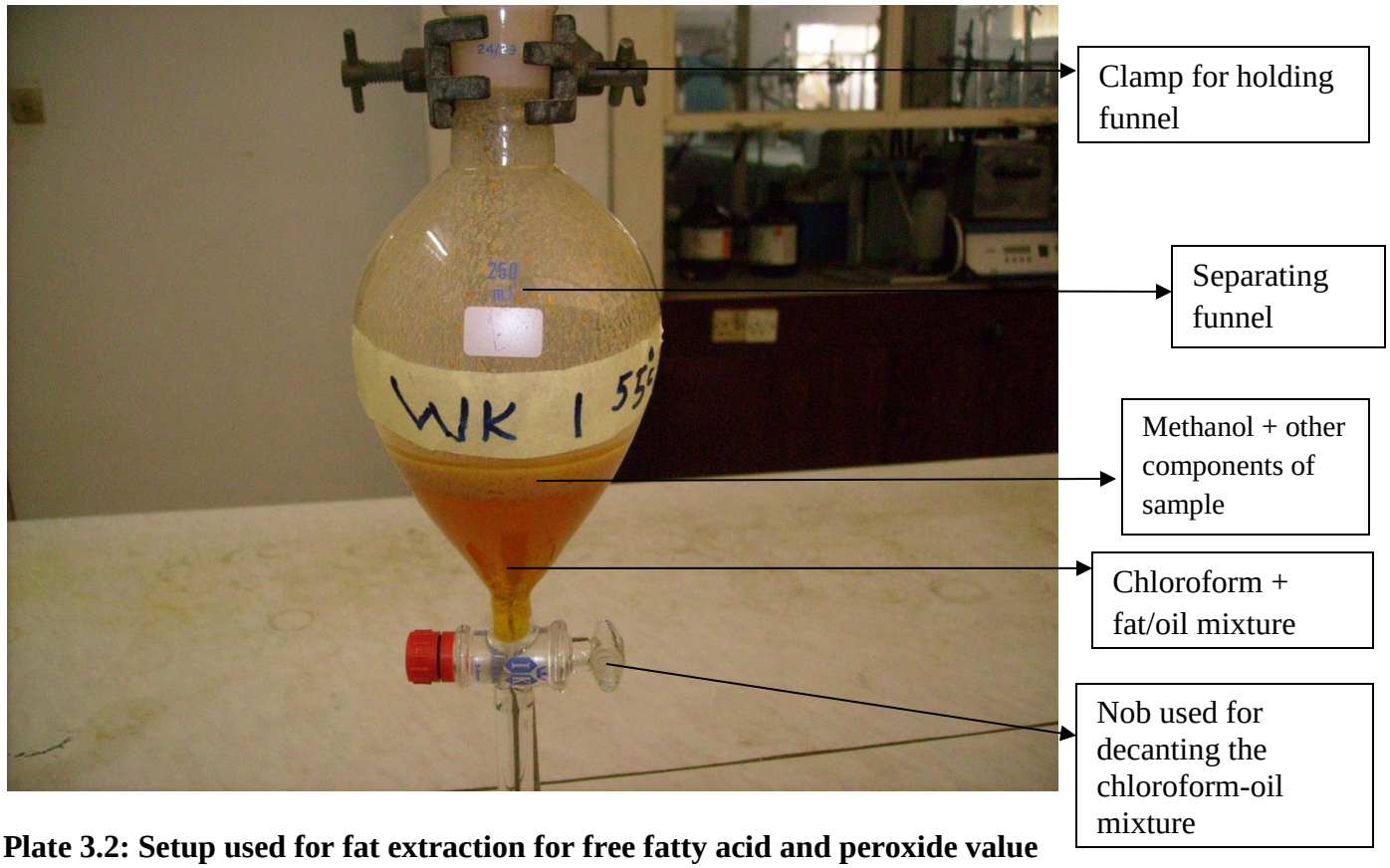

Plate 3.2: Setup used for fat extraction for free fatty acid and peroxide value determination

3.4 Specific Objective 3: Chemical composition determination (Proximate analysis)

Proximate analysis was conducted on the final canned peanut soup base. These included moisture content, protein, fat, ash and crude carbohydrates.

3.4.1 Moisture content

The moisture content was determined using AOAC method 925.40 (AOAC, 2005).

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3.4.2 Crude fat determination

The crude fat content was determined using the Soxhlet method according to AOAC (2005) method 948.22.

3.4.3 Protein determination

Kjeldahl method was used to determine the nitrogen content of the peanut soup base as outlined in AOAC (2005) method 955.04C. The protein content was then calculated as the product of nitrogen content and a factor of 5.46 for peanuts.

3.4.4 Crude ash

The ash content was obtained as the weight of the inorganic residue after the carbonization (at 600°C) of the test portion of peanut soup base in a furnace to a constant weight of white ash.

3.4.5 Crude carbohydrate

The crude carbohydrate content was calculated as the difference between the sum of the other components and 100%, that is:

Crude Carbohydrates = 100% - (% protein + % moisture + % crude fat + % crude ash)

3.5 Specific objective 4: Consumer survey of canned peanut product

Canned peanut soup bases were processed as described in section 3.2.2.5 and 3.2.2.6. They were distributed to 50 randomly selected peanut soup consumers within Accra and Koforidua metropolis. The consumers were instructed to reconstitute the condensed soup base for soup preparation.

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A designed assessment form (Appendix 7.4) was given to these 50 consumers to help obtain their views and comments about the canned peanut soup base product. The assessment form had four sections: the general information about peanut soup preparation at home; canned peanut soup base assessment; other information about the canned soup base and sensory evaluation (preference and attribute intensity for soup qualities prepared using the canned soup base).

3.6 Data analysis

All experiments were carried out in either duplicate or triplicates, and except for the sensory evaluation data, all other data obtained were expressed as means ± standard deviation. These means and standard deviations of measured variables were calculated using Microsoft Office Excel 2010. Analysis of variance (ANOVA) to compare treatment means (at $p \leq 0.05$) and Multiple Range test of treatments found to be significantly different for sensory data were done using StatPoint Statgraphics Centurion (version 15).

Response surface regression analysis was done using Minitab (version 14). Paired t-test was also conducted to assess the effect of the storage temperatures on the L* (lightness) values of the peanut soup base stored at 27 and 55˚C respectively as well as L* (lightness) values of before and after retorting using Minitab (version 14). Graphs were drawn using Microsoft excel 2010.

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CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

The results of the experiments are presented and discussed below.

4.1 Optimization of roasting conditions

4.1.1 Effect of roasting temperature-time combination on colour (L-value) of roasted peanuts and peanut pastes

Colour is an important indicator of the roasting process and its development is generally used as a measure of degree of roast (Manzocco *et al.*, 2000).

In the tristimulus colour scale, the L values were calibrated at L = 100 denoting white and L = 0 denoting dark/black. Table 4.1 shows the variability in the colour (L-value) of roasted peanuts obtained for the different roasting temperature-time combinations.

Table 4.1 L-value obtained from the 16 different roast temperature-time combinations

Treatment/Roasting temperature (°C)	Roasting time (minutes)	Colour of roasted peanuts (L-value)	Colour of peanut paste (L-value)
150	60	43.16 ± 0.03	43.55 ± 0.01
150	60	44.53 ± 0.01	44.51 ± 0.11
157	45	47.32 ± 0.00	47.31 ± 0.00
140	70	48.63 ± 0.01	48.48 ± 0.02
150	30	49.65 ± 0.01	49.76 ± 0.02
150	30	49.67 ± 0.02	49.82 ± 0.03
130	60	52.12 ± 0.01	52.02 ± 0.49
130	60	52.16 ± 0.01	52.81 ± 0.00
140	45	53.28 ± 0.01	53.17 ± 0.01
140	45	53.61 ± 0.01	53.57 ± 0.01
140	45	53.65 ± 0.02	53.66 ± 0.01
140	45	53.73 ± 0.01	53.70 ± 0.02
123	45	54.98 ± 0.01	54.91 ± 0.01
130	30	55.69 ± 0.01	55.41 ± 0.02
130	30	55.79 ± 0.01	55.73 ± 0.01
140	20	56.76 ± 0.01	56.78 ± 0.02

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The mean colour (L-value) of the roasted peanuts ranged from 56.76 to 43.16 for roasting at 140˚C for 20 minutes and 150˚C for 60 minutes respectively. Roasting peanuts at high temperatures (150˚C) for long times (60 minutes) obtained dark colours with low L-values. On the other hand low temperature roasting for short periods provided relatively light coloured products, with high L-value. Plate 4.1 shows the variability in roast colour at different temperature-time roast conditions.

The regression model for L-values on the roasting temperature and time (Table 4.2) was fairly good, with an R-squared of 85%, and indicated that all the model components had significant effects ($p \leq 0.05$) on the colour (L-value) of the roasted peanuts. These effects were however all negative, suggesting the decreasing effects of both temperature and time on the lightness colour (L-values) of the roasted peanuts.

Table 4.2 Estimated regression coefficients for L-value of roasted peanut

Model component	Coefficient	p-value
Constant term	104.375	< 0.001
Roast temperature	-0.32541	< 0.001
Roast time	-0.15933	< 0.001
R^2	85.0%	
R^2–Adjusted	84.3%	

A stepwise regression analysis of the model showed that the influence of roasting temperature could explain about 53% of the roasted peanut colour (L-value) differences while roasting time explained about 32% of variations in roasted peanut colour (Table 7.5.1 in appendix 7.5). This means that though both factors affected the colour of the peanuts during roasting, the

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temperature at which the peanuts were roasted had a much greater influence on the colour of roasted peanuts than the roasting time.

The combined effect of roast temperature and roast time on the colour of the roasted peanuts is shown in the contour plots for L-value as generated from the regression model (Figure 4.1). Roasting at low temperatures for short periods of time produced light to medium roast coloured peanuts. On the other hand, roasting at high temperatures for long time periods produced peanuts with dark roast colour. According to reports from (Buckholz *et al.*, 1980; Oupadissakoon and Young, 1984), roasted peanuts usually fall into one of the three main degrees of roast which include light roast (53.10 ± 1.00); medium roast (48.50 ± 1.00) and dark roast (43.00 ± 1.00).

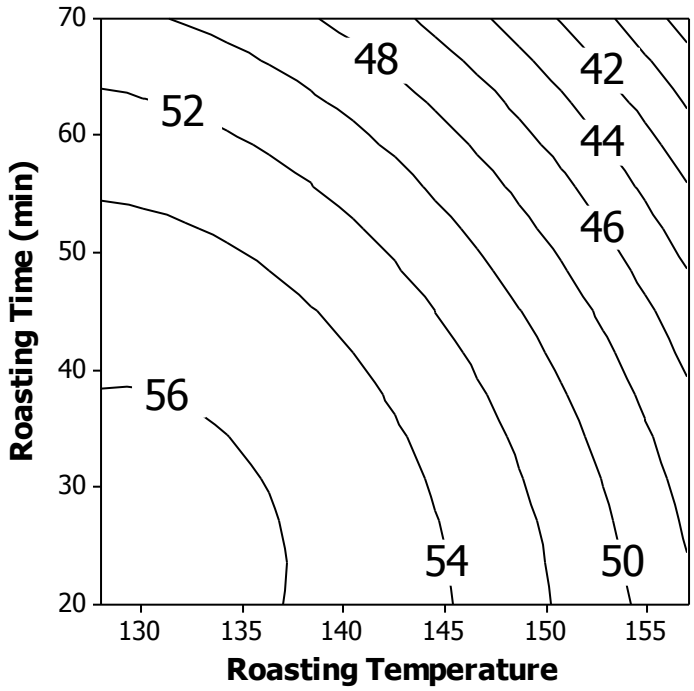

Figure 4.1 Contour plot of colour (L-value) of roasted peanuts verses roast time (minutes) and roast temperature (˚C)

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It was observed from the contour plot of the L-value that at a given roast temperature, L-value of the roasted peanuts decreased as the roast time increased (Figure 4.1). Also at any given roast time duration with increase in roast temperature, L-value of the roasted peanuts again decreased. The decrease in the L-value means the roasted peanuts became darker. Thus the colour of the roasted peanuts darkened as both roasts temperature and roast time increased. This was supported by the stepwise regression analysis that decomposed the total regression into partial r-squares for the variables and indicated the greater role of temperature in darkening the peanut roast colour than the roasting time. This buttresses the statement made by Ames *et al.* (1994) about the fact that as temperature of roasting increases (for a given time), the final colour appears darker. Sena *et al.* (2001) also stated that during roasting of most nuts, brown pigments generally increase as browning and caramelisation reactions are in progress.

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150˚C/60 min, L* = 43.16 ± 0.03

130˚C/60 min, L* = 52.12 ± 0.01

140˚C/70min, L* = 48.63 ± 0.01

130˚C/30 min, L* = 55.79 ± 0.01

150˚C/30 min, L* = 49.65 ± 0.01

140˚C/45 min, L* = 53.65 ± 0.02

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128˚C/45 min, L* = 54.98 ± 0.01

50˚C/60 min, L* = 44.53 ± 0.01

157˚C/45 min, L* = 47.32 ± 0.00

140˚C/45 min, L* =53.28 ± 0.01

130˚C/60 min, L* = 52.16 ± 0.01

130˚C/30 min, L* = 55.69 ± 0.01

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140˚C/45 min, L* = 53.73 ± 0.01

140˚C/20 min, L* = 56.76 ± 0.01

140˚C/45 min, L* = 53.61 ± 0.01

150˚C/30 min, L* = 49.67 ± 0.02

Plate 4.1 Roasted peanuts from the 16 different roast temperature-time combinations

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4.1.2 Effect of roasting temperature and time on colour (L-value) of peanut paste

Roasted peanuts were milled into a smooth peanut paste. The colour (L-value) of the paste did not change much and were almost the same as those of the roasted peanuts (Table 4.1). This suggests that when peanuts are roasted to light or medium roast colour, the paste obtained would have similar colour. Likewise dark roasted peanuts would produce dark coloured paste. Thus the colour of the peanut paste is directly dependent on the colour of the roasted peanuts. Plate 4.2 shows the variability in roast colour at different temperature-time roast conditions.

4.1.3 Colour of peanut soup base before retorting as a function of colour of peanut paste

In the processing of peanut soup base, peanut paste was slurred in (predetermined) amount of water and ingredients, filled into a can, seamed and retorted at a schedule time and temperature. The colour (L-value) of the soup base before retorting was dependent on the colour of the paste used for the processing. This is because even though the precooking of the soup base before retorting (observed from the flow chart) affected the colour due to the heat application, the initial colour of the paste started with actually had the most effect in that if the paste is dark, product's colour after the precooking would appear more darker (that is taken into consideration the heat applied from the precooking stage). However, with the addition of water and other ingredients, the colour of the paste became lighter and thus the L-values increased moderately, thus the paste was diluted when these other ingredients were added (Table 4.3).

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Table 4.3 Soup base colour before retorting for the 16 different treatments

Roast temperature (˚C)	Roast rime (minutes)	Colour of peanut paste (L-value)	Colour of soup base before retorting (L-value)
150	60	43.55 ± 0.01	48.97 ± 0.09
150	60	44.51 ± 0.11	50.08 ± 0.11
157	45	47.31 ± 0.00	50.48 ± 0.25
150	30	49.76 ± 0.02	53.18 ± 0.13
140	70	48.48 ± 0.02	54.61 ± 0.35
140	45	53.17 ± 0.01	54.72 ± 0.48
150	30	49.82 ± 0.03	54.87 ± 0.12
140	20	56.78 ± 0.02	56.37 ± 0.29
140	45	53.57 ± 0.01	56.62 ± 0.22
130	60	52.02 ± 0.49	56.74 ± 0.05
140	45	53.66 ± 0.01	57.36 ± 0.07
130	30	55.41 ± 0.02	57.67 ± 0.31
123	45	54.91 ± 0.01	58.20 ± 0.30
130	60	52.81 ± 0.00	58.57 ± 0.24
140	45	53.70 ± 0.02	58.77 ± 0.12
130	30	55.73 ± 0.01	59.54 ± 0.19

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Plate 4.2 Colour of peanut paste obtained from the 16 different roast temperature-time combinations

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4.1.4 Effect of roast temperature, roast time and retort time on colour of soup base after retorting

The peanut soup base colour (L-value) after retorting is the colour of the final product. The paste obtained from the temperature-time combinations was used in the processing of canned soup base. The canned soup base was retorted according to specified temperature-time schedules, after which the colour (L-value) of the final product was measured. Table 4.4 shows the variations in the colour (L-value) of the canned soup base retorted at different temperature/time combinations. Generally, all the treatments produced soup base with decreased colour (L-value) after retorting. These colour changes ranged from 47.85 to 57.59.

Table 4.4 Soup base colour after retorting for the 16 different treatments

Roast temperature (˚C)/roast time (minutes)	Retort time (minutes)	Colour of soup base after retorting (L-value)
150:60	45	48.40 ± 0.10
150:60	65	47.85 ± 0.10
157:45	55	48.23± 0.17
150:30	45	51.66 ± 0.05
140:70	55	51.23 ± 0.11
140:45	55	50.33 ± 0.37
150:30	65	51.73 ± 0.14
140:20	55	48.32 ± 0.27
140:45	38	57.59 ± 0.13
130:60	45	54.27 ± 0.13
140:45	72	53.29 ± 0.14
130:30	45	55.45 ± 0.28
123:45	55	50.12 ± 0.09
130:60	65	53.02 ± 0.03
140:45	55	54.63 ± 0.20
130:30	65	55.21 ± 0.19

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Dongdem (2013) observed that the colour (L-value) of the product after retorting showed consistent lower values as the processing temperature and time increased suggesting that the final soup base colour was affected by the thermal process. The author also observed that the colour (L-value) of the product decreased as the processing time increased at both low and high temperatures. The decreased L-value described darkening of the product colour as the severity of the thermal process increased.

The data for the canned, retorted soup base colour (L-value) was fitted to a multiple regression model (Table 4.5). The regression model showed that all the 3 factors had significant effects on the colour of the soup base after retorting (product's final colour) with the model explaining about 72% of the variations in the colour of the soup base.

Table 4.5 Estimated regression coefficients for L-value of roasted peanut

Model component	Coefficient	p-value
Constant term	91.655	< 0.001
A: Roast temperature	-0.22683	<0.001
B: Roast time	-0.07686	< 0.001
C: Retort time	-0.06960	0.006
R^2	72.0%	
R^2–Adjusted	70.1%	

The colour (L-value) of the soup base after retorting as a function of roasting temperature and retorting time, as well as roasting time and retort time are shown in Figures 4.2 and 4.3 respectively. Increasing the retort time caused a decrease in the colour (L-value) of the soup base irrespective of roasting temperature and/or roasting time (Figures 4.2 and 4.3). The decreased

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observed in L-values depicts darkening of the product colour as the severity of the thermal process (retort time) increased. Considering also the roasting temperature and roasting time in addition to the retort time, the results (Figures 4.2 and 4.3) indicate that as both roast temperature and roast time increase, the L-value decreased (thus colour darkens). Generally, the colour of the soup base after retorting darkened (L-value decreases) as roast temperature, roast time and retort time increased due to the increase in the severity of the thermal process (retort time) and non-enzymatic browning (Maillard reactions). An increase in retort time caused a decrease in the final product colour because of the heat from the retort.

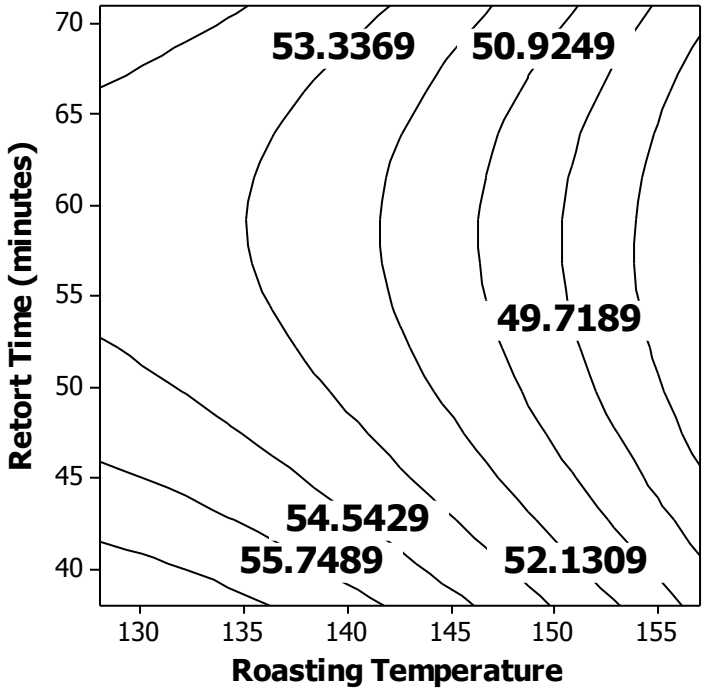

Figure 4.2 Contour plot of colour (L-value) of canned peanut soup base as a function of retort time (minutes) and roasting temperature (˚C)

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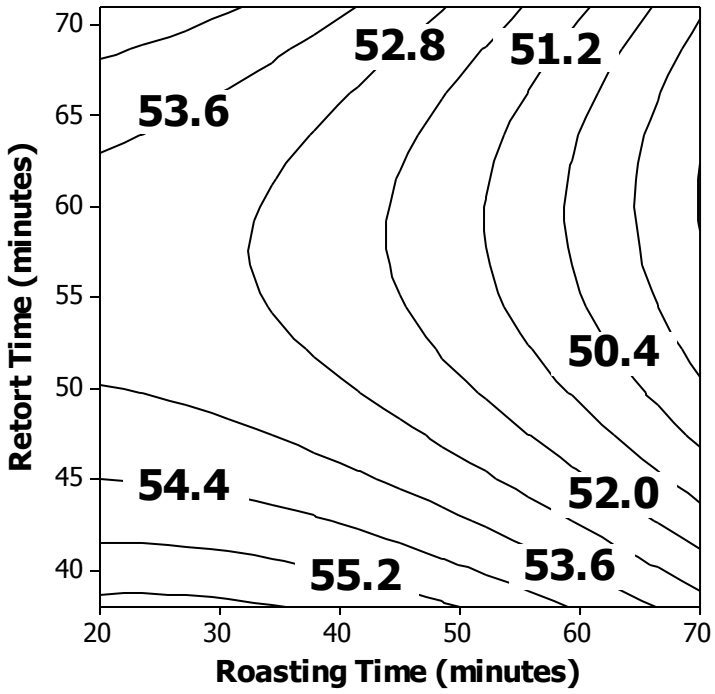

Figure 4.3 Contour plot of colour (L-value) of soup base as a function of retort time (minutes) and roasting time (minutes)

According to Awuah *et al.* (2007), aside the achievement of commercial sterility, thermal processing targets to minimize changes in final product qualities. The authors also state that no matter how small the heating source may be, some reactions are promoted and these could affect overall final product quality. Thus the decrease in canned soup base colour (L-value) could be attributed to Maillard reaction (non-enzymatic browning) which after several reactions are known to produce brown compounds called melanoids (Fennema, 1996). This is because peanuts are rich in the essential chemical constituents-sugars and proteins which are required for non-enzymatic browning reactions.

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4.1.5 Effect of retort/process time on the total colour difference (ΔE*)

Total colour change (ΔE*) was calculated to determine the extent/degree of change in canned peanut soup base colour as a function of retort time. The changes in product colour were calculated from the L* a* b* values of the soup base before and after retorting. Table 4.6 shows the total colour change for the individual treatments. Considering the different retort times, the least retort time (38 minutes) recorded the least colour change. This was followed by 45, 55 and finally 65 and 71 minutes respectively. These values indicate that retorting at a shorter time (with constant process temperature) produced the lowest change in product colour and a longer retort time produced a large change in product colour. The total colour changes observed with respect to the different retort times were towards darker product colour (decreased L-values).

The colour of processed foods is known to be an essential determinant of their acceptability by consumers. The vegetables which were used in making the canned peanut soup base contain naturally occurring pigments such as chlorophyll and anthocyanins which could have been heat degraded to pyropheophytin and other brown pigments (Awuah *et al*., 2007). Maillard reactions during the thermal processing could also have contributed to the increasing total colour differences with the severity of the thermal processing (that is the retort time). The colour difference could be an important quality indicator in the optimizing processes since excessive browning of the product may not be desirable.

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Table 4.6 Total colour differences between non-retorted and retorted peanut soup base processed at different retort time

Sample/Treatment	Retort time (minutes)	ΔE*
1	38	2.18 ± 0.76^{a}
2	45	3.61 ± 0.07^{b}
3	45	4.22 ± 0.10^{bc}
4	45	4.27 ± 0.16^{bc}
5	45	4.28 ± 0.27^{bc}
6	55	4.48 ± 0.08^{c}
7	55	4.61 ± 0.23^{c}
8	55	4.64 ± 0.41^{c}
9	55	4.68 ± 0.21^{c}
10	55	4.81 ± 0.16^{cd}
11	55	4.83 ± 1.21^{cde}
12	65	5.36 ± 0.25^{def}
13	65	5.48 ± 0.14^{efg}
14	65	5.58 ± 0.18^{fg}
15	65	5.61 ± 0.15^{fg}
16	71	6.08 ± 0.01^{g}

ΔE* - Total colour difference. Sample/Treatment represents the different roast temperature-time combinations (Table 4.4)

The change in product colour increased as the retorting time increased. This means that retorting for longer times would render product colour to darken and in the case of the canned peanut soup base, the dark colour would be undesirable making it unacceptable to consumers (Awuah *et al.*, 2007). This is because more application of heat energy causes a higher kinetic change in the various reactions taking place and this affects the colour of the final product.

4.2 Determination of sterilization value (F_o) at retort time of 55 mins

Dongdem (2013) established the thermal processing time for the canned peanut soup base to be between 45-51 minutes. He stated that this could give a relatively shelf stable product. However,

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the sterilization value (F_o) for the product was less than 3 minutes, the F_o value for low acid canned foods. This suggests that the thermal process schedule established by Dongdem (2013) for peanut base soup lacked the severity required for low acid canned foods to ensure safety from botulism. Thus products retorted at 38 and 45 minutes respectively would not be "safe" from the risk of botulism though these retorting times give the minimum change in product colour as observed from Table 4.6. On the other hand, 65 and 72 minutes retort time (Table 4.6) would be too long a time to work with. This is because from earlier discussions on the effect of retort time on total colour change, it was observed that these two retort times recorded the highest change as a result of the long application of heat to the product.

A heat penetration test conducted with the retort time of 55 minutes with a retort temperature of 122˚C revealed that the product could achieve a sterilization value of 3 minutes at that retort time. Figure 4.4 describes the heat penetration curve obtained from the two processing parameters used. According to Berry and Pflug (2003), the sterilizing value (*Fo*) describes the total lethal effect or the severity of a thermal process when a reference temperature of 121.1°C and a *z* value of 10°C are used to establish the process. This becomes necessary because of the low acidity of the canned peanut soup base (that is pH ≥ 4.60). The product took a longer time to cool after retorting (Figure 4.4). The product temperature was higher (about 72˚C) and this could have resulted in the achievement of the minimum sterilization value (3 minutes) for the product.

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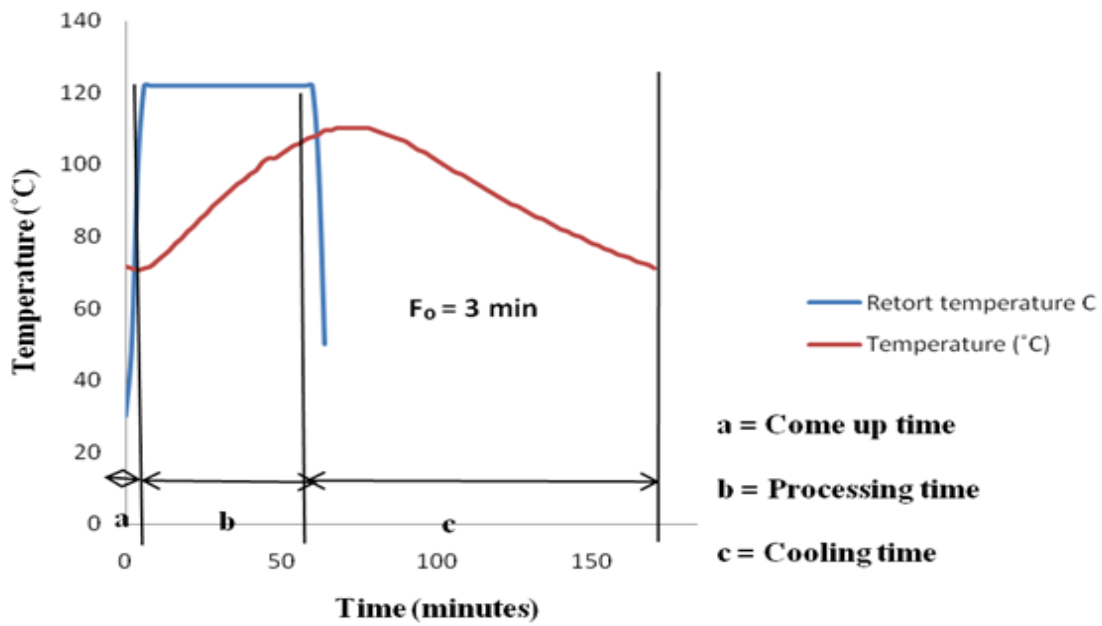

Figure 4.4 Heat penetration curve for canned peanut soup base retorted at 122°C / 55 min

Note: Size of can is 99x118mm (tinplate)

4.3 Determination of optimum roasting conditions (roast temperature and roast time) for canned peanut soup base

4.3.1 Effect of roast temperature and roast time on sensory attributes of soup from canned peanut soup base

Each of the soup base processed using the different paste obtained from the different temperature-time combinations and also retorted at different times was used in preparing peanut soup. A sensory analysis was done on the different soups using a balanced incomplete block design (BIBD), (Appendix 7.2). Panelists were asked to rate the intensity of soup colour, aroma, flavour and aftertaste using a 10cm line scale with 1cm indicating a low intensity and 10cm indicating a high intensity.

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Table 4.7 shows the mean rating scores for the soup attributes. Generally, the mean intensities of the soup attributes were below 8cm (with respect to the 10cm line scale used). Significant differences were observed in all the attributes for the soups. For soup colour, treatments 150:60:45 and 150:60:65 obtained the highest intensity of 7.64cm and 7.02cm respectively, where 150:60:45 describes a sample that was obtained after from a paste from peanuts roasted at 150˚C for 60 minutes and retorting of canned product for 45 minutes.

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Table 4.7 Mean sensory attributes of canned peanut soup base from16 different treatment combinations of peanut roast temperature (Rte), roast time (RT) and retort time (ReT)

Treatment Rte:RT:ReT	Colour	Aroma	Flavour	Aftertaste
150:60:45	7.64 ± 1.01^{e}	7.18 ± 3.66^{c}	4.42 ± 3.83^{abc}	4.74 ± 3.79^{abcd}
140:45:38	2.68 ± 1.29^{a}	4.16 ± 2.44^{abc}	5.76 ± 2.43^{abc}	6.88 ± 1.84^{cd}
140:45:55	6.56 ± 1.56^{de}	4.80 ± 2.91^{abc}	4.88 ± 2.00^{abc}	6.70 ± 1.71^{cd}
130:60:55	3.14 ± 2.17^{a}	3.24 ± 0.84^{ab}	6.88 ± 1.73^{c}	6.24 ± 1.90^{bcd}
140:20:55	5.98 ± 2.00^{cde}	2.84 ± 1.86^{a}	4.68 ± 1.83^{abc}	5.12 ± 2.58^{abcd}
130:60:45	2.62 ± 1.51^{a}	6.04 ± 2.55^{abc}	3.28 ± 1.64^{ab}	2.24 ± 1.27^{a}
150:30:65	3.58 ± 1.40^{ab}	5.42 ± 3.60^{abc}	4.24 ± 2.67^{abc}	3.36 ± 2.70^{abc}
130:30:45	2.58 ± 1.81^{a}	5.04 ± 3.09^{abc}	4.90 ± 3.44^{abc}	6.98 ± 1.68^{e}
157:45:55	6.36 ± 3.12^{de}	4.08 ± 3.28^{abc}	6.60 ± 3.61^{bc}	4.56 ± 3.49^{abcd}
150:60:65	7.02 ± 1.79^{e}	2.70 ± 1.37^{a}	3.66 ± 3.11^{abc}	5.90 ± 2.94^{bcd}
140:45:55	4.58 ± 2.52^{abcd}	3.66 ± 2.82^{ab}	2.46 ± 2.00^{a}	4.38 ± 4.03^{abcd}
140:70:55	6.80 ± 1.50^{de}	3.52 ± 2.51^{ab}	4.32 ± 3.10^{abc}	4.16 ± 4.23^{abcd}
140:45:72	3.84 ± 2.53^{abc}	6.25 ± 1.61^{bc}	6.66 ± 2.42^{bc}	4.74 ± 2.79^{abcd}
130:30:65	2.76 ± 1.67^{a}	6.38 ± 2.70^{bc}	4.64 ± 3.67^{abc}	4.74 ± 3.88^{abcd}
150:30:45	3.58 ± 1.48^{ab}	4.96 ± 2.67^{abc}	5.22 ± 2.23^{abc}	4.80 ± 1.02^{abcd}
123:45:55	5.78 ± 1.69^{bcde}	4.02 ± 3.12^{abc}	4.88 ± 3.26^{abc}	2.90 ± 2.73^{ab}

Means are average rating scores of 20 panelists using a 10cm line scale (1cm indicated a low attribute intensity and 10cm indicated a high attribute intensity for the attributes. Values with different superscripts within the same column are significantly different ($p < 0.05$)

The final canned soup base colour was dependent on roast temperature-time combination as well as the product retort time.

For peanut soup aroma, treatment 150:60:45 (which represent roast temperature of 150˚C, roast time of 60 minutes and retort time of 45 minutes respectively) recorded the highest intensity of

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7.18cm with 150:60:65 recording the lowest intensity (2.70cm), Table 4.7. With the exception of 3 treatments (130:60:45; 140:45:72 and 130:30:65) which were around 6cm, the rest were rated from 2.70cm to 5.42cm. A similar trend (as observed for soup aroma) was observed for peanut soup flavour with just three treatments recording intensities in the range of 6cm.

The soup aroma, flavour and aftertaste go together in that a lexicon developed for peanut flavour indicate that for medium roasted peanuts, they appear to have a roast "peanutty" aroma; light roasted peanuts tend to have a raw beany aroma; dark roasted peanuts produce dark roast aroma and very dark roasted peanuts produce an ashy aroma (Johnsen *et al.*, 1988).

Table 4.1 showing the different roast temperature-time combinations used for the roasting revealed that each combination produced roasted peanuts that fell into one of these peanut flavour lexicons. This means the various soups prepared from them also developed different forms of soup aroma, flavour and aftertaste. The significant variations seen with respect to the different attributes give an indication that the treatments greatly influenced the intensity rating of the soups.

4.3.2 Optimum roasting conditions for canned peanut soup base

The contour plots of all the sensory attributes of the soup generated from the regression models, were superimposed on each other to obtain the optimum region (Figure 4.5) in which all criteria were met. The criteria were defined by predetermined maximum and minimum values for all the attributes at between 3cm and 7cm using the 10cm line scale. Two optimum roast temperature and time combinations which were selected from the optimum region were 125˚C/28 minutes and 123˚C/21 minutes. These two were used to validate the roast conditions for processing the canned peanut soup base as predicted by the regression models.

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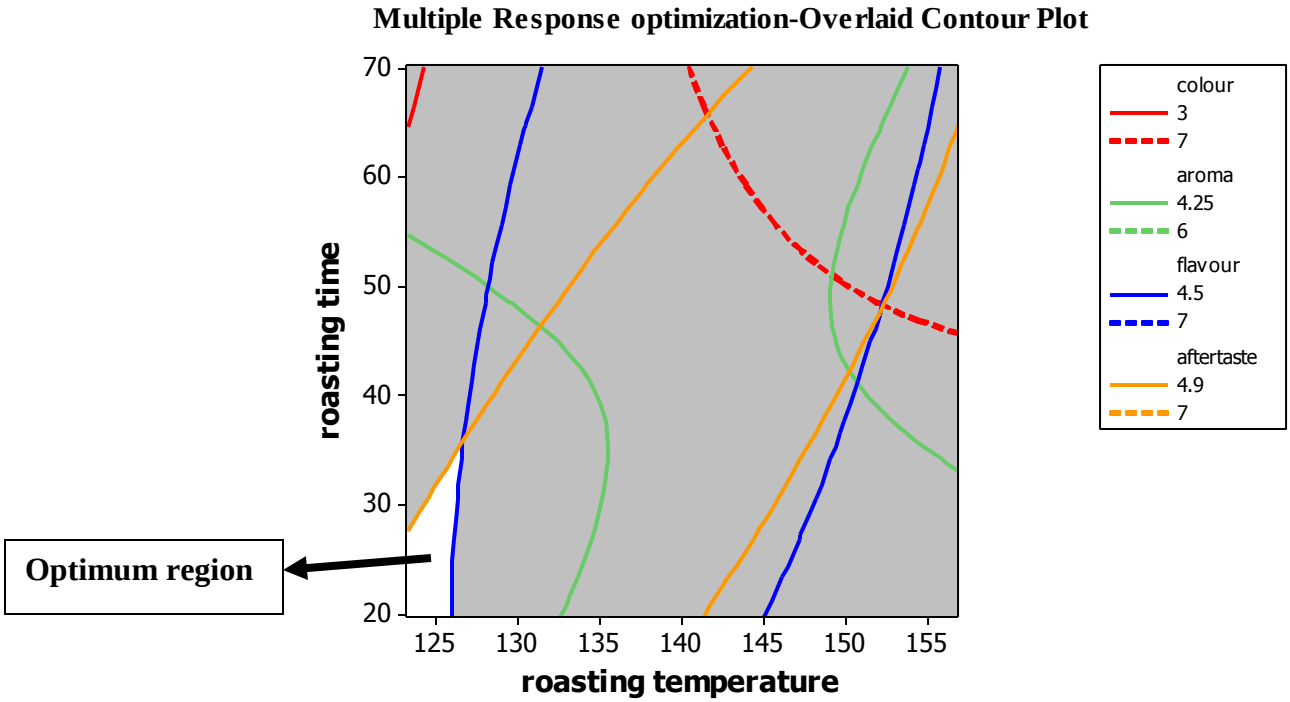

Figure 4.5 Overlaid contour plots of peanut soup attributes indicating the optimum region

4.3.3 Validation of peanut roasting time and temperature

To confirm the regression models for the roasting conditions, two optimal roasting time-temperature combinations were selected from the optimum region together with two others outside the region. Peanuts were roasted using these four different combinations and the paste obtained from them were used in the processing of four different canned soup bases with thermal process schedule (retort temperature and time) been 122˚C for 55 minutes. Peanut soup samples were prepared from them and served to 36 sensory panelists. Table 4.8 shows the roast time-temperature combinations for the validation process.

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Table 4.8 Roast time-temperature from optimum and non-optimum regions used for validation for peanut roast conditions for canned peanut soup base

Treatment	Roast temperature (˚C)	Roast time (minutes)
OR 1	125	28
OR 2	123	21
NO 1	130	60
NO 2	150	36

OR- Optimum region NO- Non-optimum region

The soup obtained from OR 2 recorded the lowest colour intensity of 2.98 with NO 2 having the highest colour intensity of 6.30. This was obvious in that the colour of paste obtained from that temperature-time treatment was darker as compared to the other 3 treatments. For aroma, the soups from the optimum region (OR1 and OR2) had the highest rating. The same trend (as observed for aroma) was observed for soup flavour ratings. For soup aftertaste, OR1 had the highest rate of 5.10 with NO1 having the lowest rate of 2.80. However, significant differences ($p \leq 0.05$) were recorded in all the attributes (Table 4.9) for the different samples.

Generally, the mean rating for all the attribute intensity for OR1 were within the limits for the predicted rating intensities. Based on the predicted scores from the first sensory, treatment from OR1 in terms of roasting temperature and time could give the most desirable peanut soup base. Much lower aroma, flavour and aftertaste were recorded by the two treatments outside the optimum region (NO 1 and NO 2).

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Table 4.9 Sensory attribute intensity of canned peanut soup base prepared from 4 different treatments for validation for peanut roast conditions for the peanut soup base

Treatment	Colour	Aroma	Flavour	Aftertaste
Predicted score	3.00-5.34	4.49-6.00	4.50-6.00	4.16-5.12
1: OR 1	4.20 ± 2.17^{b}	4.96 ± 2.57^{b}	4.64 ± 2.85^{b}	5.10 ± 3.28^{b}
2: OR 2	2.98 ± 1.93^{a}	4.97 ± 2.43^{b}	4.72 ± 2.31^{b}	4.01 ± 2.55^{ab}
1: NO 1	4.53 ± 2.11^{b}	4.28 ± 2.47^{ab}	4.44 ± 2.11^{ab}	2.80 ± 1.98^{a}
2: NO 2	6.30 ± 2.38^{c}	3.31 ± 2.56^{a}	3.43 ± 2.03^{a}	4.20 ± 2.47^{b}

Means are average rating scores of 36 panelists using a 10cm line scale (1cm indicates low attribute intensity and 10cm indicates high attribute intensity) for the attributes. Values with different superscripts within the same column are significantly different ($p < 0.05$)

4.4 Shelf-life analysis of canned peanut soup base

Optimization of processing operations does not necessarily mean the product is completely stable. It only contributes to the manufacturing of products with consistent properties in terms of the final appearance.

The next aspect of product development after the various optimizations are done is to conduct a shelf life studies to estimate approximately how long the product would stay on the shelf before it starts to deteriorate. Temperature was the main factor selected because aside water activity, humidity and the type of packaging, temperature is one key factor which affects most food materials during storage.

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4.4.1 Sensory evaluation

Sensory evaluation of the product stored at the two temperatures was done before and after storage using 15 trained panelists. A paired t-test conducted on the responses showed no significant differences ($p \leq 0.05$) in product texture at both storage temperatures. However, significant differences ($p \leq 0.05$) were observed for product colour, aroma and thickness at the accelerated storage temperature (55˚C), Table 4.10b. The differences observed at the two temperatures indicate that the panelists could detect changes in product sensory attributes after the storage period. The results from the sensory were backed up with other objective measurements.

Table 4.10a Paired T-test for sensory attributes of canned peanut soup before and after storage at 27 °C for a period of eight (8) weeks

Attribute	Mean difference	95% CI for mean difference	p-value
Colour	0.85 ± 1.49	(0.02, 1.67)	0.045
Aroma	0.83 ± 2.79	(-0.71, 2.38)	0.267
Texture	0.53 ± 2.43	(-0.81, 1.88)	0.410
Thickness/consistency	-0.27 ± 3.84	(-2.39, 1.85)	0.787

Table 4.10b Paired T-test for sensory attributes of canned peanut soup before and after storage at 55 °C for a period of eight (8) weeks

Attribute	Mean difference	95% CI for mean difference	p-value
Colour	-5.34 ± 1.86	(-6.37, -4.31)	≤ 0.001
Aroma	-4.05 ± 2.65	(-5.52, -2.58)	≤ 0.001
Texture	0.40 ± 2.38	(-0.92, 1.72)	0.525
Thickness/consistency	-4.01 ± 2.03	(-5.13, -2.88)	≤ 0.001

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The colour of the product after the eight week storage period at 55˚C had darkened as compared to those stored at 27˚C. Darkening of the product at elevated storage temperature could be associated with non-enzymatic browning. The aroma of the products stored at 55˚C weakened after the eight week storage period and this could be associated with rancidity development as evidenced in the increase in both peroxide value and free fatty acid content due to the high temperature. Panelists observed major changes in product stored at 55˚C.

4.4.2 Effect of storage temperatures on colour of canned peanut soup base.

Figure 4.6 shows the trend of L-values recorded for the canned peanut soup base at the two storage temperatures for the 8 week duration. The baseline colour of the product (before storage) L=54.56. For products stored at 27˚C, a fairly constant colour (L-value) was observed throughout the entire 8 week storage period.

For canned peanut soup base products stored at 55˚C (accelerated storage temperature), a decrease in colour (L-value) after the first week of storage was observed. This decrease was lower as compared to first week of products at 27˚C. The product's colour (L-value) continued darkening (decrease in the L-value) throughout the 8 week storage period with a sharp decrease occurring at week 5 through to week 8 (Figure 4.6).

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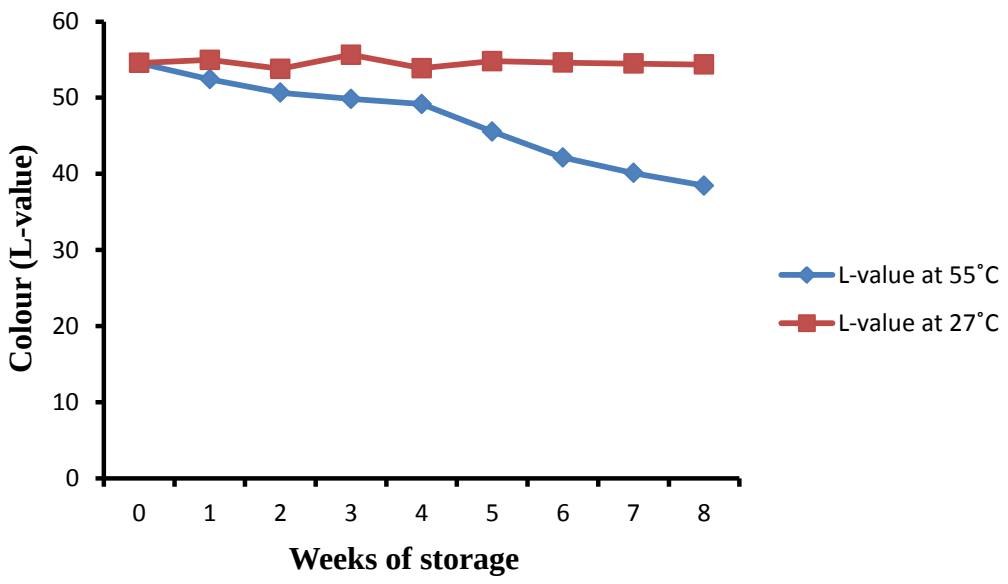

Figure 4.6 Colour (L-value) of canned peanut soup base stored at two different temperatures for a period of eight (8) weeks

A comparison made between canned peanut soup base stored at 27˚C and those stored at 55˚C, revealed that colour of products stored at the latter temperature became darker throughout the 8 week storage period but those at the former still had almost the same colour as that of the baseline. This means the increase in storage temperature had an effect on the product colour during the storage period. The decrease in colour (L-value) of canned peanut soup base stored at 55˚C could be associated with non-enzymatic browning reaction (Millard reaction). This is because at 55˚C, the amount of heat comparably was higher (about 3 times) than at 27˚C and this caused the formation of melanoidin compounds which darken the colour of the soup base. Also there is the theory of temperature quotient which states that an increase in temperature by 10˚C causes the rate of reactions to double up (Seward and DeVries, 2008). This means the rate at which the melanoids formed was about three times that of 27˚C and this gives a clear indication

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about the drastic change (decrease) in product's colour (L-value) right from week 1 at 55˚C as compared to those stored at 27˚C.

The results obtained from the sensory tests confirm observations of the objective colour (L-values). The panelists were able to detect changes in the product colour stored at 55˚C (Table 4.10b). From these observations, it could be stated that the product in terms of its colour becomes undesirable if stored at high temperatures in that the colour darkens (L-value) decreases for a period of time.

4.4.3 Effect of storage temperatures on peroxide value of canned peanut soup base

The peanut soup base is a high lipid content product, and a cause of storage instability could be lipid oxidation. Consequently indices of lipid oxidation were monitored during the storage at 27 and 55˚C. The average peroxide value (PV) was 2.055 for the freshly processed canned peanut soup base. At the end of the 8 week storage period, the PV for canned peanut soup base products stored at 27˚C increased gradually throughout the 8 week storage period (Figure 4.7). The PV content for products at 55˚C however saw a much drastic increase for the entire 8 week period of storage.

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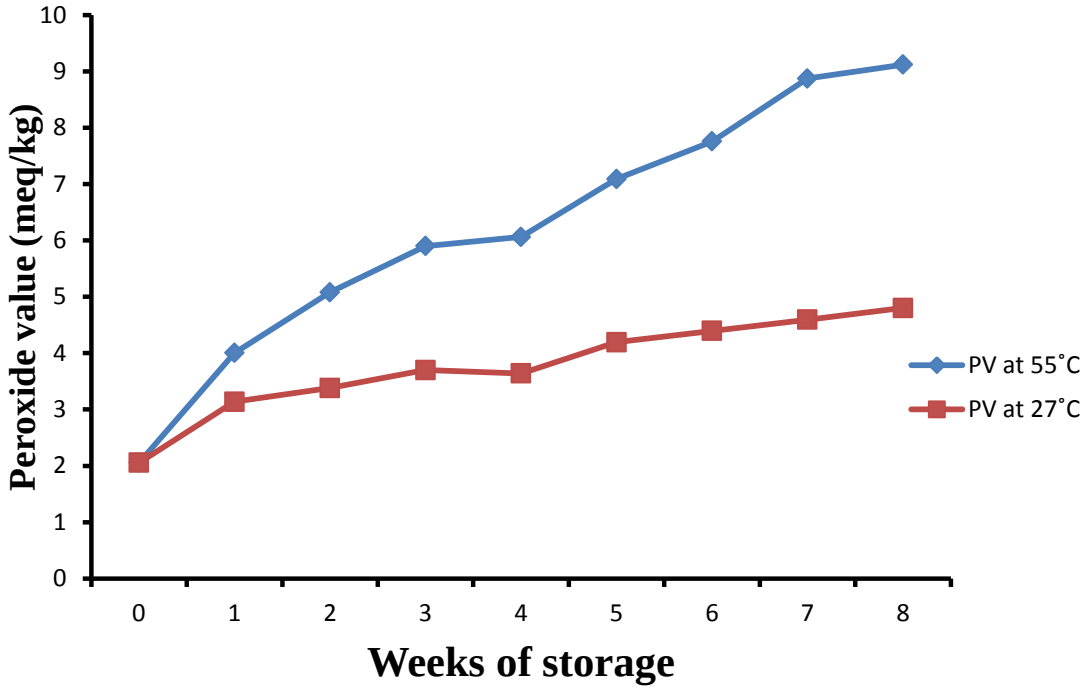

Figure 4.7 Peroxide value (PV) of the canned peanut soup base at two different temperatures for a period of eight (8) weeks

In the canned peanut base soup, oxidation is bound to occur due to the presence of moisture and this could be attributed to the increase in PV of products stored at the two temperatures (27 and 55˚C) and the higher the temperature the higher the effect as observed in Figure 4.7. According to Lea (1962), rapid oxidation is stimulated by factors like air, light and heat amongst others. Thus heat with respect to the accelerated temperature (55˚C) becomes a major factor aside the oxygen and moisture within the product.

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4.4.4 Effect of storage temperatures on free fatty acid (FFA %) values of canned peanut soup base

Free fatty acid is the percentage by weight of a specified fatty acid, for example oleic acid. Free fatty acids determination is used to monitor lipid hydrolysis especially in oils/fat and also fat containing foods. Though there were increases in FFA% of the products stored at both temperatures, those of 55˚C were comparably higher than those stored at 27˚C (Figure 4.8). These higher free fatty acid contents for products stored at the accelerated temperature of 55˚C could be associated with the high storage temperature as well as the moisture content of the product. These aided the hydrolysis of the fatty acids from the triacyl glyceride molecules to increase the free fatty acid content.

The free fatty acid value of canned peanut soup base stored at 27˚C increased from 0.54% to 1.40% from week 1 to week 8 respectively. The increase was gradual at this temperature for the entire storage period as compared to those observed for products stored at 55˚C. Even though those at 55˚C recorded large increase in their free fatty acid values, a sharp increase was observed at week 5 (Figure 4.8).

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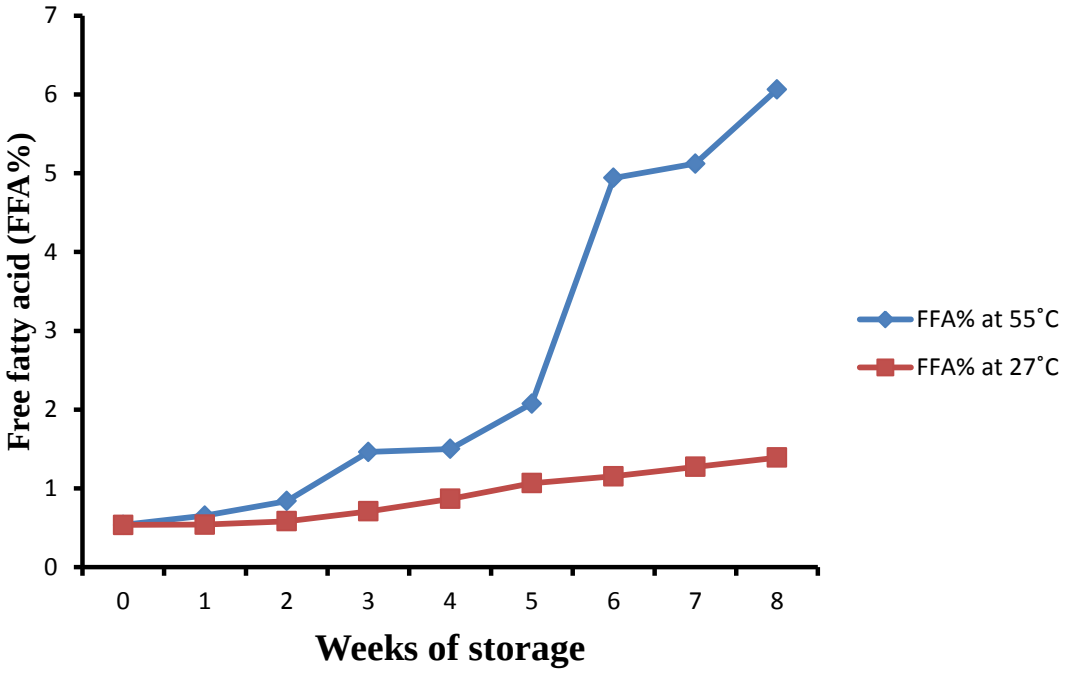

Figure 4.8 Free fatty acid (FFA %) content of canned peanut soup base product stored at two different temperatures for a period of eight (8) weeks

4.4.5 Effect of storage temperatures on pH of canned peanut soup base

pH is a parameter used to determine the acidity or alkalinity of a given solution. In food manufacturing and preservation, foods are categorized into high acid and low acid foods. The canned peanut soup base falls into the low acid food group together with other food products like meats, seafood and milk and other soups. Low acid foods are those with pH greater than 4.60 (Galvin *et al.*, 1995).

The pH of products stored at 27˚C increased slightly from week 1 to week 5 and remained almost constant from week 6 to week 8 but those stored at 55˚C rather revealed an almost constant pH (as compared with baseline pH of 5.00) for the first four weeks after which a sharp

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decrease in pH occurred at week 5 which increased slightly and remained constant up to week 8 (Figure 4.9).

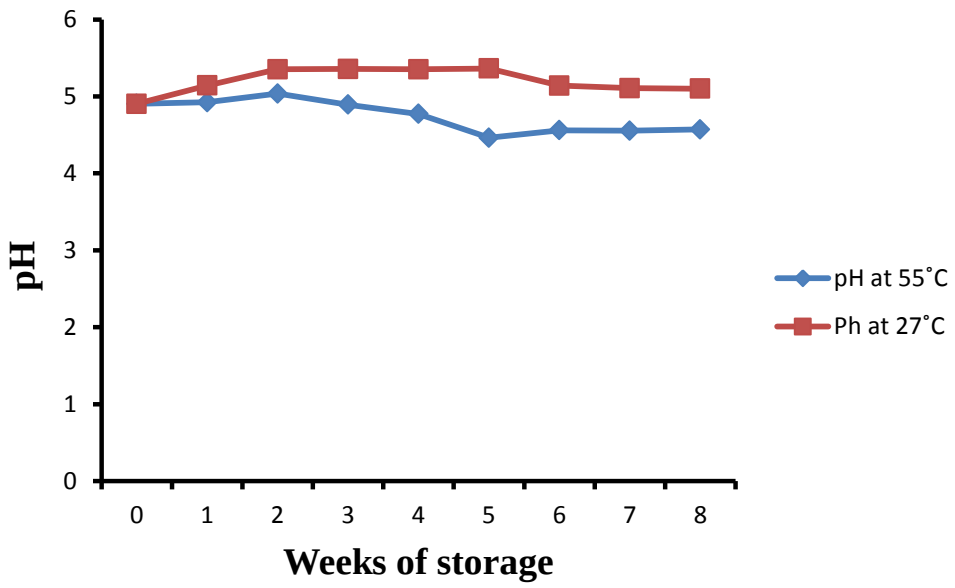

Figure 4.9 pH of canned peanut soup base product stored at two different temperatures for a period of eight (8) weeks

The decrease in pH at week 5 for products stored at 55˚C could probably be as a result of the formation of free fatty acids in the product during storage. According to Wrolstad *et al.* (2005), free fatty acid measures the amount of free acid groups existing in fat/oil as well as fat/oil containing foods. Though fatty acids are the predominant source of free acid groups, some other acid groups including acid phosphate and in some case some amino acids are also present (Wrolstand *et al.*, 2005). All could have contributed to the decrease because at that high temperature as well as the high moisture content of the canned peanut soup base, the formation of these free acid groups increased and as a result caused a slight reduction in the product's pH.

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The slight rise and fall in pH for those stored at 27˚C could be due to variations in temperature at which pH readings were taken.

4.4.6 Shelf life calculations

The prediction of a product's shelf life is an indication of the time that the producer could expect his/her product to stay on the shelves and depending on the product distribution chain temperature (s), different commercial shelf lives could be predicted (Sinigaglia *et al.*, 2003). The importance of the storage temperature is very apparent and a careful control of storage temperature, together with the use of high quality raw material, is among the principal tools to achieve a high production standard and acceptable shelf-life.

The shelf life of the canned peanut soup base was calculated using the Arrhenius theory which relates temperature influence to the rate constant of reaction rates. Free fatty acid values were selected as the shelf life predictor. This was because the rate of lipid deterioration, as free fatty acids (Figure 4.8) showed a sharp increase at week 5 and could be used as a cut-off point for the onset of product deterioration at the accelerated temperature storage. The values obtained for free fatty acids at both temperatures (27 and 55˚C) were converted into logarithmic forms and plotted against the storage weeks to obtain a plot similar to an Arrhenius plot (Figure 4.10)

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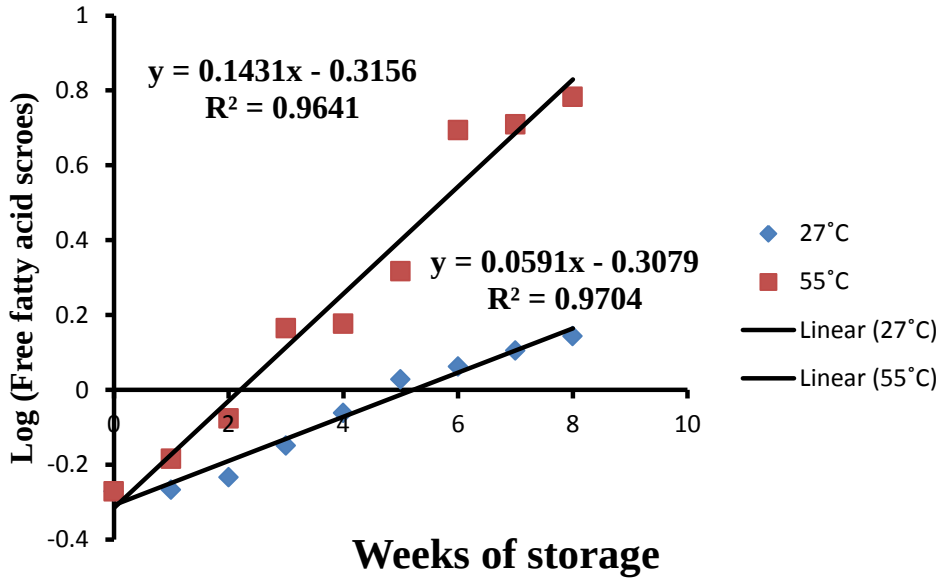

Figure 4.10 Arrhenius plot for free fatty acid content during storage of canned peanut soup base at 27˚C and 55˚C

The Arrhenius plot was transformed into a shelf life plot (free fatty acid degradation graph), Figure 4.11 and this was used in the calculation of shelf life for the canned peanut soup base as 67 weeks. This was done taken into consideration the 50-70% safety margin in setting of product shelf life (Patrick, 2000).

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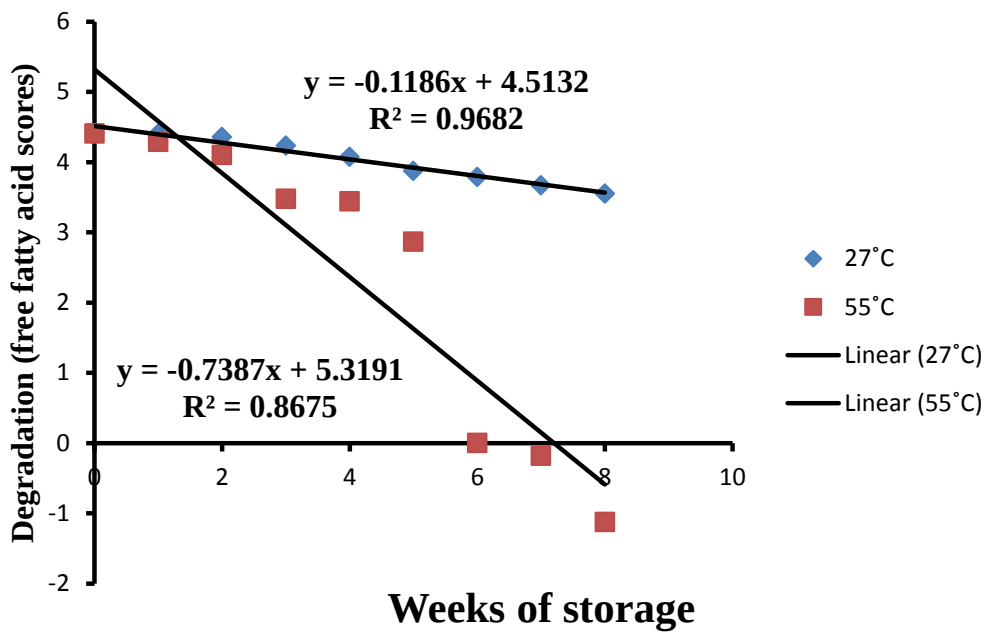

Figure 4.11 Shelf life (degradation) plots for canned peanut soup base

4.5 Consumer survey and evaluation of canned peanut soup base product

Just like any newly developed food product, the canned peanut soup base had to undergo a consumer product evaluation to find out consumers views and comments about the product. In view of this, an assessment form was generated to help obtain responses with respect to the product as well as their rating and acceptance level of product's final characteristics. 50 peanut soup consumers were randomly selected within Accra and Koforidua metropolis for the product evaluation.

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4.5.1 General information on peanut soup preparation at home

The first part of the questionnaire dealt with general information about peanut soup preparation at home. Responses obtained from the question, "how long does it normally take to prepare groundnut/peanut soup?" revealed that the time required for most consumers to prepare peanut soup was 45-60 minutes or above 60 minutes (88%) with only 12% using between 30-40 minutes to cook peanut soup (Figure 4.12).

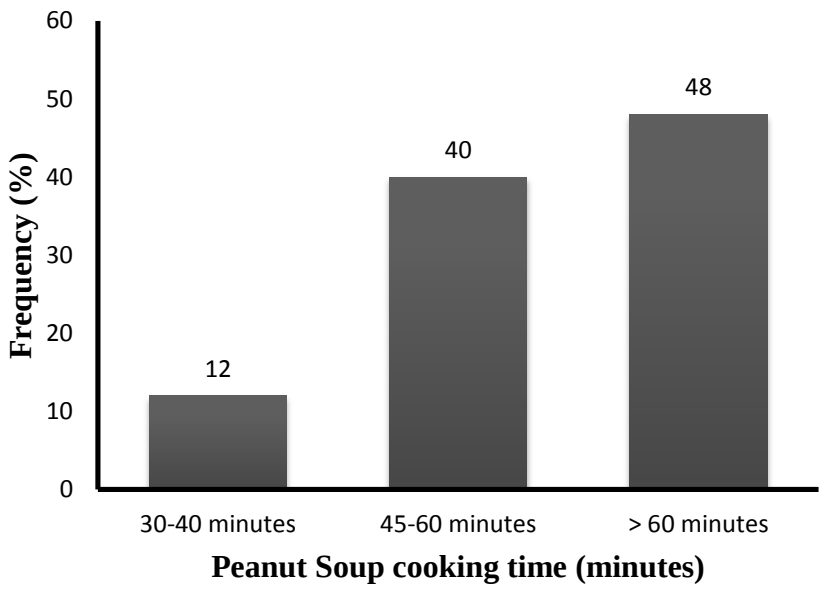

Figure 4.12 Time duration generally used by consumers in preparing peanut soup at home

These responses were seen to be based on the quantity of soup prepared and the time taken for it to cook well (reach their desired consistency and taste). This was observed from a follow up question on the quantity of soup prepared at home and how long it takes to cook well (Table 4.11). It was observed that more time was spent in preparing larger quantities of soup than for

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smaller quantities. One of the consumers at that section stated that "she prepares soup that would be enough to serve about 7 people and uses close to 105 minutes (1 hour 45 minutes)". These responses differed from one consumer to another but in the end, the observation made was that most consumers use more than an hour (60 minutes) in preparing peanut soup with a few using below 60 minutes (Table 4.11).

Table 4.11 Quantity of peanut soup prepared at home and time spent in the preparation (n = 32)

Amount of peanut soup prepared (ml)	No. of Respondents	Time spent in preparing that amount of peanut soup (minutes)
1000-1305 ml	5	30-45
1500-1740 ml	3	45
2272-2610 ml	3	52-60
3000-3480 ml	5	55-70
4350-4567 ml	2	80
5000-5220 ml	5	96
6090 ml	9	90-120

1 canned peanut soup base can = 870 ml

Concerning the type of spices used for seasoning the meat or fish used for preparing their peanut soups, three main spices which included ginger, onion and garlic were listed by almost every consumer. Other spices mentioned were pepper, onga 3 in 1 mix, badia and benny seasonings and maggi cubes (different types). Some also mentioned that they use some amount of salt to season their meat/fish to make it tasty.

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4.5.2 Canned soup base assessment

The second section of the assessment form contained questions pertaining to the canned soup base. Consumers were asked questions with respect to the usage of the canned peanut soup base in soup making.

With regards to reconstitution of the peanut soup base with the addition of extra water during preparation (aside the amount stated in the instructions), 52% of consumers responded that they did not add extra water, but the remaining 48% representing 24 consumers said they added extra water during soup preparation (Figure 4.13).

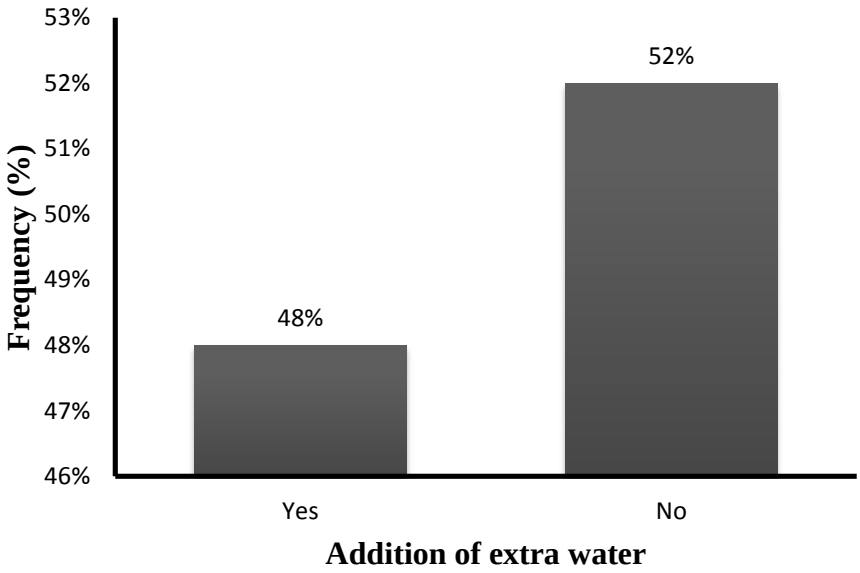

Figure 4.13 Percentage of respondents who added extra water during preparation of soup from the canned soup base

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For consumers who said they added extra water, a further question was asked to find out the amount of extra water added and the reasons for the addition. Responses to this question revealed that most of the consumers added one more can of water (870 ml water) during the preparation of their soup with the canned soup base. Generally, it was observed that the amount of water added as extra ranged between 217.5 ml (1/4 product can) to 2,175 ml (2.5 product can), Table 4.12. Their reasons for adding the extra water was because after adding the amount stated in the instructions, the consistency of the soup was still too thick, and needed to be thinned down with extra water.

Table 4.12 Amount of extra water added during soup preparation using the canned peanut soup base (n=24)

Amount of water (millilitres)	Number of consumers who used that amount of water	Reasons for addition of extra water
217.5 ml	1	The peanut soup base was thick
435 ml	2	
500 ml	2	
870 ml	12	
1,305 ml	4	
1,740 ml	2	
2,175 ml	1	

Note: 1. The volume of product can is equivalent to 870 ml of water

2. The canned peanut soup base has about 36% solids

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4.5.3 Cooking time for peanut soup

Table 4.13 shows the number of consumers who responded either 'Yes' or 'No' to the question as to whether they needed extra cooking time during soup preparation using the canned soup base (that is when the soup base concentrate was diluted with water), apart from the cooking time specified in the instructions. The additional time required by respondents ranged between 5 minutes to 40 minutes (Figure 4.14). Adding the extra cooking time to the specified one in the instructions for cooking peanut soup from the canned peanut soup base implies that peanut soup can be made from the peanut soup base within time duration of 45-80 minutes by most consumers. This confirms that most consumers generally prepare groundnut/peanut soup either between 45-60 minutes or above 60 minutes (Table 4.11).

Table 4.13 Assessment on whether the time given to cook the canned peanut soup base product was enough

Response	No. of respondents	Frequency (%)
Yes	25	50
No	25	50
Total	**50**	**100**

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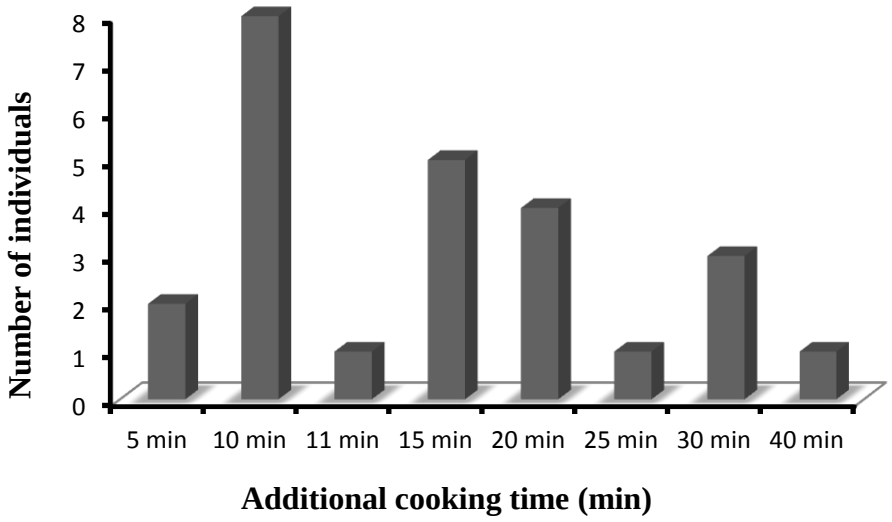

Figure 4.14 Time added to cooking peanut soup from the canned peanut soup base (n=25)

4.5.4 Serving size of canned peanut soup base

Consumers' responses concerning the number of people the soup prepared from the canned soup base product can serve indicated that the soup could serve between 2 to 14 individuals (Table 7.5.2 at appendix 7.5). When asked whether the soup prepared from the canned soup base was consumed within a day, only 9 respondents, representing 18% of the consumers stated that soup prepared from the canned soup base was consumed within a day with the remaining 41 (82%) stating 'No', that is the soup was not consumed within a day. A further question about whether the rest of the soup was enough to feed the entire household again revealed that 24 out of the 41 consumers responded "Yes" with 17 saying "No". This they explained had to do with the number of individuals within the household and also the quantity/amount of soup consumed by each individual when eating.

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4.5.5 General product rating

More than 50% of the consumers rated the product from excellent through to very good and good (Figure 4.15) with the remaining (6%) rating it as average and needing some more improvement. This provides a positive response from consumers about the newly developed canned peanut soup base.

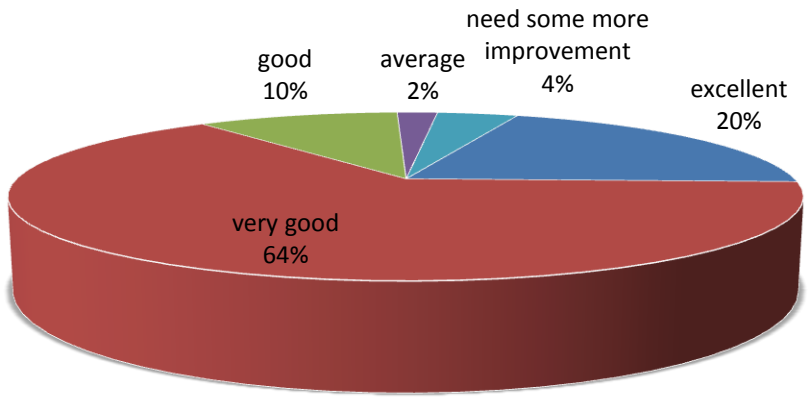

Figure 4.15 General rating of the canned peanut soup base product

For the product recommendation section, only one consumer was not sure about recommending the product to either a friend or relative. His reason for this response was that, "he preferred peanut soup prepared with fresh tomatoes and not from tomato paste". The remaining 41 responded that they would recommend it to a friend/relative. The two main reasons stated by almost every consumer as to why they would recommend the product to others were:

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- It is easy to prepare and also very convenient
- It saves time and energy in the kitchen

Other reasons which were stated aside the two main above also included:

- Very good and taste very nice
- Rich, neatly prepared and of high quality
- Gives the original traditional taste of peanut soup
- Less mess in the kitchen and also less stressful
- Contains all the basic ingredients used for peanut soup making (everything mixed already)
- For him/her to try and see if he/she likes it

Some general comments which were stated by consumers concerning the canned peanut soup base at the comment section also included the following:

- Smaller cans should be manufactured for those who may not be able to use all of the big can at once as well as those who are single
- Very innovative idea and hope to see it on the market soon
- Very good for working mothers and bachelors
- Product is good especially for Ghanaians outside the country
- Makes life very easy and simple in the kitchen
- A very good product and ingredients are moderately chosen and also well packaged
- Product should be registered and produced on a large scale for export and local consumption

4.5.6 Preference and attribute intensity of soup from canned peanut soup base

The sensory attributes of soup prepared from the canned soup base in terms of their intensities and acceptability were also assessed by the consumers. For overall acceptability of soup prepared from the canned, 58% of the consumers scored it as “like very much” (using the 9-point hedonic

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scale) with 20% and 12% scoring it as “like extremely and like moderately” respectively (Table 4.14).

Only few consumers disliked the attributes with respect to the soup prepared from the canned peanut soup base. Their reasons were that they preferred peanut soup prepared from fresh ingredients rather than processed ones.

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Table 4.14 Assessment of soup (prepared from canned peanut soup base) attributes acceptability and overall acceptability

	Sensory attributes (No. of respondents and frequency (%) n = 50					
9-point hedonic scale	**Colour**	**Aroma**	**Flavour**	**Taste**	**Pepper**	**Overall acceptability**
Like extremely	7 (14%)	7 (14%)	7 (14%)	14 (28%)	7 (14%)	10 (20%)
Like very much	29 (58%)	28 (56%)	27 (54%)	28 (56%)	5 (10%)	29 (58%)
Like moderately	12 (24%)	10 (20%)	13 (26%)	5 (10%)	10 (20%)	6 (12%)
Like slightly	-	2 (4%)	1 (2%)	2 (4%)	6 (12%)	2 (4%)
Neither like nor dislike	1 (2%)	2 (4%)	1 (2%)	1 (2%)	6 (12%)	1 (2%)
Dislike slightly	1 (2%)	1 (2%)	1 (2%)	-	7 (14%)	-
Dislike moderately	-	-	-	-	6 (12%)	2 (4%)
Dislike very much	-	-	-	-	3 (6%)	-
Dislike extremely	-	-	-	-	-	-

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The intensity ratings for soup colour are shown by Table 4.15. The other soup attributes intensity ratings are shown in appendix 7.5.

Table 4.15 Response from assessment of product on colour intensity of soup prepared from canned peanut soup base (n = 50)

Colour intensity score	No. of Respondents	Frequency (%)
Very light brown	6	12
Moderately light brown	16	32
Slightly light brown	18	36
Just right	8	16
Slightly dark brown	2	4

One attribute that received a lot of comment was the pepper intensity (the amount of pepper) within the product. From Figure 4.16, it may be noted that most of the consumers rated the product as not having enough pepper (not hot). It can be seen generally that the pepper intensity was rated from “slightly not hot” to “not hot”.

The responses give an impression that those who rated the product as “very hot” were probably individuals who did not like pepper in general and to them, that amount made the product very hot (had too much pepper). Those who rated the product as “not hot” commented that if possible there should be two types of product: one with pepper and one without or with the same level of pepper as this or if possible the amount of pepper could be stated on the can so that those who think it is not enough could add more to their taste.

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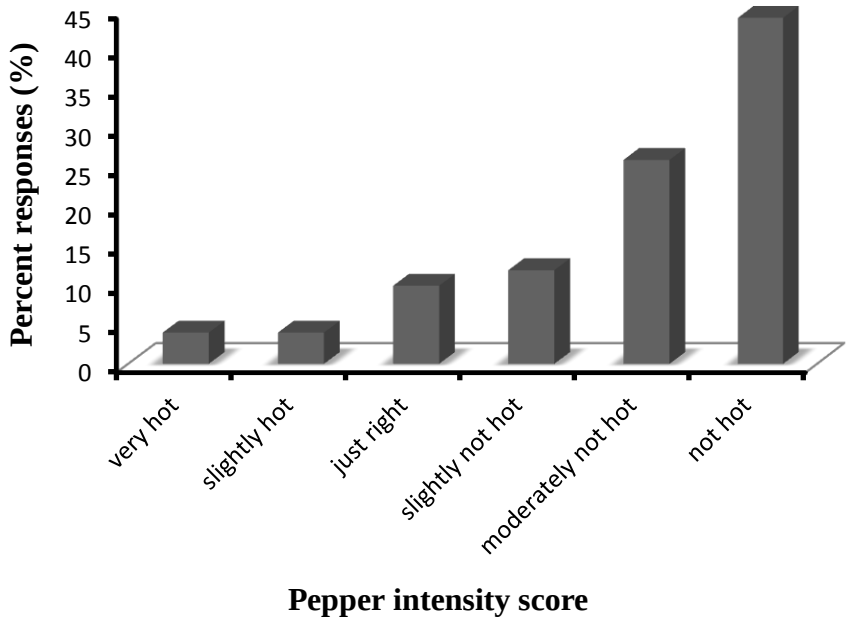

Figure 4.16 Pepper rating of soup prepared from canned peanut soup base

4.6 Proximate analysis of canned peanut soup base

The proximate analysis determined on the canned peanut soup base included moisture, fat, protein and ash content as well as total crude carbohydrates. Table 4.16 shows the values for the various chemical compositions of the product.

Generally, the canned peanut soup base is made up of about 64% moisture. The product which has peanut paste as its main ingredient had a fat content of 22% thus due to the addition of the other ingredients which might have diluted some of the fat during processing.

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Table 4.16 Chemical composition (proximate analysis) of canned peanut soup base

Analysis	Mean ± S.D (%)
Moisture	63.96 ± 2.14
Crude fat	21.81 ± 9.00
Crude protein	6.54 ± 0.50
Crude ash	2.27 ± 0.03
Carbohydrate	5.48 ± 0.03

Most phenomena involved in the improvement in or loss of both nutritional and physiological properties of food proteins result from the protein denaturation and chemical modification of amino acids (Finot, 1997). During canning process, the loss of proteins can be due to three possible reasons namely pre-cooking, thermal destruction and diffusion into the liquid in the can. These reasons could have contributed to the protein content (about 7%) observed for the canned peanut soup base (Table 4.16).

Ash content is a measure of the total amount of minerals present within a food. According to NFSS (2010), it is the inorganic remaining substance after the water and organic matter have been removed after ignition. Crude ash content for the canned peanut soup base was found to be 2.3% and this gives an indication about the mineral content in the product.

Carbohydrate content was observed to be about 5.5% (this was done using the difference method). Though peanuts contain up to about 20% carbohydrates, due to the various heating processes from peanut roasting through to product retorting, this amount together with

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carbohydrate contributions from the other ingredients could have decreased due to the non-enzymatic reaction which utilizes sugars and proteins (amino acids) for the production of pigments which contribute to colour and flavour of product.

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CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

i. A peanut roast temperature-time of about 125˚C for 28 minutes could give a desirable peanut paste colour (L-value = 55.20) for an acceptable canned peanut soup base

ii. The thermal process schedule of the canned peanut soup base was established to be as follows: Retort temperature = 122˚C, Retort time = 55minutes, Z = 10˚C and Fo = 3minutes for a tinplate can size of 99 x 118mm.

iii. The canned peanut soup base (concentrate) will store for a period of sixty-seven (67) weeks at a temperature of about 27˚C and still be acceptable to the consumer.

iv. Most consumers showed great interest in the canned peanut soup base and thus awaits its introduction on the market. They explained it would be ideal for working mothers.

v. Consumers rated the sensory attributes of the soup prepared from the canned soup base as "like very much" using the 9-point hedonic scale

vi. The chemical characteristics (proximate composition) of the canned peanut soup base (concentrate) revealed that the product had moisture content of more than 50% (about 64%) with crude fat, crude protein, crude ash and carbohydrate been 21.81%, 6.54%, 2.27% and 5.48% respectively.

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5.2 Recommendations

i. A canned peanut soup base should be developed such that there would be no need for further cooking, and it should be ready to eat (that is ready to use).

ii. A further consumer study could be conducted using a central location approach which would involve more consumers

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7.0 APPENDICES

APPENDIX 7.1 BALLOT SHEET FOR EVALUATION OF CANNED PEANUT SOUP BASE

DEPARTMENT OF NUTRITION AND FOOD SCIENCE

UNIVERSITY OF GHANA

BALLOT SHEET FOR EVALUATION OF CANNED PEANUT SOUP BASE PRODUCT

NUMBER: _____ DATE: _____

INSTRUCTIONS: Read carefully before you begin

You have been provided with 4 coded samples of peanut soups. Please evaluate them from left to right. After tasting a sample, kindly rinse your mouth with the water provided and **wait for about 30s before evaluating the next sample.** *Re-tasting of samples is allowed.*

ATTRIBUTE INTENSITY: Use the line scales to rate intensities of soup attributes by placing a mark on the line and writing the code of the sample on top of the mark.

ACCEPTABILITY: Please rank the intensity of your **liking** of each peanut soup attribute using the scale below:

Scale: **1=like extremely** **6= dislike slightly**

2= like very much **7= dislike moderately**

3= like moderately **8= dislike very much**

4= like slightly **9= dislike extremely**

5= neither like nor dislike

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1. **Colour**
   Observe the colour of the peanut soups provided before you.

   a. **Attribute intensity**: Rank the soups according to intensity of ***colour*** (light to dark brown) by making a tick on the line below and writing the code of the sample above it.

Light brown **Dark brown**

   b. **Acceptability**: Write the codes of the samples in the boxes below in the order in which you have been presented. Indicate your **LIKING** for ***colour*** of the soups by writing the appropriate score from the 9-point hedonic scale in the space below the code.

Sample code				
Score	_____	_____	_____	_____

2. Peanut soup aroma

   a. **Attribute intensity**: Rank the soups according to the aroma intensity (strong peanut soup aroma to weak soup aroma) by making a tick on the line below and writing the code of the sample above it.

Key: *SPSA: Strong peanut soup aroma*

WPSA: Weak peanut soup aroma

SPSA **WPSA**

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b. Acceptability: Write the codes of the samples in the boxes below in the order in which you have been presented. Indicate your **LIKING** for soup aroma by writing the appropriate score from the 9-point hedonic scale in the space below the code.

Sample code	☐	☐	☐	☐
Score	_____	_____	_____	_____

3. Peanut soup flavour

Take a spoonful of the coded peanut soup and sip.

a. **Attribute intensity**: Rank the soups according to flavour intensity by making a tick on the line below and writing the code of the sample above it.

Strong flavour **Weak flavour**

b. **Acceptability**: Write the codes of the samples in the boxes below in the order in which you have been presented. Indicate your **LIKING** for soup flavour by writing the appropriate score from the 9-point hedonic scale in the space below the code.

Sample code	☐	☐	☐	☐
Score	_____	_____	_____	_____

4. Aftertaste

Take a spoonful of the coded peanut soup provided and sip.

a. Attribute intensity: Rank the soups according to perception of ***aftertaste*** by making a tick on the line below and writing the code of the sample by it.

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No aftertaste — Very intense aftertaste

b. Acceptability: Write the codes of the samples in the boxes below in the order in which you have been presented. Indicate your **LIKING** for perception of ***aftertaste*** for the soups before you by writing the appropriate score from the 9-point hedonic scale in the space below the code.

Sample code	☐	☐	☐	☐
Score	_____	_____	_____	_____

5. Overall acceptability

Overall, how much do you **LIKE** each of the peanut soup provided before you?

Sample code	☐	☐	☐	☐
Score	_____	_____	_____	_____

Comments:

…….....
.....
.....

Thank you for your participation!

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7.2 Balanced incomplete block design for t=16, b=20, k=4, r=5, λ=1, N=80

JUDGE NUMBER	SAMPLE															
	(A)1	(B)2	(C) 3	(D)4	(E)5	(F)6	(G)7	(H)8	(I)9	(J)10	(K)11	(L)12	(M)13	(N)14	(O)15	(P)16
1	448	813	976	688												
2					959	714	678	900								
3									172	446	912	646				
4													311	849	873	397
5	659				914				935				772			
6	653					337				674				425		
7	719						543				993				549	
8	826							669				459				554
9		169			919					946					325	
10		293				874			614							289
11		113					917					365	332			
12		961						524			192			889		
13			657		799							334			461	
14			265			896					415					557
15			127				384		771					296		
16			001					919		200			708			
17				011	009						818			023		
18				061		555						871	090			
19				723			559			400						434
20				123				601	711						249	

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APPENDIX 7.3 BALLOT SHEET FOR EVALUATON OF CANNED PEANUT SOUP BASE STORED AT 27˚C AND 55˚C

DEPARTMENT OF NUTRITION AND FOOD SCIENCE

UNIVERSITY OF GHANA

BALLOT SHEET FOR EVALUATION OF CANNED PEANUT SOUP BASE STORED AT TWO DIFFERENT TEMPERATURES

DATE: _____ GENDER: _____

INSTRUCTIONS:

You have been provided with 2 coded samples of canned peanut soup base. Please evaluate them for the following quality indices. Please do not **TASTE** any of the samples.

ATTRIBUTE INTENSITY: Use the line scales to rate intensities of attributes by placing a mark on the line and writing the code of the sample on top of the mark.

COLOUR

Rank the soup base according to intensity of colour (light to dark brown) by making a tick on the line below and writing the code of the sample above it.

Light brown **Dark brown**

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ODOUR/SMELL/AROMA

Take the coded samples before you (one after the other) and smell. Please rank and indicate the intensity that best describes the smell by making a tick on the line below and writing the code of the sample above it.

Strong aroma **weak aroma**

TEXTURE

Take some portion of the samples with the plastic spoons. Feel with your fingers and describe the texture by making a tick on the line with code above it. Wipe hands with tissue after feeling each sample.

Smooth **Rough**

THICKNESS

Stir the samples with the plastic spoons provided. Describe the degree of thickness by making a mark on the line with the code written above.

Thick **Thin**

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APPENDIX 7.4 ASSESSMENT FORM FOR CANNED PEANUT SOUP BASE

DEPARTMENT OF NUTRITION AND FOOD SCIENCE

UNIVERSITY OF GHANA

CANNED PEANUT SOUP BASE PRODUCT ASSESSMENT FORM FOR CONSUMER SURVEY AND SENSORY EVALUATION

Please answer the following questions

General information about groundnut/ peanut soup preparation

1. How long does it normally take you to prepare groundnut/peanut soup?

a. 30-45 minutes b. 45-60 minutes c. Above 60 minutes d. others, specify……..

1b. With respect to Q1a above, could you please indicate the quantity of soup prepared and how much time is spent in preparing that amount

……
……

2. List the types of spices used in seasoning your fish/meat?

……
……..

3. How much water would you use to prepare soup from one (1) margarine tin of peanut/groundnut paste? (use the can size of the base as a standard measure of the water)

……
……..

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INTRODUCTION

You have been provided with a canned peanut (groundnut) soup base to be used for making groundnut soup. The main ingredients are peanut (groundnut) paste, tomato paste, onion, pepper and ginger.

Preparation of peanut soup from soup base

1. Season the fish or meat with the desired seasonings and steam
2. Pour the can of peanut soup base over the seasoned meat/fish
3. Add 1.5 to 2 can-fulls of water into the mixture (depending on the desired thickness) and add salt to taste. Stir and allow boiling for 35-40mins.

(If after 40mins it is not well cooked to your taste, continue boiling to your taste and record the extra cooking time used).

Canned peanut soup base assessment

1. During the preparation of the soup, did you need to add extra water in addition to the amount given in the instructions? a. Yes b. No

2. If Yes, about how much did you have to add using the product can as the weighing object and why?

……

……..

3. Did the product cook well within the time interval stated in the instructions?

a. Yes b. No

4. If No, how much additional time was added to cook the product to the desired taste?

……..

5. How many people do you think the soup prepared from the canned soup base can serve?

……..

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6. Was the soup prepared from the canned soup base all consumed within a day?

   a. Yes b. No

7. If No, was the amount left enough to feed the entire household again? a. Yes b. No

8. How much will you be willing to pay for the product if introduced on the market?

a. GH¢ 4.00 b. GH¢ 4.50 c. GH¢ 5.00 d. others, specify……

9. On the whole, how would rate the product?

   a. Excellent b. very good c. Good d. Average e. Need some more improvement

10. Would you recommend this product to a friend/relative?

a. Yes b. No c. Not sure

11. Give reason(s) for the choice of a particular response from question 10 above

……
……

12. Any other comment

……
……
……

***If any clarification or explanations are needed, please call 0278307685/0546946356 or send an e-mail to genegospel@yahoo.com**

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PREFERENCE AND ATTRIBUTE INTENSITY FOR SOUP QUALITIES PREPARED USING THE CANNED PEANUT SOUP BASE

SAMPLE CODE:

ATTRIBUTE INTENSITY: Rate intensities of attributes by writing the sample code in the box that best describes it.

ACCEPTABILITY: Please rate the intensity of your **liking** of each sensory attribute of the soup prepared from the canned soup base by scoring it using the scale below:

1= like extremely

2= like very much

3= like moderately

4= like slightly

5= neither like nor dislike

6= dislike slightly

7= dislike moderately

8= dislike very much

9= dislike extremely

Colour: Observe the colour of the soup prepared

Attribute intensity: Rate the soup according to intensity of ***colour*** by writing the sample code in the box that best describes it.

Very Light brown						**Very dark brown**

Acceptability: Indicate your **LIKING** for ***colour*** of the soup by writing the appropriate score from the 9-point hedonic scale in the box.

Score: [ ]

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Peanut/groundnut soup aroma:

Attribute intensity: Indicate the intensity of the aroma of the soup prepared from the canned soup base by writing the soup code in the box that best describes it.

Very Strong aroma						**Very weak aroma**

Acceptability: Indicate your **LIKING** for aroma of the soup by writing the appropriate score from the 9-point hedonic scale in the box.

Score: ☐

Taste

Acceptability: Indicate your **LIKING** for ***taste*** of the soup by writing the appropriate score from the 9-point hedonic scale in the box.

Score: ☐

Peanut/groundnut soup flavour:

Attribute intensity: Rate the soup according to intensity of ***flavour of soup prepared from the canned soup base*** by writing the soup code in the box that best describes it.

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Very Strong flavour						**Very weak flavour**

Acceptability: Indicate your **LIKING** for ***flavour*** of the soup by writing the appropriate score from the 9-point hedonic scale in the box.

Score: ☐

Hotness (in terms of pepper)

Attribute intensity: Rate the soup according to intensity of ***hotness*** by writing the soup code in the box that best describes it.

Very hot						**not hot**

Acceptability: Indicate your **LIKING** for hotness of soup by writing the appropriate score from the 9-point hedonic scale in the box.

Score: ☐

Overall acceptability

Overall, how much do you **LIKE** the soup prepared using the peanut soup base?

Score: ☐

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Comment:

……

……

……

Thank you for your participation!

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APPENDIX 7.5 OTHER RESULTS FROM RESEARCH WORK

Table 7.5.1 summary of stepwise selection of roast temperature and roast time

Variable	Partial R-squared	Model R-squared	Mallows C-p	p-value
Roasting temperature (˚C)	0.5330	0.5330	95.6807	< 0.0001
Roasting time (minutes)	0.3165	0.8496	3.000	< 0.0001

Table 7.5.2 Number of people soup prepared from canned peanut soup base can serve (n = 50)

Number of people soup can serve	No. of respondents	Frequency (%)
2	1	2
3	1	2
4	5	10
5	6	12
6	10	20
7	7	14
8	7	14
9	4	8
10	7	14
11	1	2
14	1	2

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Table 7.5.3 Response on aroma intensity of soup prepared from canned peanut soup base (n = 50)

Aroma intensity score	No. of Respondents	Frequency (%)
Very strong	7	14
Moderately strong	15	30
Slightly strong	13	26
Just right	10	20
Slightly weak	2	4
Moderately weak	1	2
Very weak	2	4

Table 7.5.4 Response on flavour intensity of soup prepared from canned peanut soup base (n = 50)

Flavour intensity score	No. of Respondents	Frequency (%)
Very strong	7	14
Moderately strong	18	36
Slightly strong	16	32
Just right	5	10
Slightly weak	3	6
Very weak	1	2

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APPENDIX 7.6 CANNED PEANUT SOUP BASE PRODUCT

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APPENDIX 7.7 LETHALITY DATA FOR DETERMINATION OF F_O VALUE FOR CANNED PEANUT SOUP BASE

The process lethal rates (*L*) product temperature (*T*) was calculated using a reference temperature of 121.1°C and a *z* value of 10°C given by equation (1). The *Fo* value was calculated as the product of the standard time interval (2 minutes) and the sum of the lethal rates (*L*) during the heating and cooling phases (equation 2).

$$L = \text{Log}^{-1}(T - 121.1/10) \quad \text{(1)}$$

$$F_o = 2\,\Sigma\, L \quad \text{(2)}$$

Where *L* - lethal rate, *T* – product temperature at SHP and *Fo* – sterilizing value (Warne, 1988).

Time (min)	Retort temperature (˚C)	Product Temperature (˚C)	Lethal rates (L)
0	30	71.76	0.0
2	50	71.27	0.0
4	100	70.77	0.0
6	122	71.27	0.0
8	122	71.76	0.0
10	122	73.23	0.0
12	122	74.71	0.0
14	122	76.17	0.0
16	122	78.13	0.0
18	122	79.6	0.0
20	122	81.57	0.0
22	122	83.05	0.0
24	122	85.03	0.0
26	122	86.53	0.0
28	122	88.55	0.0
30	122	90.08	0.0
32	122	91.62	0.0
34	122	93.18	0.0
36	122	94.77	0.0
38	122	95.83	0.0
40	122	97.45	0.0

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42	122	98.55	0.0
44	122	100.78	0.0
46	122	101.91	0.0
48	122	101.91	0.0
50	122	103.06	0.0
52	122	104.22	0.0
54	122	105.41	0.1
56	122	106	0.1
58	122	107.21	0.1
60	122	107.82	0.1
62	100	108.44	0.1
64	50	109.69	0.1
66		109.69	0.1
68		110.32	0.2
70		110.32	0.2
72		110.32	0.2
74		110.32	0.2
76		110.32	0.2
78		110.32	0.2
80		109.69	0.1
82		109.06	0.1
84		108.44	0.1
86		107.82	0.1
88		107.21	0.1
90		106.6	0.1
92		105.41	0.1
94		104.22	0.1
96		103.64	0.1
98		102.48	0.2
100		101.34	0.0
102		100.21	0.0
104		99.1	0.0
106		98	0.0
108		97.45	0.0
110		96.37	0.0
112		95.3	0.0
114		94.24	0.0
116		93.18	0.0
118		92.14	0.0
120		91.1	0.0
122		90.08	0.0

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124		89.06	0.0
126		88.55	0.0
128		87.54	0.0
130		86.53	0.0
132		85.53	0.0
134		85.03	0.0
136		84.04	0.0
138		83.05	0.0
140		82.06	0.0
142		81.57	0.0
144		80.58	0.0
146		80.09	0.0
148		79.11	0.0
150		78.13	0.0
152		77.64	0.0
154		76.66	0.0
156		76.17	0.0
158		75.2	0.0
160		74.71	0.0
162		74.22	0.0
164		73.23	0.0
166		72.74	0.0
168		72.25	0.0
170		71.27	0.0
		F_o Value	**3.0**