COLLEGE OF BASIC AND APPLIED SCIENCES
DEPARTMENT OF NUTRITION AND FOOD SCIENCE

DEVELOPMENT AND EVALUATION OF THE FUNCTIONAL, NUTRITIONAL QUALITY AND CONSUMER PERCEPTION AND ACCEPTABILITY OF A SESAME SEED AND PEANUT BASED COMPLEMENTARY FOOD FOR INFANTS 6-24 MONTHS

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DECLARATION

I hereby declare that the work reported in this thesis and submitted at the Department of Nutrition and Food Science at the University of Ghana for a Master of Philosophy in Food Science is my original work. I confirm that it has not been previously submitted for a degree at any Higher Education Learning Institution.

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DEDICATION

I dedicate this work to my parents

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ABSTRACT

Malnutrition among children is still prevalent in most part of Ghana. This is very common in the rural regions of the country where cereal flour is the main source of complementary food for infants. In light of that, legumes such as cowpeas and peanuts are used to enrich the quality of complementary foods to improve child nutrition. Utilization of legumes in complementary feeding come with shortfalls such as the presence of nutritional inhibitors. In this regard, different processing techniques have been employed to ensure nutrient bioavailability and product acceptability during complementary food development. Prominent among the processing techniques are fermentation, sprouting and roasting. The goal of this work was to investigate the effects of processing methods on the functional and nutritional quality of a sesame/peanut based complementary food. A least cost formulation of complementary food with adequate nutritional profile was obtained using rice, cowpeas, and either sesame or peanuts, by the application of linear programming methodology The solution for the linear programming was to achieve a diet of minimum cost and optimum macronutrient content (protein, fat, carbohydrate and energy) in line with the WHO recommendation for complementary foods for infants between ages 6 to 24 months. Based on the solution to the linear program constraints, one formulation was obtained for products made from peanuts and that made from sesame. The design of the study after obtaining the formulations from the linear program, entailed the following factors: fermentation (fermented and non-fermented rice), sprouting (sprouted and non-sprouted cowpeas), roasting of the peanuts and sesame. The formulations were drum dried to obtain a product that could be milled into flour and easily reconstituted with water into a porridge to feed infants. Physiochemical properties, nutritional profile, in-vitro protein digestibility, mineral bioavailability and phytate levels of all the formulations and drum dried products were evaluated. Microbiological safety evaluation consisted of coliforms, yeast and moulds, *E. coli* and aflatoxin levels. Particle size distributions and moisture sorption behaviour of each flour were studied to assure final product texture (and consistency) as well as flour storage stability (under varying relative humidity’s). Profitability and cost analysis of the products were evaluated to satisfy the minimum cost requirements of the linear programming procedure.

Micronutrient inhibitor (phytate) content was significantly lower in samples containing sprouted cowpeas than in samples containing non-sprouted cowpeas. Samples with sesame seeds showed higher digestibility than those with peanuts. Drum drying increased the water absorption capacity, swelling and solubility indices of the formulations. Formulations using fermented rice and sprouted cowpeas had higher L* values. The total colour difference (ΔE) of the formulations increased after drum drying due to browning. Drum drying of the formulations increased the resistant starch levels from 0.35±0.0 to 4.45±0.04. The average particle size was higher for drum dried products that incorporated fermented rice, sprouted cowpeas with either sesame or peanuts than those that had unfermented rice and non-sprouted cowpeas with either sesame or peanuts. Formulations made using fermented rice and sprouted cowpeas with either sesame or peanuts had higher moisture sorption at room temperature (i.e. more hygroscopic) and may not keep long without good moisture barrier packaging.

The uncooked formulations (flours) containing fermented rice flour were more acceptable to caregivers than when drum dried. Formulations with fermented rice, sprouted cowpeas and either peanuts or sesame were liked less than those with non-fermented rice, unsprouted cowpeas with either sesame or peanuts. However, drum dried formulations containing non fermented rice (and sesame or peanuts) were more acceptable to caregivers.

All the products indicated a positive outcome in terms of cost. However, drum dried samples containing sesame showed the highest net present value of about GH₵161,202 per 10 years processing time. The results suggest that fermentation and sprouting has the potential of

enhancing the nutritive value of complementary foods and acceptable alternative uses for sesame seeds and peanuts for infant nutrition

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CHAPTER ONE

1.0 Introduction

1.1 Background

Germination, fermentation and roasting, are examples of simple and inexpensive traditional processing methods that have been applied over the years in developing countries to develop complementary foods. Their applications require very simple equipment and have frequently been used individually or in combination to improve the quality of complementary foods (Egounlety & Aworh, 2003). These traditional processes impart attributes such as texture, organoleptic quality, reduced bulk, enhanced shelf life and reduced cooking time in food (Ejigui *et al.*, 2007). The processing technologies of fermentation, germination and roasting have also been shown to effectively reduce antinutrients (such as phytates) and enhance the bioavailability of iron and in zinc in cereals and legumes (Luo *et al.*, 2014; Ertop and Bektas, 2018). Extensive research efforts on improving bioavailability, nutritive value and diversification of complementary foods by adopting these processing technologies have been reported (Suri and Tanumihardjo 2016; Ertop and Berta, 2018).

During the process of fermentation, microbial enzymes including proteases, amylases and phytates are activated. These enzyme-induced processes impart technological and nutritional benefits to fermented cereal foods (Poutanen *et al.*, 2009). Germination is known to enhance the nutritional quality of cereals, increase some vitamins, aid in production of enzymes, soften the kernel structure and reduce anti-nutritional factors (Tian *et al.*, 2010). According to Ayernor and Ocloo (2007), the key reason for the germination process is to activate hydrolytic enzymes. Kaukovirta-Norja *et al.*, (2004) showed that, the activity of these activated enzymes during germination results in structural changes and the synthesis of new compounds which have high bioactivity and the potential of increasing the nutritional value of the seed. Previous studies reported that, soaking significantly reduced the phytate, trypsin inhibitor activity (TIA), and tannins levels of legumes (Vijayakumari *et al.*, 2007).

1.2 Rationale

Early childhood nutrition is considered very important, by virtue of its vital role in a child's development (Ghosh *et al.*, 2014). The energy and nutrients in complementary foods are important to fulfil the daily nutritional requirements for infants (Nestel *et al.*, 2003). In most developing countries, complementary foods are made using simple traditional and inexpensive processing techniques (Aworh, 2008). The importance of these traditional processing techniques for cereal-legumes mixes has already been established (Feitosa *et al.*, 2018; Nkhata *et al.*, 2018). This is mostly aimed to reduce the antinutrients in plant based foods.

Cereals-legumes complementation are simple and affordable ways to achieve good quality protein from relatively inexpensive sources. This is partly due to the synergy between these two groups, as cereals are deficient in the amino acid lysine but have enough sulphur-containing amino acid (methionine) which are absent in legumes. As a result, the blend of cereals and legumes are known to give amino acid patterns that sufficiently stimulate proper growth (Suri *et al.*, 2014). In Ghana, studies have been done to assess the synergistic benefits of cereal-legume (millet, sorghum, rice, peanuts, maize) fortifications as well as the extension of roots and tubers in complementary foods (Amagloh *et al.*, 2015; Laryea *et al.*, 2018). However, sesame seeds have not been much utilized in cereal based complementary food, in spite of its good nutritional profile and abundance in Ghana. Sesame seeds are well-known to contain good quality proteins than many legumes and have high quantities of micronutrients including vitamin E, calcium, potassium, phosphorus, vitamin B and iron (Onabanjo *et al.*, 2009). Besides these, they are rich in sulphur containing amino acids, but with limited lysine content (Quasem *et al.*, 2009; Self Nutrition Data, 2010). Sesame seeds also have been associated with numerous nutritionally important compounds including monounsaturated and polyunsaturated fatty acids, dietary fibre, phytochemicals, antioxidants, phytosterol and lignans (Asghar *et al.*, 2014). These compounds have bioactive properties that may contribute to the prevention of diseases such as cancer, cardiovascular disease, osteoporosis, oxidative stress and other degenerative diseases (Asghar *et al.*, 2014). These beneficial functional properties and rich nutritional composition of sesame may make it an excellent component in complementary foods. Thus, its inclusion in a complementary food formulation will help boost the quantity and quality of the protein and micronutrients for infant feeding. It also serves as a substitute for peanuts which can induce varying levels of allergic reactions in some children, compared to sesame. Peanuts were used as control because it is widely used in complementary foods in most developing countries such as Ghana.

Finally, with price surge on imported infant formula's such as Lactogen, Aptamil and SMA, there has been the need to formulate and produce locally cheap but nutritious complementary foods in the country. This will utilize readily available raw materials and as such ensure comparatively cheaper products for the ordinary Ghanaian.

1.3 Main objective

The objective for this study was to develop and evaluate the functional and nutritional qualities of a sesame and peanut based complementary food.

1.4 Specific objectives

The specific objectives are to;

- ✓ Investigate the effect of pre-treatment (natural fermentation, germination, drum drying and roasting) and legume type on the nutritional profile, antinutrient and bioavailability of Iron, Zinc and Calcium of the formulated complementary food.

- ✓ Investigate the effect of pre-treatment and legume type on the physicochemical/functional properties of the formulated and drum dried complementary foods.
- ✓ Determine consumers' perception and acceptability of the complementary food produced.
- ✓ Cost analysis and profitability on the products developed.

CHAPTER TWO

2.0 Literature review

2.1 Importance of complementary feeding

The first 1000 days after a baby is born is marked as an important window for averting undernutrition and other non-communicable diseases amongst children (Martorell, 2017). Complementary feeding is described as a way of progressively transitioning a baby from breastmilk onto semi-solid foods. After 6 months of age, the baby is weaned into semi-solid foods. This six-month guideline has been recommended by the World Health Organisation based on evidence necessitating the importance to young children. (Dewey and Vitta, 2013). According to Kabir *et al.*, (2012), inadequacy in complementary feeding practices has serious effect on a child's growth and development. Moreover, it has been reported that the mortality rate of children under-five can be reduced by 13% with optimal breastfeeding and an estimated six percent or six hundred thousand deaths can be prevented by making sure that complementary feeding is optimally achieved (Dagne *et al.*, 2019). In Ghana, we still battle the scourge of malnutrition due to inappropriate complementary feeding (quality and quantity) being one main cause. Nutrition-related factors are currently the leading cause of the global burden of disease amongst children (Black *et al.*, 2003). A third of children globally are estimated to be stunted and a quarter underweight; this is a situation which is projected to worsen in developing countries (De Onis *et al.*, 2004). Study conducted by the Ghana Health Service in 2008 reported that one-fourth of infants in Ghana receive no complementary food until nine months of age (Ghana Statistical Services, 2009). In light of this, a lot of researchers have considered complementary feeding as a very effective intervention to significantly help reduce the incidence of stunted growth and build a stronger early immune system (Dewey & Adu-Afarwuah 2008; Suri *et al.*, 2014). Taking cognisance of the importance of this feeding, the WHO has projected that infants should be breast fed exclusively up to 6 months, then after this period infants can be transitioned onto complementary foods that are nutritionally safe and adequate. This should be in conjunction with breastfeeding for at least 2 years (Ghosh *et al.*, 2014).

2.2 The concept of cereal-legume blends in complementary foods

The high prevalence of undernourished infants has led to the use of cereal legume blends with adequate protein contents for complementary feeding. These blends have been relied on for infant nourishments, particularly in Africa, and Ghana. It is consequently not unexpected that a number of cereal-legume based mixes are starting to flood the Ghanaian market as complementary foods in recent times. Blends of cereals and legumes supply relatively good and adequate proteins and energy due to the fact that legumes supply lysine known to be lacking in cereal and the cereals in return give the amino acids cysteine and methionine to augment the low levels in legumes (Mensa-Wilmot *et al.*, 2003). However, legumes are rarely utilized for complementary food due to their impacts of discomfort and indigestibility in children (Adeyemo and Onilude, 2018).

2.3 Nutrient requirements of complementary food

Scarcity and poor quality of some complementary food, suboptimal feeding practices coupled with frequency of infections have been identified as important negative contributory factors to the health and growth of infants. There is strong evidence that stunted growth occurs even in exclusively breastfed infants after the 6 months due to the introduction of insufficient quantities of nutrient-dense complementary foods (Dewey and Vitta, 2013). Due to these observations, several researchers have suggested that greater emphasis must be placed on dietary quality instead of the weight of food. (Hoppe *et al.*, 2003). Thus, there is a need to focus on both the quality and quantity of the weaning foods during the formulation process. The attributes of a complementary food that determines its quality are energy density, macro and micronutrient content, micronutrients availability, protein digestibility, absence of, or minimal antinutritional factors and food texture appropriate for that age. Ugwu (2009) also documented that, a qualified complementary food should fulfil qualities such as a good density, soft or semi-solid in texture, complete in nutrients, utilizable in the child's body and easy availability. Emphasis has been placed on protein and energy needs due to the risk of protein-energy malnutrition (PEM) and retardation in the linear growth of children in the developing world. As a consequence, over reliance on cereals and root crops in the poorer areas in developing countries has resulted in increased prevalence of vitamin A, iron and zinc deficiency. Dewey (2002) reported that, a well constituted complementary food must be rich in energy and micronutrients especially iron and zinc, and because these are essential for optimum growth, they must adequately meet the nutritional requirements of the child. Hence, fortification of complementary foods with micronutrients is a strategy adopted to meet the daily requirement of infants and young children (Añorve-Valdez *et al.*, 2018).

2.4 Ingredients (cereal and legumes) used in formulating complementary foods

2.4.1 Rice

Rice (oryza sativa) has been named as the second commonly cultivated cereal and staple globally (Muthayya *et al.*, 2014) with the lowest sodium content in comparison to other basic foodstuff. Besides the aforementioned nutritional attributes of rice and rice products, the uniqueness of rice starch and rice flour also contributes to their versatility as a food product. Rice starch granules are the smallest in size compared to other cereal starches and results in a smooth, creamy, short-textured paste and clean taste (Wani *et al.*, 2012). Starches from rice are usually very stable in food products. This is used in many applications in the food industries as coating agents, water binders and flavour enhancers. Rice proteins contains high amount of lysine compared to that in other cereals (Vasal, 2004). These characteristics has made rice flour very suitable in infant food production. However, in use for growing children, rice will require addition of other leguminous protein sources such as from peanuts, cowpeas and soybeans to complement the limiting amino acid. The low allergic potential makes rice relatively safe for use in baby foods.

There have been many works done on rice-based complementary foods. Munasinghe *et al.*, (2012) studied formulations made using three extruded yoghurt-based complementary foods and blending with brown rice, soybean, mung bean and powdered milk. In their study they compared the products with cerelac a commercially produced infant food. They concluded in the study, that combinations of these ingredients are good approach in targeting malnutrition alleviation in developing countries. A similar study was conducted by Eshun *et al.*, (2011) by combining rice with soybeans and groundnuts They concluded from their study that this combination could also be used to reduce malnutrition in the developing countries. Ikujenlola and Fashakin (2005) investigated the functional properties of a rice, germinated corn flour and cowpea meal blend for complementary food. They reported that combinations made using germination method resulted in marked lowering of paste viscosity from >10,000 cps to 3000 cps at 10% DM.

2.4.2 Cowpeas

Cowpeas (*vigna unguiculata*), which is a versatile crop are among the most important cultivated legumes and has proved to have better agronomic advantages and good complementarity in foods (Islam *et al.*, 2008*;* Uarrota *et al.*, 2019). Cowpea grain contains approximately 23–32% protein and 50–60% carbohydrate (Jayathilake *et al.*, 2018). The significant protein, calories and some water-soluble vitamins content, makes cowpea a potential food ingredient (Devi *et al.,* 2015). The development of low-cost high protein food supplements from combination of locally available cereal-legumes that treated through different processing methods has offered a viable solution in developing countries to the limited access to animal proteins (Mohammed *et al.*, 2016). For this reason, the complementary food blends in Ghana are developed from alternative protein sources such as soybean, cowpea and/or groundnut as means to improve protein and energy levels. Different studies have sought to complement cereals used in complementary foods with cowpeas or other legumes. A study conducted by Ngoma *et al.*, (2018) looked at the processing options for cowpea flour to be incorporated in a cowpea blended maize porridge for infants and concluded that cowpea flour processed by roasting, dehulling and boiling has the potential to offer a useful addition to complementary food for children in sub-Sahara Africa by offering limiting nutrient to the maize.

2.4.3 Sesame seeds

Sesame seeds (*sesamum indicum*) are categorized as oilseeds. They are limited in lysine but rich in other essential amino acids that are of importance to the human body (Self Nutrition Data, 2010). They are largely consumed in the form of a paste and or complemented with other blends in Africa and other parts of the world (FAO, 2009). They come in the form of creamy white colour or as black as charcoal. The seed are also rich in micronutrients such as zinc, iron, phosphorus etc. They are mostly consumed for its perceived health benefits in cancer prevention, hypertension etc. It has also been known to have utility in the management of headaches and migraines, stress, constipation and cholesterol (Self Nutrition Data, 2010).

Sesame is an oilseed that is popularly known as ‘beniseed’ because it contains better quality protein than most legumes, a large amount of vitamin E which is an antioxidant, calcium, potassium, phosphorus, vitamin B and iron (Onabanjo *et al.*, 2009).

Sesame-based complementary foods have been extensively studied by a number of researchers. Onabanyo *et al.,* (2009) formulated a complementary food produced from sorghum, sesame seeds, carrot and crayfish and reported that the composite flour yields products with enhanced functional characteristics and high nutritive value. A study carried out by Adepeju *et al.,* (2016) on developing complementary food from fermented sorghum, germinated soybean and defatted sesame concluded that these local resources have great potential in the formulation and preparation of complementary foods. Okafor et al. (2008) examined the chemical, microbial and sensory properties of complementary foods from a blend of Nigerian foodstuffs and reported that the inclusion of protein from sources like bambara, soybean, sesame and corn yielded complementary food with high protein-energy values and acceptable organoleptic property.

2.4.4 Peanuts

The common complementary foods in many developing countries are known to be low in quality proteins (Abeshu *et al.,* 2016). Supplementation of these complementary foods with grain legumes or oil seeds is one of many strategies to augment its nutritional value (Ghosh *et al.,* 2014). Peanut is high in quality edible oil and a significant source of resveratrol which is a chemical compound known to have a numerous health benefits, such as anti-aging, anti-cancer, anti-inflammatory, antiviral, life prolonging and neuro-protective effects (Meredith and Anderson, 2003). The downside with peanut consumption in children is allergies affecting between 1.8 and 3% of children in many westernized countries (Mateo-Morejón *et al.,* 2017). There seems to be a sudden increase in the number of reported cases in the past 10 to 15 year period. This is an indication that the prevalence might have tripled in some countries including the United States and even developing countries including Ghana. (Nwaru, *et al.*, 2014; Turke, 2017). To limit of allergies, studies suggest introduction of peanuts between the ages of 4 to 11 months (Du Toit *et al.*, 2015; Ferraro *et al.*, 2019).

2.5 Traditional processing methods used in complementary foods production

In developing countries, it is clear that protein-energy malnutrition is not only linked to deficient intake of food but also the nutritional quality (Brown, 1991). The quality of the foods is mostly lined to the availability of good and quality macro and micronutrients. However, with regards to the micronutrients, concerns of high phytates have been the factor compromising the quality of especially plant-based foods (Hotz and Gibson, 2007). In view of the reliance on cereals as the main source of food in most low-income countries, the negative impacts of low mineral bioavailability and associated medical problems are very serious. Strategies and interventions proposed to upgrade food quality are always focused on its practicability and acceptance at the household level due to the poor living standard of majority of people in rural communities. Conventionally, methods such as fermentation, sprouting and heat treatment (roasting) have been linked to reduction of some antinutrients. Strategies to mitigate the issue without compromising on the product viscosity includes incorporating oil and a sugar (non-gelatinized carbohydrates) (Suri *et al.*, 2014). The process of drum drying, and extrusion cooking are not practicable at household level and can be very complicated and expensive to adopt in developing countries where as germination, fermentation, and roasting are simple and cost effective in a sustainable way for the production of complementary foods (Ikujenlola, and Fashakin, 2005).

2.5.1 Germination or sprouting

Germination is the stimulation of the metabolic activity of seed as a result of liquid soaking. This process leads to a number of complex chemical changes such as (a) the breakdown of materials, particularly storage components such as starch and protein, into a more usable form for the growing seed; (b) the transport of materials from one part of the seed to another; and (c) the synthesis of new substances, such as vitamins. These changes alter the flavour, cooking properties, and nutritional quality of foods made from germinated grains. Phytates and lectins (antinutrients) are also degraded resulting in the availability of minerals (Soetan and Oyewole, 2009). Although there is a consensus that malting increases the nutritional value and flavour of cereals and legumes (Baranwal, 2017) it also contributes to loss of minerals and other water-soluble vitamins to the surrounding water through leaching (Nkhata *et al.*, 2018). Germination process results in the release of enzymes that breaks down the starches into simple forms. Germination is attributed to metabolic enzymes including some proteinases which result in the release of some amino acids and peptides leading to the synthesis or utilization of many new forms of proteins by consumers. So, the quality of proteins may be improved by sprouting of legumes and other seeds (Gulewicz *et al.*, 2008).

Investigations by Shah *et al.*, (2011) on the effect of sprouting time on the biochemical and nutritional qualities of two mung bean varieties concluded with an improved nutritional composition in protein and ascorbic acid content. Similar observation was made by Tajoddin *et al.*, (2011) after germinating mung beans and examining the changes that resulted in phytate reduction during the process of germination. Jirapa *et al.*, (2001) investigated the use of germinated cowpea meal with the view of improving the nutritional quality of a rice-based infant complementary food. The result suggested improved protein and starch digestibility. In their study, the protein digestibility corrected amino acid scores (PDCAAS) of the 24 h germinated cowpea meal (GCM) complementary food was found to be higher (55.49%) than that of the control cowpea meal (CCM) complementary food (46.74%) (Jirapa *et al.*, 2001). Vitamin A activity in the 24 h (GCM) complementary food was also found to be higher than in the CCM complementary food. In vitro starch digestibilities of 24 and 48 h GCM complementary foods were higher than that of CCM complementary food. Sensory panellists gave higher acceptability score to the 24 h GCM complementary food as compared to the 48 h GCM and the CCM complementary food. Similar trend was seen in other works carried out by various authors on alternative methods to improve the nutritional composition of products through the method of germination (Tizazu *et al.*, 2011; Berhanu *et al.*, 2015; Okoth *et al.*, 2017). Germination in complementary food has also been studied on its effect on reducing viscosity and bulk of complementary foods (Saalia *et al.*, 2012).

2.5.2 Fermentation

Conventional fermentation makes use of microorganisms found in food and food processing environments such as lactic acid bacteria (LAB), to cause biochemical breakdown of food constituents to produce desirable changes in food. Generally, the bacteria require the use of a food substrate in order to propagate. Fermentation as food preservation technology has long been in existence. Fermented foods have become one of the main dietary components in the developing world (Mosha and Vicent 2004). Consequently, this processing method has gained popularity in developing countries. Natural fermentation occurs in an assorted colony of microorganisms such as moulds, bacteria and yeasts. The resulting fermented products contain compounds that are dependent on the microorganisms involved in the process. Some of the formed compounds during fermentation include alcohols (mainly ethanol), aldehydes and ketones such as acetaldehyde, acetoin, 2-methyl butanol and organic acids like, acetic, butyric, lactic, palmitic, propionic and pyruvic acids. The microbes are not detrimental to human health but produce enzymes such as amylase, lipase and protease that hydrolyse food complexes into simple safe products which in turn impart the desired characteristics of fermented food products (Abiola and Oyetayo, 2016).

2.5.3 Roasting

Roasting is another processing method practised at the household level for a long time; that lead to improvement of flavour, colour, texture and overall acceptability of the product. In the process of roasting, moisture content reduces, and texture becomes hard such that it can easily snap off. If done properly, it can develop desired flavour, aroma and acceptable colour changes (Mridula *et al.*, 2007). Thus, colour is seen as a good indicator of the roasting process in food. Grains (cereals and legumes) are roasted in a hot roasting pan over direct heat at about 140- 150ºC for 3-5 minutes. During roasting, many volatile substances such as hexanal are removed through evaporation. The elimination of such grassy undesired substances and the simultaneous start of maillard reactions result in an attractive flavour. Roasting has a slight viscosity-reducing effect on some cereals, but this is not significant in cereal-pulse mixtures. Tannins, phytic acid and oligosaccharides levels cannot be minimized by roasting. A study conducted by Adeoye *et al.,* (2018) evaluated the quality of complementary food formulated using processing method of fermentation and roasting. They reported an increase in the protein, fat and fibre content with products developed using fermentation method, and an increase in carbohydrate and energy with products developed employing the method of roasting.

2.6 Industrial processing employed in the production of complementary foods

2.6.1 Drum drying and quality parameters of some drum dried products

Drum drying method has been considered as one of the major industrial processing methods in developing instant foods (Valous *et al.*, 2002). The purpose of the dryer was to cook and dry food slurries into flakes (Tang *et al.*, 2003). Thus, it has been used to develop products such as powdered milk, instant baby foods and many more (Kostoglou and Karapantasios, 2003; Pua *et al.*, 2007). There are three types of drum dryers employed at the industrial level namely the single or twin drum dryer, the vacuum drum dryer and the double drum dryer. The vacuum drum dryer is used to dry heat sensitive products. The drum dryers have common components such as the scrapper, feeder and pressure gauge. However, some come with automated compartments to control the pressure and the speed of the dryer (Tang *et al.*, 2003).

There has been works done by many authors using the drum dryer in developing infant foods. Laryea *et al.*, (2018) explored its use in formulating a sweet potato-based complementary food and reported improved effect on the functional and nutritional content after drum drying the formulations. Majzoobi *et al.*, (2011) investigated on altering starches in wheat flour by the process of drum drying. They reported molecular structure changes and crystallinity in the starches after drum drying. Due to that, increased swelling and water absorption was observed.

Among the different types of technologies which are used in processing complementary food products, drum drying technology offers many advantages over other traditional forms of processing, the greatest of which is that it is a continuous process. Also, by varying factors such as ingredients, drum temperature, and residence time, a wide variety of complementary foods can be produced.

2.7 Nutritional bioavailability inhibitors

Legumes form important complements in the development of complementary foods, but they possess antinutrients that impedes the proper absorption of minerals throughout digestion in the body (Michaelsen *et al.*, 2009; Abizari *et al.*, 2012). Thus, in developing countries where the quality of complementary food is of great importance due to the occurrence of malnutrition, mineral bioavailability has become very essential.

There are two major categories of anti-nutrients (secondary plant metabolites): the heat-labile group, such as protease inhibitors and lectins, which are sensitive to usual processing temperatures and the heat-stable group including tannins, alkaloids, pyrimidine glycosides and saponins which are by definition stable under usual processing temperatures. Plant-based foods with high concentrations of anti-nutrients compromise the bioavailability of Fe and Zn (Gibson *et al.*, 2010). Whole grains mostly used in traditional complementary foods in developing countries contains high levels of anti-nutrients and dietary fibre. Milling decreases fibre and anti-nutrients in whole grains. De-hulling legumes that have colour eliminates the polyphenols and phytate. De-hulling again decreases tannins in chickpeas and reduces fibre in other legumes. For unfortified plant-based complementary foods, the level of iron is very significant, and the phytate content is known to decrease the amount of non-haem iron that can be absorbed (Hurrell & Egli, (2010). The inhibitory effect of phytate on non–haem iron and zinc bioavailability has been shown to be dose-dependent (Hallberg and Hulthen, 2000), hence effort has been geared towards identifying methods for reducing phytate levels in foods. Fermentation, sprouting and soaking are examples of some inexpensive methods used to reduce antinutrients. These have all yielded positive results in the reduction of nutritional inhibitors. Bazaz *et al.*, (2016) studied the effect of the method of sprouting in formulating a hypoallergic complementary food and reported that sprouting significantly enhanced protein content and in vitro protein digestibility, subsequently decreasing the antinutrients. James *et al.*, (2018) reported similar results by investigating the effect on both the fermentation and sprouting on the production of millet-based infant formulae.

2.8 Food product development and sensory evaluation

Food product development is a process of developing new food products or improving upon existing ones. It is an integral part of the food industry and has been linked to the business and managerial aspects (Earle and Anderson 2001). According to Stewart-Knox and Mitchell (2003), it is a necessity, if a food industry will want to survive in the current competitive food market. To the food industry, lack of food products development and sensory evaluation will lead to failure. Thus, food industries without food product development or process will have to compete on the market based on price alone, which will in tend favour only the industry with the lowest cost inputs. The increase in population, societal changes and rising incomes have led to changes in consumer choice of food and food preferences (Winger and Wall, 2006). These and other reasons such as health and environmental consideration, convenience, company profitability and technological developments has brought about the existence of new products on the market (Earle and Anderson, 2001). Food product development is usually consumer-driven and is therefore affected by consumer demands. Food companies despite being set up to provide consumers with food products also need to make profits. Food companies therefore resort to new food product development or improve upon existing products already on the market. This direction has led to development of innovative food products and with improvement on existing products to accommodate consumer convenience. New technologies such as freeze-drying, drum-drying and extrusion have also led to the development of instant food products. Some foods are also developed to meet consumer health needs. For example, they may be formulated with reduced fat and salt and increased vitamins and minerals. The process of diversifying the use of other legume substitutes in complementary food development, for example use of sesame seeds in complementary food, would contribute to the improvement of macro and micronutrients needs of consumers.

Food product development usually following the stages in concept evaluation, research, product testing and launching (Stewart-Knox and Mitchell, 2003). These stages may be followed systematically to obtain an efficient process of product development or overlapped to make it less tedious and time saving. Despite these various stages, a consumer-driven product is more likely to survive on the market (Costa and Jongen, 2006). Therefore, a product may be nutritious, health beneficial, convenient and safe for consumption, but as long as it does not appeal to the sensorial attributes of consumers, such product will fail.

2.9 Economic impact of complementary food production

Postharvest losses have been shown to determine physical losses and quality reduction of crops that diminish their economic value and makes them suitable for human consumption. Postharvest losses at its worst can be up to 80% of the total production globally (Abass *et al.*, 2014). Fox (2013) revealed that post-harvest losses are projected to be between only 20-40% in Africa alone. This is worrying due to the already low agricultural productivity in Africa. World Bank added that, sub-Saharan Africa alone loses food grains worth about USD 4 billion every year (Zorya *et al.*, 2011). Hence, by encouraging blends of cereals and legumes or their utilization, not only are we contributing to nutritional security and value addition, but capacity building of farmers is also encouraged.

The issue with affordability of nutritious complementary food in poorly resourced communities has propelled researchers to consider cost, processing methods and the selection of raw materials in formulations. Satter *et al.*, (2013) compared the cost of locally prepared complementary food to that of commercially prepared food. In their findings, they reported a cheaper cost on traditional processed complementary food to that of imported complementary food of the same quality. Pulami and Katwal, (2010) calculated retail price of the complementary food in their study. The contingency cost (10%) and 10% profit margins were considered. From their findings, it was observed that it is possible to develop cost effective traditional complementary food blend. Ijarotimi and Aroge, (2005) calculated cost of soybreadfruit-supplemented food and reported that the cost of producing the soy-bread-fruit-supplemented food ($1.92) was less than that of the commercial complementary foods, i.e. between $5.42 and $12.08. Undoubtedly, looking at these trends, the low-income family cannot afford to produce these commercial complementary foods and for such people an alternative low-cost weaning formula is necessary.

CHAPTER THREE

3.0 Materials and methods

The study employed the use of locally sourced ingredients that is; broken rice, cowpeas, peanuts and sesame. The linear programming method was used to achieve a nutritious, minimum-cost porridge mix with optimum macronutrient content in line with the WHO recommendation for complementary food for infants between ages 6 to 24 months (Dewey and Lutter, 2003). The design of the study after obtaining the formulations from the linear program solution, entailed fermentation (fermented and non-fermented rice), sprouting (sprouted and non-sprouted cowpeas), roasting of the peanuts and sesame. Proximate composition, antinutrients, functional properties, sensory evaluation and cost analysis were evaluated for the products developed.

3.1 Preparation of fermented and unfermented rice flours

Broken rice (*oryza sativa*) was obtained from a local market in Accra, Ghana and sorted to remove foreign materials. 400g of the rice was steeped at room temperature in clean water for 12 hours. Using a sieve, the water was drained and allowed to air dry for 30 minutes and milled with a food disintegrator (HC-300Y, Zhejiang, China). Clean water was added to the rice meal in a ratio of 1:2 to make a dough with approx. 43% of moisture which was then allowed to ferment spontaneously for 24 hours at room temperature. The dough was then spread thinly on aluminium trays and oven dried using the air oven dryer (Gallenkamp OV-160, Gallenkamp Co, England, UK) set at 40°C for 8 hours. The dehydrated dough was allowed to cool and milled using a hammer mill (Brook Crompton, 2-TDA905J, England, UK), equipped with sieve mesh size (1.0mm). The flour obtained was packaged and stored in a freezer at 4◦C until it was used for the product formulation (Figure 3.1).

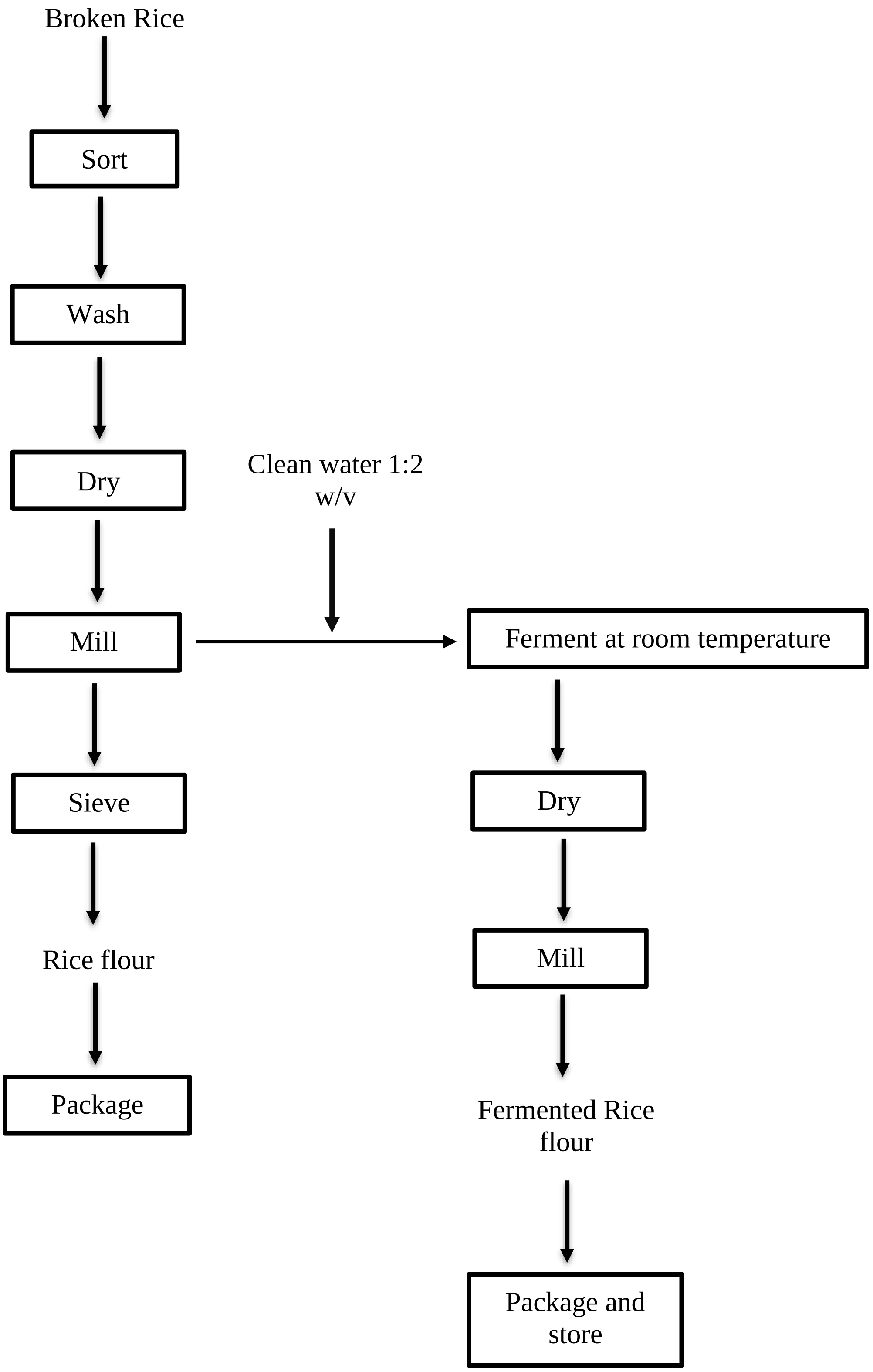


Figure 3.1 Process flow diagram for fermented and unfermented rice flour

3.2 Preparation of roasted and germinated cowpeas

Black eye cowpeas *(Vigna unguculata)* was obtained from madina market, a local market in Accra, Ghana. They were carefully sorted by hand to remove foreign materials and broken seeds. 3 kg of cowpeas were washed in clean water and submerged in clean water (1:5 w/v) for 30minutes at room temperature and then used for sprouting. The water was drained off, and the seeds were kept between thick layers of moistened fibre cloth and allowed to germinate in the dark for 30 hours. Fresh water was sprinkled on the seeds periodically to be sure that the set up remained cool and well hydrated. After approximately 30 hours, the sprouts (shoots and radicles) were broken off and possible moulded seeds were discarded. The sprouted cowpeas were dried in an air oven (Gallenkamp OV-160, Gallenkamp Co, England, UK) at 90-100°C for 50 mins. The beans were then winnowed and milled using a food disintegrator (HC-300Y, Zhejiang, China), packaged in a Ziplock® bag and stored in a refrigerator till it was used for formulation. On the other hand, 2.5 kg of cowpeas (non-germinated) were roasted (120-130°C), milled and packaged in ziplock bags. It was stored refrigerator until used for formulation (Figure 3.2).

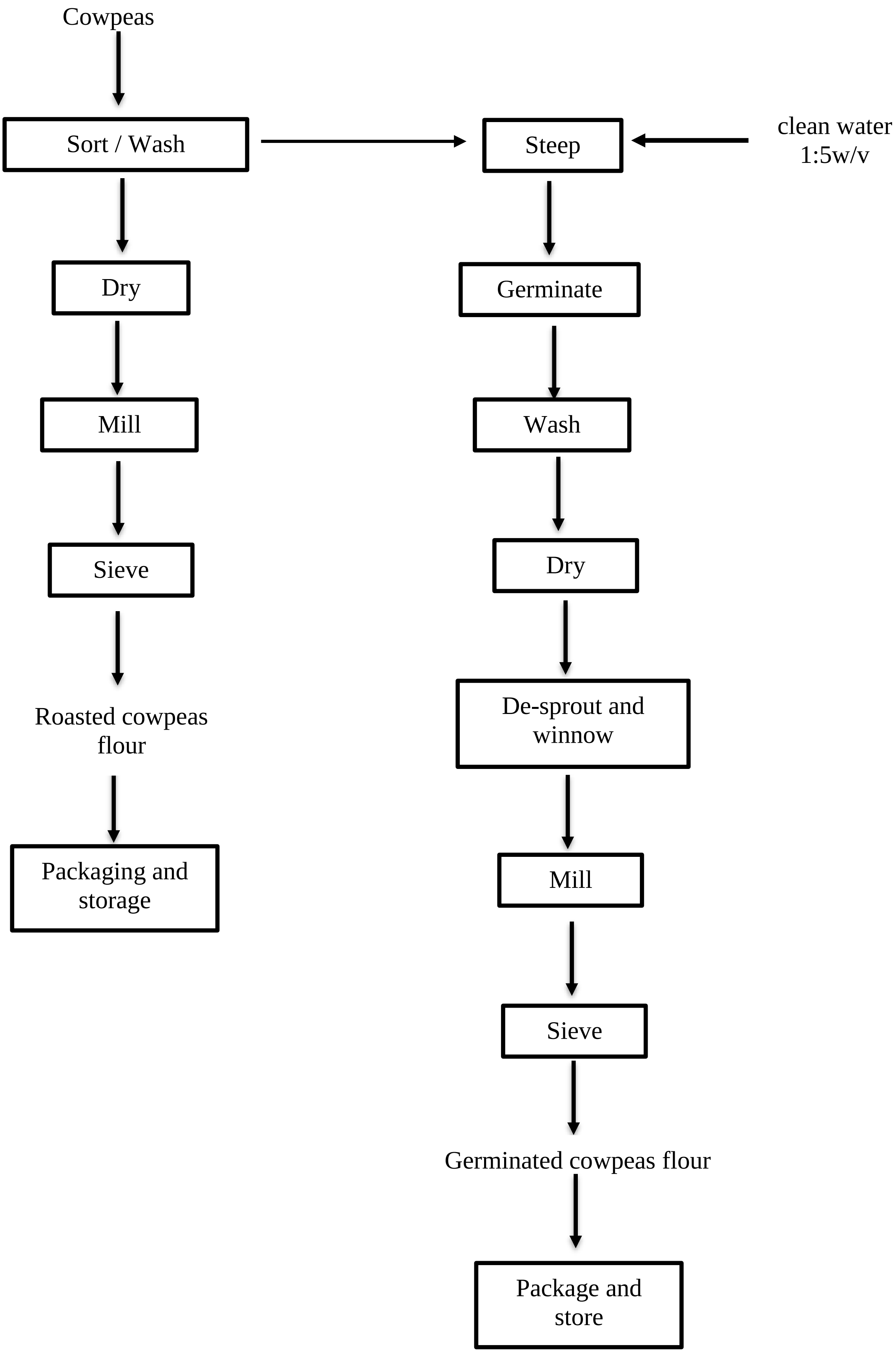

Cowpeas
Sort / Wash
Dry
Mill
Sieve
Roasted cowpeas flour
Packaging and storage
Steep
clean water 1:5w/v
Germinate
Wash
Dry
De-sprout and winnow
Mill
Sieve
Germinated cowpeas flour
Package and store

Figure 3.2: Process flow diagram for unsprouted and sprouted cowpea flours

3.3 Preparation of sesame seeds

Sesame seeds white variety (*sesamum indicum)* were obtained from a farmer in Tamale, Ghana. The seeds were cleaned and washed in water. By immersing the seeds in water, shrivelled seeds and unwanted materials were removed by floatation method. The seeds were thoroughly washed, after which they were dried and roasted to be used for the formulations (Figure 3.3).

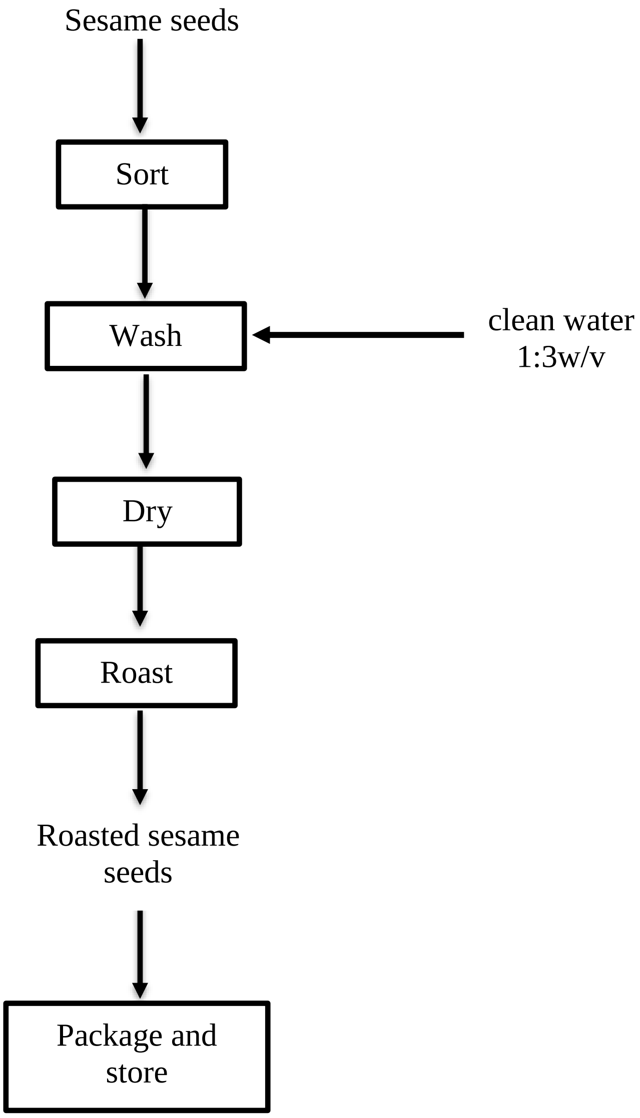


Figure 3.3: Process flow diagram for roasted sesame seeds

3.4 Preparation of roasted peanuts

Raw peanuts (chinese variety) were obtained from a local market in Accra, Ghana. The peanuts were sorted to remove unwanted materials and roasted (Gallenkamp OV-160, Gallenkamp Co, England, UK) at 130°C for 1 hours. They were then cooled and stored until used for the formulation (Figure 3.4).

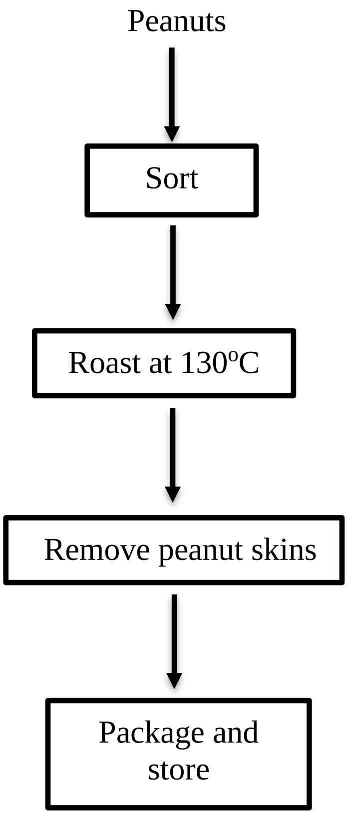


Figure 3.4: Process flow diagram for roasted peanuts

3.5 Formulation derivation using mathematical modelling

Linear programming (LP) as defined by Briend *et al.*, (2003) and Suri *et al.*, (2014) was applied to derive optimum formulations for the food mixes using MATLAB® (Version 9.4 2018). The optimization was based on minimizing cost for the formulation but within the constraints of the nutritional requirement as stipulated by the World Health Organization (WHO) for the target group of 6 – 24 months old infants. The recommended complementary food composition for children 6 to 23 months according to Lutter *et al.*, (2003) is shown in

Table 3.1. The nutritional restriction imposed to the mathematical model in the formulation is shown in table 3.2 (Lutter and Dewey, 2003; Suri *et al.*, 2014). However, there were no constraints put on cereal. Energy, protein, fat and carbohydrate and the cost per each ingredient utilized in the formula used are shown in Table 3.3. The information from table 3.3 and 3.4 was fed to the computer program (MATLAB script) and the iterations for the solution resulted in the basic minimum cost formulation in Table 3.4. The minimization statement is captured in the mathematical equation below;

$$\text{Min } F = \sum_{j=1}^{n} cjxj$$

With the following boundary conditions;

$$\sum_{j=1}^{n} aijxj \leq bi \quad (i = 1...n) \text{ and } x_j > 0 \ (j = 1…n)$$

where:

F signifies the total minimum cost for the formula;

c (j=1….n) signifies the unit cost of ingredient "j" (units in grams)

xj (j=l….n) signifies the quantity of ingredient "j" in the elaboration of the formula;

aij (i=1…n), (j=1….n) signifies the contribution of each ingredient in the formula to the nutritional requirements and i and j is the ingredient and nutrient we are dealing with respectively

bi (i=1….n) signifies the maximum (or minimum) levels of nutrient requirement.

xj > 0 signifies the quantity of the ingredients should be greater than 0

Table 3.1: Recommended nutrient composition (100g) for a fortified complementary food assuming an average breast milk consumption for infants 6 – 23 months.

Components/nutrients	Recommended amount
Complementary food in dry weight (g)	100
Energy in kcal	440
Carbohydrate (g)	70.4-86.9
Protein (g)	6-11
Fat (g)	12.7
Vitamin A (µg RE)	500
Biotin (µg)	2.9
Choline (mg)	91.8
Folic acid (µg)	83
Niacin (mg)	6.1
Pantothenic acid (mg)	0.7
Riboflavin (mg)	0.36
Thiamine (mg)	0.36
Vitamin B6 (mg)	0.44
Vitamin B12 (mg)	0.52
Vitamin C (mg)	140-280
Vitamin D (µg)	2-4
Vitamin E (mg)	10
Calcium (mg)	200-400
Copper (µg)	400-800
Iodine (µg)	180
Iron (mg)	14
Magnesium (mg)	80-120
Manganese (mg)	1.2
Phosphorus (mg)	150-200
Selenium (µg)	20
Zinc (mg)	8.3

RE, retinol equivalents

(Lutter and Dewey, 2003)

Table 3.2: Nutritional restriction imposed to the mathematical model in the production of the complementary food.

Variable	Constraints
Overall Weight (g)	100
Calories (kcal)	440
Protein (g)	6-11
Fat (g)	12.7
Carbohydrates (g)	70.4-86.9
Legume	≤25%

(Lutter and Dewey, 2003)

Table 3.3: Nutrient Composition and cost of ingredients utilized in the mathematical formulae

Components	Rice	Cowpea	Peanuts	Sesame
*Energy (Kcal)	350	336	567	570
*Protein (g)	6.5	23.52	25.8	17.81
*Fat (g)	0.52	1.26	49.24	48
*Carbohydrates (g)	79.15	60.03	16.13	26.19
Cost (GH₵/100g)	0.49	0.76	0.72	2.00

* USDA Food Composition Databases retrieved on October 9, 2018 at 7:16pm

Table 3.4: Weights of raw materials used in the formulation of the complementary food generated from linear programming iterations.

Sample code	Unfermented rice flour	Fermented rice flour	Unsprouted cowpeas	Sprouted cowpeas	Peanuts	Sesame seeds	Drum drying
A	-	71.01	-	25	-	3.99	-
B	79.53	-	10	-	10.47	-	-
C	-	79.53	-	10	10.47	-	-
D	71.01	-	25	-	-	3.99	-
E	-	71.01	-	25	-	3.99	+
F	71.01	-	25	-	-	3.99	+
G	79.53	-	10	-	10.47	-	+
H	-	79.53	-	10	10.47	-	+

3.6 Drum drying

Samples E, F, G, H, were obtained by mixing the formulations as shown in Table 3.4 with water (1:2 v) to form slurries and drum dried using laboratory atmospheric double GOUDA drum dryer (Andritz Gouda Waddinxveen-Holland). The samples were drum dried at drum speed of 35 RPM and temperature of 180°C. The dried products were collected and milled (Waring Pro Prep Chopper Grinder, USA) into flour. The flours were packaged in the double zipper plastic bags and stored at 4◦C until further analyses.

3.7 Determination of nutritional profile of the products

3.7.1 Moisture content

Moisture content was assessed using to the method described by AOAC (2012). Approximately 2 g of sample of flour was placed in pre-weighed moisture dishes. The weight of the samples was adjusted to the nearest 0.01g. The flour samples were dried in an oven at 105°C for 5 hours. The samples were then placed in a desiccator for about 30-45mins before the final weight was recorded. Throughout the study, moisture contents were measured in triplicate and the mean and standard deviations calculated for each analysis. Moisture was calculated as loss in weight of the moisture dish and sample after removal from the oven. The moisture was expressed as a percentage of the initial weight of the sample. Thus;

$$\frac{M2 - M3}{M2 - M1} \times 100$$

Where;
M1 = Initial weight of glass crucible
M2 = weight of empty glass crucible + flour sample
M3 = weight of empty glass crucible + dry flour sample**.**

3.7.2 Crude protein

In determining the percentage of protein content, AOAC (2005) method was used. About 0.25g of the samples was placed in a Kjeldahl digestion flask also containing a selenium-based catalyst and 25ml of concentrated sulphuric acid (H_2SO_4) added in a fume chamber. The flask was swirled gently to effect proper mixing and heated in a digestion chamber until digestion was completed after 5 hours. The digest was allowed to cool and transferred into a 100ml volumetric flask and topped up to the mark using distilled water. About 10ml of the diluted digest was put in the steam distillation unit, which was previously flushed with distilled water. About 18ml of 40% Sodium Hydroxide (NaOH) was then added to the solution in the steam distiller after which about 25ml of 2% boric acid was pipetted into a conical flask and two drops of bromocresol green-methyl red mixed indicator added. This mixture was placed under the condenser outlet of the distillation system, with the tip of the condenser completely immersed in it. The distillation was carried out until the boric acid solution changed from pink to yellow green. The solution in the conical flask was titrated against 0.1 Hydrochloric acids (HCl) solutions and the end point recorded. The distillation and titration processes were done with triplicate samples of the diluted digest. A blank was taken through the same steps using distilled water instead of the sample. The crude protein content was then calculated using a factor of 6.25.

$$\text{Nitrogen } \% = \frac{(\mathbf{VS} - \mathbf{Vb})\ \mathbf{1.407} \times \mathbf{100} \times \mathbf{NA} \times \mathbf{100}}{\mathbf{Ms} \times \mathbf{10}}$$

Where;

Protein = % total nitrogen × 6.25

Vs= Titre value of acid titration against digested sample solution

Vb = Titre value of acid titration against the digested blank

NA= Normality of acid (0.1N HCl)

Ms = Initial mass of sample= Density of sample × volume

6.25= General Protein conversion factor

3.7.3 Fat

Crude oil was extracted using the principle of Soxhlet extraction as described by AOAC (2005) method. Two grams (2 g) of each sample was placed into a labelled fat-free thimble. These were then weighed, plugged with glass wool and introduced into the Soxhlet extractors. Clean dry receivers' flasks were also weighed and fitted into the extractors. The extraction units were then assembled, and cold water run through the system. Extraction was carried out for 3h after which the hexane was recycled. At the end of this time, the thimbles containing the samples were removed and placed in an oven at 60˚C for 3 hours and dried to constant weight.

The crude fat was obtained as the difference in weight before and after the exhaustive extraction.

3.7.4 Energy

Employing the Atwater general factor system, energy values of the samples were estimated by calculation and the mean and standard deviations recorded for each. Protein (4 kcal/g), fat (9 kcal/g) and carbohydrate (4 kcal/g) (Borquaye, *et al.*, 2017) as shown in the equation below;

$$\text{Energy (kcal)} = (\text{crude protein} \times 4) + (\text{fat} \times 9) + (\text{carbohydrate} \times 4)$$

3.7.5 Total ash and carbohydrate content

Total ash was analysed using the conventional method by dry ashing in muffle furnace (Vecstar CAL9400, Clackson Laboratory, Chula Vista, CA, USA) at 550 °C.

Total carbohydrates were determined by difference: Carbohydrates = 100% - (protein + moisture + crude fat + crude ash).

3.7.6 Crude fibre

The samples were transferred from the crude fat determination into a 750 ml Erlenmeyer flask and approximately 0.5 g of asbestos added. Two hundred millilitres of boiling 1.25% H_2SO_4 added immediately, flasks were set on hot plate and connected to cold finger condenser. The contents were allowed to come to boil and remained so until samples were thoroughly wet. After 30 min, the flasks were removed and immediately filtered through a linen cloth placed in a funnel and washed with boiling water to rinse off the acid. The charged asbestos was washed back into the flask with 200 ml boiling of 1.25% NaOH. The flask was connected to a condenser and its content allowed to boil for 30 min, after which it was filtered through linen cloth and thoroughly washed with boiling water. The residue was transferred into crucibles containing water and washed, cooled in a desiccator and weighed. The crucible was ignited in an electric furnace for 20 min, cooled and reweighed (AOAC, 2005).

3.7.7 Invitro protein digestibility

In vitro protein digestibility of the samples was determined following the method described by Akeson and Stahmanna (1964) with modification. Approximately 0.2g of sample was placed in 50 mL centrifuge tube and 15 mL of 0.1N HCl containing 1.5 mg pepsin added and mixed thoroughly and the tube incubated at 37◦C for 3 h. The suspension was then neutralized with 3.3 mL of 0.5 M NaOH, followed by addition of 4 mg of pancreatin in 7.5 mL of 0.2 M phosphate buffer (pH 8.0) containing 0.005 M sodium azide. The mixture was then gently shaken and incubated at 37◦C for 24 h. After incubation, the sample was treated with 10 mL of 10% trichloroacetic acid and centrifuged at 2000g for 20 min at room temperature. Nitrogen in the supernatant was estimated using kjeldahl method. The percentage of protein digestibility was calculated as;

$$\text{Protein digestibility (\%)} = \frac{\text{Nitrogen (in supernatant)} - \text{Nitrogen (in blank)}}{\text{Nitrogen (in sample)}} \times 100\%$$

3.7.8 Mineral content and availability (Fe, Zn And Ca)

3.7.8.1 Mineral content

The mineral content was determined by Atomic Absorption Spectrum (AAS), (Perkinelmer corp, 1968). Two grams of ash from the determination of ash content was dissolved in 50 mL of 5% hydrochloric acid (HCl). After complete dissolution of ash, the solution was filtered into a 100 mL volumetric flask and topped to the 100 mL mark with 5%

hydrochloric acid (HCl). Digested samples were stored in plastic containers and stored at 4°C prior to analysis. Standards and samples were analysed by flame atomic absorption spectrophotometry with a novAA 400P (Analytik Jena, Germany). Minerals were determined with their specific hollow cathode lamps at wavelengths specified by the manufacturer. Standards and reagent blanks were run at regular intervals to ensure consistent instrument performance. All samples were analyzed in triplicates. The solution was then stored for the mineral determination using the Perkin-Elmer Analyst 400. The iron was read at wavelength of 248.33, zinc at 213.86 and calcium at 422.67.

Calculation of mineral content;

$$\text{Mineral Content (e.g. Fe)} = \frac{\text{AAS reading}}{1000} \text{ x } \frac{100}{1000} \text{ x } \frac{100}{\text{weight of sample}}$$

3.7.8.2 Availability of mineral content

Enzymatic digestion in vitro was performed according to the method developed by Skibniewska *et al.*, (2002) with modification. Samples (approximately 2 g) of a finely ground food product was weighed in conical flasks and treated with deionized water (20 ml) and shaken for 10 min. After the solution pH had been brought to 2.0 with 1M HCl (Suprapure, Merck) to create a suitable condition for the pepsin (Sigma Poznan, Poland), the enzyme was added in the form of a solution containing 0.5g enzyme per 100g. Then the sample was incubated with shaking in a water bath at 37°C. During this stage the pH was periodically monitored and, if necessary, adjusted by adding 6M HCl (Suprapure, Merck). After 2h the pH of the solution was raised to 6.8–7.0 by adding 6% $NaHCO_3$ solution (Extrapure, Merck), then a 0.4% solution of pancreatin (Sigma) in 0.1M $NaHCO_3$ was added at the rate of 10ml per 40ml of sample solution. After that the sample was incubated for another 4h. Then the mineralised sample was centrifuged at 4000rpm for 30min and decanted by draining through medium-hardness filters. The filtrate was transferred into a borosilicate glass flask and evaporated on an aluminium electric heating block. The sample was ashed in a mixture of acids as described earlier.

Bioavailability was then calculated as a percentage of the total reference mineral in the sample.

$$\text{Bioavailabilty} = \frac{X}{Y} \times 100\%$$

Where X is the reference mineral in the filtrate and Y is the total content of the reference mineral.

3.7.9 Phytate determination

Phytate in the food samples were determined according to the method described by Annor *et al.*, (2016) with modifications. Ten (10) grams of a finely ground sample (40 screen) estimated to contain 5 to 50g P-phytate was weighed into a 125 ml Erlenmeyer flask. Phytate was extracted with 50 ml 3% solution of trichloroacetic acid for 30 min with constant agitation. The resulting suspension was centrifuged (Denley BS400 Centrifuge, Payne, England) at 160 revolutions per minute for 30 minutes and a 10 ml aliquot of the supernatant liquid was transferred into a conical centrifuge tube. 4 ml of $FeCl_3$ solution prepared to contain 2 mg $Fe3+$ was added, blowing through the pipette rapidly. The centrifuge tube containing the sample was heated for 45 minutes in a water bath (Nickel Electronics Ltd, England) at 90-100 °C. (When the supernatant was not clear after 30 minutes, 2 drops of the solution of sodium sulphate at 3% in trichloroacetic acid (TCA) was added and heated for 10 more minutes). The solution was centrifuged for 15 minutes at 160 revolutions per minutes and the supernatant liquid was carefully poured off. The remaining precipitate was washed twice with 20 ml TCA at 3% solution, dispersing it well and heating for 10 minutes in boiling water and centrifuging for 15 minutes at 160 revolutions per minute. The wash was finally repeated once more with distilled water. The resulting precipitate was dispersed in a little distilled water followed by the addition

3 ml of 1.5N NaOH solution and stirring. The volume of the solution was brought to approximately 30 ml with distilled water and heated in boiling water for 30 minutes. The solution was filtered whilst hot with a Whatman No.4 filter paper. The precipitate was washed with 60 ml of hot distilled water and the filtrate was discarded. The precipitate left in the paper was dissolved with 40 ml of 3.2N solution of HNO_3 transferring it to a 100 ml volumetric flask. The paper was washed several times with distilled water, collecting it in the flask. The sample was then cooled to room temperature and calibrated with distilled water. Five ml of this solution was transferred into a 100 ml volumetric flask and diluted to approximately 70 ml with distilled water. 20 ml of 1.5N KSCN was then added and the solution was made up to the 100 ml mark with distilled water. Absorbance of the solution was read (approximately within 1 minute) in a spectrophotometer (Spectrophotometer UV-120-02, Shimadzu Cooperation, Japan) at 480 nm. All readings were corrected by the reading of a blank carried out alongside each set of samples in order to eliminate the effect of any colour produced by the reagents.

The phytate content was then calculated from the iron concentration by assuming a constant Fe: P molecular ratio of 4:6 in the precipitate.

3.8 Functional properties

3.8.1 Swelling power and solubility index

Swelling power and solubility index were determined using the method described by Oladale and Aina (2007) with modifications. Aqueous suspension of the formulated complementary food (1g) in 40 mL of distilled water was put in graduated centrifuge tubes, capped and heated in a water bath with shaker at 85°C for 30min. Afterwards, the tubes were cooled to room temperature and centrifuged at 2,200 RPM at an acceleration speed of 8 for 15min. Precipitated paste was carefully separated from the supernatant and weighed (Wo). The supernatant was evaporated in a hot air oven at 105°C and the residue then weighed (Wr). All determinations were done in triplicate and the swelling power (SP) and solubility index (SI) were respectively calculated as;

$$SP = \frac{\text{Weight of precipitated paste (Wp)}}{\text{Weight of sample (Wo)}} \text{ X } 100\%$$

$$SI = \frac{\text{Weight of residue in supernatant (Wr)}}{\text{Weight of sample (Wo)}} \text{ X } 100\%$$

3.8.2 Bulk density

The bulk density was determined according to the method described by Yadav *et al.,* (2011) with modifications. Twenty grams (20 g) of flour was weighed into a graduated cylinder. The cylinder was tapped continuously until a constant volume was obtained. The bulk density was calculated as weight of flour (g) divided by its volume (cm^3).

3.8.3 Water and oil absorption capacity

Water and oil absorption capacity (WAC & OAC) for each flour sample were determined according to the method by Klunklin and Savage (2018). One gram (1g) of the sample was mixed with 10 mL of distilled water/oil in a centrifuge tube and allowed to stand at room temperature ($28 \pm 2^{\circ}C$) for 1 h. It was then centrifuged at 2,200 rpm for 30min. Water/Oil was drained, and the paste weighed. The absorbed oil was converted to weight (in grams) by multiplying by the density (vegetable oil, 0.924 g/ml). The water and oil absorption capacities were calculated as gram of water/oil absorbed per gram of the sample. This was done in triplicates and then water absorption repeated using distilled water at 70°C for each sample.

3.8.4 Emulsifying capacity

The emulsion capacity and stability were determined according to the method described by Chandra *et al.*, (2015). One-gram sample, 10 mL distilled water and 10 mL soybean oil) was prepared in calibrated centrifuge tube. The emulsion was centrifuged at 2000 × g for 5 min. The ratio of the height of emulsion layer to the total height of the mixture was calculated as emulsion activity in percentage.

3.8.5 Flow behaviours of slurries

The flow behaviour of 10%, 15% and 20% aqueous suspensions of the drum dried samples were determined using the Brookfield viscometer (Brookfield Engineering Labs Inc., Stoughton MA, USA) equipped with spindle No. 2 and run at varying rpms. The data obtained was fitted to the Herschel Buckley model from which the flow behaviour index (n) and the consistency index (k) were determined.

3.8.6 Resistant starch and total starch determination

Approximately 50 g of samples were weighed and transferred to a wide-mouthed plastic jar and mixed well by shaking and inversion. Prior to that the moisture content of the samples was determined using the procedure described in the AOAC (2012). The methodology for resistant starch determination was done according to the Megazyme Starch Assay Procedure (2018). The samples were incubated in a shaking water bath with pancreatic α-amylase and amyloglucosidase (AMG) for 16 h at 37°C, during which time non-resistant starch was solubilized and hydrolysed to D-glucose, by the combined action of the two enzymes. The reaction was completed by the addition of an equal volume of ethanol, and the RS was recovered as a pellet on centrifugation. Then, it was washed twice by suspension in ethanol (50% v/v), followed by centrifugation (with free liquid removed by decantation). RS in the pellet was dissolved in 2 M KOH by stirring in an ice water bath over a magnetic stirrer. This solution was neutralized with acetate buffer and the starch was quantitatively hydrolysed to glucose with AMG. D-Glucose was measured with glucose oxidase/peroxidase reagent (GOPOD), and this was a measure of the RS content of the sample. Non-resistant starch was determined by combining the original supernatant and the washings, adjusting the volume to 100 mL and measuring D-glucose content with GOPOD. The total starch content was calculated as the sum of resistant and non-resistant starch. All analyses were performed in at least two technical replicates, and results were reported as mean values on a DM basis.

Calculations:

The calculations for resistant starch, non-resistant (solubilised) starch and total starch content (% on a dry weight basis) in the test sample were as follows;

Resistant Starch (g/100g sample) (samples containing $> 10\%$ RS):

$= \Delta E \times F \times 100/0.1 \times 1/1000 \times 100/W \times 162/180$

$= \Delta E \times F/W \times 90$

Resistant Starch (g/100g sample) (samples containing $< 10\%$ RS):

$= \Delta E \times F \times 10.3/0.1 \times 1/1000 \times 100/W \times 162/180$

$= \Delta E \times F/W \times 9.27$

Non-Resistant (Solubilised) Starch (g/100g sample):

$= \Delta E \times F \times 100/0.1 \times 1/1000 \times 100/W \times 162/180$

$= \Delta E \times F/W \times 90$

Total Starch = Resistant Starch + Non-Resistant Starch

Where:

ΔE = absorbance (reaction) read against the reagent blank

F = conversion from absorbance to microgram (the absorbance obtained for 100 µg of D-glucose in the GOPOD reaction is determined and F= 100 (µg of D-glucose) divided by the GOPOD absorbance for this 100 µg of D-glucose.

100/0.1 = volume correction (0.1 mL taken from 100 mL).

1/1000 = conversion from micrograms to milligrams.

W = dry weight of sample analysed

= “as is” weight x [(100-moisture content)/100].

100/W = factor to present RS as a percentage of sample weight.

162/180 = factor to convert from free D-glucose, as determined, to anhydro-D-glucose as occurs in starch.

10.3/0.1 = volume correction (0.1 mL taken from 10.3 mL) for samples containing 0-10% RS where the incubation solution is not diluted and the final volume is ~ 10.3 mL

3.9 Physicochemical properties

3.9.1 Total colour difference

Flours colour was measured using a Minolta CR 300 series spectrophotometer (Minolta Co. Ltd., Osaka, Japan). L*, a* and b* values were expressed in the colour space defined by the International Commission on Illuminaion (CIE). The chroma meter was calibrated with a standard white tile (Lt*= 94.83, at*= -0.25, bt*= 2.85)

Where;

L*= darkness to lightness

a* = green to red

b* =blue to yellow

3.9.2 Particle size distribution

Particle size distribution of the raw formulations and drum dried products were determined following the method described by Sakhare *et al.*, (2013) with modifications. The determinations were made by placing approximately 200g of each flour sample on the topmost sieve of a nest of sieves of successively decreasing apertures. The stack of test sieves was shaken for 3 min at an amplitude of 3 in a sieve shaker (Ro-Tap model RX-29, W.S. Tyler, Mentor, Ohio) using sieves with sizes 230, 200, 120, 100 and 50µm. The initial weight of the sieves was recorded. The final weight after sample's particles have been distributed in the various sieves were also measured and recorded. To obtain the weight of particles distributed in the sieves, the initial weight of the sieve was subtracted from the final weight after particles have been thoroughly distributed into the various sieves. Particles that passed through the 230 and 200µm were labelled as course and those that passed through the 120, 100 and the 50 microns were labelled as fine.

3.9.3 Moisture sorption behaviour (isotherms)

The standard gravimetric method was followed for the moisture equilibrium studies at different temperatures (27°C and 30°C) as described by Ocheme *et al.*, (2013). It consisted of moisture sorption measurements using six (6) different concentrations of acid (H_2SO_4) solution ranging through 5, 15, 35, 45, 55 and 65% to produce water activities ranging from 0.15 to 0.96. These saturated solutions were carefully poured into glass containers, flour samples placed in plastic containers and plastic thread used to serve as support for the samples and forced into the containers to rest just above the acid solution and kept in ovens (Gallenkamp OV-160, Gallenkamp Co, England, UK) preset at two temperatures (27°C and 30°C). The samples were removed and weighed every 24h using an electronic weighing balance until consecutive readings were less than 0.05% of sample weight. The moisture content was then determined thereafter. The time to reach equilibrium moisture content ranged from 30 to 65 days depending on the water activity in each bottle. The equilibrium moisture contents were calculated as averages of triplicates from which the moisture sorption isotherms were determined. The data for the water adsorption were fitted to the GAB, BET, Oswin, Smith and Henderson models to assess their moisture sorption behaviour. Equilibrium moisture was plotted against water activity for each temperature from the data to obtain sorption isotherms for the samples. GAB and BET equations were analysed by non-linear regression, while the Henderson, Smith and Oswin equations were analysed by least square linear regression using STATGRAPHICS® statistical software version 16.1.11 Centrion XVI. The goodness of fit of models were evaluated with percentage root mean square error (%RMSE) between experimental and predicted moisture contents as described by Iglesias and Chirife (2005).

3.10 Food safety

3.10.1 Aflatoxins

Fifty grams of raw peanuts and sesame seeds was weighed into a blender jar followed by 5.0g of NaCl and 100mL of hexane. Two hundred millilitres of methanol + water solution was added in the ratio of 8:2 and blended for 3 minutes at high speed. The suspension was filtered immediately. Ten millilitres of the filtrate were transferred into a 250 mL beaker and 60 mL PBS added and stirred. Seventy millilitres of mixture were transferred onto a conditioned immunoaffinity column (IAC). The filtrate is passed through the column at a flow rate of approximately 1 drop (approx. 3ml/min). The column was washed with approximately 15 mL of water – applied in little portions of approximately 15mL-at a maximum flow rate of 5 mL/min and dry by applying little vacuum for 5-10 seconds or passing air through the immunoaffinity column by means of a syringe for 10 seconds. The aflatoxins in the peanuts was eluted in a two-step procedure i.e. applying 0.5 mL methanol on the column and letting it pass through by gravity and collecting the eluate in a calibrated 5mL volumetric flask. After a 1 min wait, a second portion of 0.75 mL methanol was added.

3.10.2 Microbiological analysis

3.10.2.1 Enumeration of total coliforms

Total coliforms were enumerated by pour plate method by weighing 10g of the composite diets to sterile polypropylene sampling bags and 90 ml of the sterile diluents (salt peptone solution) was added and homogenized in a stomacher for 30 seconds. One millilitre of the inoculum was pipetted into petri dish and tryptone soy agar media was added and swirled clockwise and anti-clockwise for uniform mixture then allow to stand for an hour before overlay with violet red bile agar media and as soon as it solidified the plates were incubated at 37°C for 24h and suspected colonies was subculture into Brilliant Green Bile Broth for the gas production in the Duran tubes inside the broth. Test tubes that were positive for gas production were subculture into E. C broth and incubate at 44°C for 24 h, the positive colonies with gas production indicated presence of faecal coliform in accordance with (NMKL.No.44,2004). Total colonies were counted and represented as log CFU/g.

3.10.2.2 Enumeration of *Escherichia coli*

Ten grams of the representative sample was transferred aseptically to a stomacher bag and 90 ml peptone water was added. The mixture was blended in a stomacher blender for 30 sec. One hundred microliters of appropriate serial decimal dilutions were transferred onto well-dried MacConkey Agar plates. Each inoculum was spread over the surface using a sterile spreader and plates were left for 15 minutes to dry at room temperature. Plates were incubated at 44°C for 24 to 48 h. Pink firm colonies on MacConkey were counted and recorded as presumptive E. coli counts. For further tests, presumptive colonies were selected and sub-cultured by streaking on nutrient agar (Oxoid, CM0003) and incubated at 37°C for 24 hours. Isolated colonies were selected and followed biochemical preliminary confirmatory test (Triple Sugar Iron/ Citrate Utilization/ Motility in SIM +Kovacs). Isolated colonies were confirmed using Microbact 24E microbial identification system. Total colonies were counted and represented as log CFU/g.

3.10.2.3 Enumeration of yeast and moulds

For each composite diet, 10.0 g was weighed and 90.0 ml sterile diluent (salt peptone solution) was added and homogenized for 30 sec for uniform mixture. One millilitre of the inoculum was pipette into empty petri dish and DRBC agar media with adjusted pH of 5.6 was poured into it and swirled clockwise and anticlockwise. Inoculated plates were incubated upright, not invented like the other plates at 25˚C for five days in accordance with (ISO21527-1;2008).

3.11 Sensory evaluation

3.11.1 Preparation of porridges

Porridges were prepared from the formulations and drum dried flours. One hundred grams of each composite flour was mixed with 550mL of distilled water. The slurry was heated on an electric stove at 75˚C for 15mins. Two grams of granulated sugar were added to the porridge. The samples were allowed to cool at room temperature (28±2°C) to 40°C (serving temperature). The porridge for each formulation was kept separate in thermos flasks to maintain the serving temperature of 40°C.

3.7.1.1 Focus group discussion

The aim was to determine the drivers for complementary food consumption for children, purchase-ability and knowledge on complementary foods of parents/caretakers. Participants (mothers and caretakers) were recruited from Takoradi Regional Hospital, Effia Nkwanta Regional Hospital and its environs. Participants recruited were between the ages of 18 to 60 years. Four focus groups consisting of 8 - 12 people: 2 parent groups with children between 7 – 24 months and 2 non-parent groups (caretakers, guardians, grandparents or nannies). All focus group discussions took place in the conference room at the Comprehensive Health Care Centre at the Effia Nkwanta Hospital, audio taped, and handwritten notes were also made. The consent of the participants and demographic information was obtained before the commencement of the discussion. Participants sat in an arrangement of a horseshoe facing the moderator (student). Each session lasted for 45 minutes. The discussion was in the local dialect ‘fante’ and transcribed in English for reporting or for further explanation during the discussion period where necessary.

3.12 Estimation of cost of the production of the product

The cost of the complementary food development was determined according to the price of the materials used in preparing the food, gas, electricity, jars, water and others. The costs of the products were compared with market price of some imported commercial baby foods and some locally produced baby food.

3.12.1 Discounted measure of products worth

Profitability estimation was based on the criteria made as stated below in order to provide the framework for consistent analysis.

1. The project(plant) has a lifespan of 15years

2. The plant at full capacity produces 400 kg of materials per month
3. The cost of operation increases by 25%, 50% and 60% in the 3rd 4-9th and 10th year respectively
4. The plant will operate at 80% capacity within the first three years and attain 100% capacity from the 4th to 9th year with 90% capacity in the 10th year
5. Exchange rate: $1 = GH¢ 5.2515 (Bank of Ghana rate: 16/07/2019).
6. Interest rate (i) = 15.2% (Bank of Ghana rate: 16/07/2019).
7. Tax rate- Corporate tax (t): 25% (Ghana revenue authority: 16/07/2019)
8. The administrative staff had an 25% increase in pay from the 5th to 9th year and 50% increase in the 10th year

3.12.2 Computation of cost and revenue

Total Cost = operation cost + total capital investment (VC+FC)

Total revenue = price of product × quantity of products (P× Q)

The revenue streams are mainly from sales of the various products.

The two major discounted measure of project worth was used to estimate the profitability of the project.

Benefit cost ratio:

$$\sum_{t=0}^{n}\frac{B_{t/(1+r)^{t}}}{C_{t/}(1+r)^{t}}$$

Where B_t denotes benefits in year t; C_t denotes cost in year t; r denotes cost of capital; t denotes number of years. The decision rule is that we accept the project if BCR ≥ 1 when the cost and benefit streams are discounted at the opportunity cost of capital. Thus, if BCR > 1 it means the product is profitable, if BCR < 1 it implies not profitable and if BCR = 1, the investment break even (Asante and Kuwornu, 2014).

3.12.3 Net present value

Net present value (NPV) is the present value of the incremental net benefit or incremental cash flow stream (Asante and Kuwornu, 2014).

$$\sum_{t=1}^{t=n} \frac{B_{t-}c_t}{(1+r)^t}$$

Where B_t denotes benefits in year t; C_t denotes cost in year t; n denotes investment lifespan; t denotes time measured in years, r denotes cost of capital. The decision rule is to accept the project if NPV is positive. This indicates that the project is viable and if two or more investment show positive NPV's the one with the highest NPV is preferable, when NPV = 0 means the investment breaks even (Asante and Kuwornu, 2014).

3.12.4 Depreciation

Depreciation (D) is the reduction in the value of an asset over a period of time. The salvage value refers to the value of an asset at the end of its expected useful life. This method of depreciation was used because of its simplicity and the ability to reflect the historical cost of assets under consideration. The formula is specified as follows.

$$D = \frac{OC - SV}{N}$$

Where D represents depreciation on capital item; OC denotes original Cost of item; SV denotes savage value; and N denotes expected useful life of capital.

3.13 Statistical analysis

Data were analysed using Minitab software version 17 and MS Excel. Mean values of triplicate determinations were reported with standard deviations. Analysis of variance (ANOVA) was conducted to determine differences in means between treatments, and LSD was used to identify where differences were significant at $p \leq 0.05$. Illustrations with bar charts and tables were done using Microsoft Office Excel 365. Thematic analysis of consumer focus group discussion was carried out using the Attride-Stirling 2001 method, with the aid of ATLAS.ti.7.

CHAPTER FOUR

4.0 Results and discussions

4.1 Preamble/Product formulations

A total of four formulations were made as shown in Table 3.4. These consisted of broken rice flour and cowpeas as basic raw materials and either peanuts or sesame as a third component. With regards to the cowpeas component, two of the products had unsprouted cowpeas and the other two had sprouted cowpeas. For the rice component, two products had fermented rice whilst the other two had non fermented rice flour (Table 3.4). The four formulations (A, B C and D) as shown in Table 4.1 were made into a dough of about 43% moisture content and then drum dried to obtain precooked flakes (E, F. G and H) of 6-8% moisture content. The characteristics (nutritional and physico-functional properties) of the four flour blends and their respective drum dried precooked products were then assessed. The outcome of this study outlined a simple and inexpensive process using familiar local technologies of cereal flour fermentation and sprouting of legumes to improve the nutritional quality of the product. Drum drying also showed an acceptable physico-functional property necessary for infant feeding.

4.2 Nutritional quality of the raw formulation and drum dried products

4.2.1 Protein content

Protein content is one important nutrient to consider in complementary food development (Bazaz *et al.*, 2016). Protein in the raw formulations varied between 12.42 for those containing peanuts (B and C) to 13.65% for those containing sesame (A and D). Products with a combination of sprouted cowpeas and fermented rice with sesame (formulation A) had significantly higher protein content than those employing a combination of non-sprouted cowpeas and non-fermented rice with sesame (formulation D) (Table 4.1). This indicates that fermentation and sprouting probably increased the protein content in the products. Mehta *et al.*, (2007) documented higher proportions of proteins in cowpeas after 28 hours germination during the sprouting process. They explained that the increase may be as result of losses in dry matter especially for the carbohydrate during respiration and enzymatic changes. Ikujenlola and Adurotoye (2014) reported a similar increase for proteins in complementary foods from blends of germinated quality maize and cooked cowpea. The lowest protein content was found in formulations with peanuts with non-sprouted cowpeas and unfermented rice. Formulations containing sesame showed significantly ($p \leq 0.05$) higher protein content than those with peanuts. Nonetheless, for all the four formulations derived from the linear program solution, the protein contents met the recommended amount of 6-11g per 100g as reported by Lutter and Dewey, (2003) (Table 4.1).

4.2.2 Fibre content

The fibre content in the raw formulations were between 1.14% to 1.80%. Formulations made using a combination of sprouted cowpeas, fermented rice and sesame (formulation A) had significantly ($p \leq 0.05$) higher fibre content than those with a combination of non-sprouted cowpeas, non-fermented rice and sesame (formulation D). On the other hand, products with a combination of sprouted cowpeas, fermented rice with peanuts (formulation B) had significantly lower fibre content than those with a combination of non-sprouted cowpeas, non-fermented rice and peanuts (formulation C) (Table 4.1). The increases in fibre might be due to the formation of more complex carbohydrates from simpler ones during the sprouting process in the formation of the shots and radical (Fouad and Rahab, 2015). All the formulations had fibre content within the scope set by Codex Alimentarius Commission (CAC), (2011) to be not more than 5%. Fibre content in infant foods sometimes raise quality issues especially in connection to its potential negative effects of reducing nutrient absorption (Fathelrahman *et* *al.*, 2015). Other negative effects of high fibre content entail higher dietary bulk and subsequently interruption of nutrient absorption in the body (Asma *et al.*, 2006). Consequently, there has always been a general agreement on minimizing fibre in infant foods (Abeshu *et al.*, 2016). Nevertheless, dietary fibre has been known to improve bowl transit time.

4.2.3 Ash content

Ash in a product is evidence of minerals content (Laryea *et al.*, 2018) and for some products, it is a quality parameter that helps to indicate possible contamination with foreign materials (Mishira *et al.*, 2014). The ash content of the formulations was in the range of 0.21 to 0.92% (Table 4.1). Products with combinations of sprouted cowpeas, fermented rice and either sesame or peanuts (formulation A and C respectively) had significantly lower ($p \leq 0.05$) ash content than those with combinations of non-sprouted cowpeas, non-fermented rice and either sesame and peanuts (Table 4.1 and Figure 4.3). The reduction may be associated with mineral leakage during the soaking of the grains (Kavitha & Parimalavalli, 2014) for both the processes of sprouting and fermentation.

Different studies reported relatively high ash content 1.47-1.93% (Adenuga, 2010) in complementary foods formulated using sweet potatoes, cowpeas and peanuts. Similarly, high ash content ranging from 4.10-4.65% were reported by Adepeju *et al.*, (2016) in complementary food using fermented sorghum, germinated soybean and defatted sesame. This could be due to the method of formulation (including metal contamination during milling) or the respective cereals and or legumes used in their study. Nonetheless, FAO/WHO/UNICEF (1972) set ash content of less than 5% in typical complementary food blends which are in line with the formulations in this study (Table 4.1).

4.2.4 Carbohydrate content

Carbohydrate forms part of the energy contributions in complementary foods (Maureen & Beth, 2012). They also contribute to the sweetness, appearance and textural characteristics of many foods having carbohydrates as their major constituent. The carbohydrate content of the formulations ranged between 60.44%-71.80% (Table 4.1). Products with combinations of sprouted cowpeas, fermented rice and either sesame or peanuts (formulation A and C respectively) had significantly lower ($p \leq 0.05$) carbohydrate content than those with combinations of non-sprouted cowpeas, and non-fermented rice and either sesame or peanuts (formulation D and C respectively) (Table 4.1). The decrease in carbohydrate may be due to the metabolic losses during germination and fermentation respectively (Mohammed *et al.*, 2017). Majority of the carbohydrate content of the formulations met Lutter and Dewy (2003) criteria. Lower carbohydrate content of 58.60-67.47% (Fathelrahman *et al.*, 2015) and 47.70-56.88% (Adepeju *et al.*, 2016) were reported for complementary food prepared using wheat flour and sesame and also using fermented sorghum, germinated soybean and defatted sesame seeds respectively.

4.2.5 Energy content

Lutter and Dewey, (2003) stated that complementary foods for children (6-24 months) should have approximately 440kCal per 100g. The energy value of the raw formulations (Table 4.1) were in the ranges of 385.43-394.63 kCal, which were lower than that suggested by Lutter and Dewey, (2003). Comparatively, the energy values of the formulations were generally within the energy values of 306.07-380.59 kCal by Fathelrahman *et al.*, (2015) in complementary food formulated using wheat and sesame flour and 388.52-403.41 kCal by Adepeju *et al.*, (2016) in complementary food formulated using fermented sorghum, germinated soybean and defatted sesame. These values are however not worrying since the products would not be eaten alone but complemented with sweeteners and or milk as these would also contribute an amount of calories. On the other hand, where sweeteners milk may not be easily assessed by poorer families the deficit can be calculated as fat and added to the formulations.

4.2.6 Fat content

Fat content ranged from 5.89-6.45% in formulations containing peanuts to 6.23-6.57% in those with sesame (Table 4.1). Products with a combination of sprouted cowpeas, fermented rice and either sesame or peanuts (formulation A and C respectively) had significantly higher ($p \leq 0.05$) fat content than those with combinations of non-sprouted cowpeas, non-fermented rice and either sesame or peanuts (formulation D and C respectively) (Table 4.1). This indicates that fermentation or sprouting possibly had effects on the increased fat content. Bazaz *et al.,* (2016) reported a higher fat content with green gram flour increase in the blend which saw higher values than products employing the same substitutions with unsprouted green gram flour. Comparative reports have made by previous authors (Onyango *et al.,* 2004; Khattak *et al.,* 2007). The fat content in formulations did not meet the recommended dietary allowance 12.7g per 100g for infant 6-23 months suggested by Lutter and Dewey, (2003).

4.2.7 Mineral content (Ca, Zn, Fe)

The mineral content of the formulations is reported in Table 4.1. Significant differences were observed for all the formulations ($p \leq 0.05$). Formulations using either peanuts or sesame without employing fermentation and sprouting method had the highest contents of Fe, Zn and Ca. This may be due to mineral leaching during soaking which was employed in the sprouting or fermentation process.

The amount of iron was highest in the sesame products than the peanut products (Table 4.1), most probably because sesame contains higher iron than peanuts. Iron deficiency is common in children thus the need for required amounts in their foods. Intake of iron content recommended for infants between 6-23 months is 14mg/100g (Lutter and Dewey, 2003). Hence in that regards, 100 g of the complementary food were generally not sufficient for this criterion. Similar observations were seen in the calcium and zinc content of the formulations where sesame products had higher contents than the peanut products.

Nonetheless, most of the formulations did not meet the recommended intake for mineral content as suggested by Lutter and Dewey (2003). However, Ghosh *et al.*, (2014) indicated that no amount of combinations can give an optimal recommended intake for mineral content in food and these are always solved by calculating the deficit and supplementing the food using vitamin-mineral premixes.

Table 4.1: Proximate and mineral content of composite complementary food per 100g dry weight

Nutrients (dry matter basis)	A	B	C	D
Moisture (%)	7.20±0.04^{c}	6.73±0.13^{d}	7.50±0.02^{b}	8.36±0.12^{a}
Ash (%)	1.19±0.04^{b}	1.06±0.00^{c}	0.92±0.04^{d}	1.21±0.01^{b}
Crude protein (%)	13.65±0.16^{a}	12.42±0.46^{b}	13.09±0.11^{ab}	12.69±0.26^{b}
Crude fibre (%)	1.55±0.07^{b}	1.80±0.21^{a}	1.61±0.01^{b}	1.14±0.01^{c}
Fat (%)	6.57±0.04^{a}	5.89±0.03^{c}	6.45±0.12^{a}	6.23±0.01^{b}
Carbohydrate (%)	70.24±0.09^{b}	71.90±0.38^{a}	70.44±0.04^{b}	69.94±0.20^{b}
Energy (Kcal)	394.63±0.57^{a}	392.97±1.73^{c}	392.13±0.46^{b}	386.44±0.32^{d}
Iron (mg)	10.11±0.00^{b}	8.99±0.00^{c}	7.46±0.00^{d}	11.81±0.00^{a}
Zinc (mg)	3.48±0.04^{a}	2.29±0.00^{c}	2.41±0.00^{bc}	3.56±0.00^{a}
Calcium (mg)	197.98±0.01^{b}	89.68±0.00^{c}	50.01±0.02^{d}	297.31±0.01^{a}

Means with the similar alphabet in the row are not significantly different at $p \geq 0.05$
Values are presented by as mean ± standard deviation
A=Fermented Rice, Sprouted Cowpeas and Sesame seeds
B=Unfermented Rice, Unsprouted Cowpeas and Peanuts
C=Fermented Rice, Sprouted Cowpeas and Peanuts
D=Unfermented Rice, Unsprouted Cowpeas and Sesame seeds

4.2.8 Phytate content

Phytates are antinutritional compounds that impedes the absorption of minerals in food. Significant ($p \leq 0.05$) reduction was seen in the phytate content in formulations with fermented rice, sprouted cowpeas and either sesame or peanuts (Table 4.2). This observation could be due to the effects of both fermentation and the sprouting treatments. Uppal and Bains (2012) observed a reduction of phytates after 24hours of sprouting cowpeas. Modgil *et al.*, (2009) linked the reduction in leached phytic ions in the water during soaking prior to the sprouting but could also be due to activation of phytases during sprouting as suggested by Afify *et al.*, (2011). The decrease in phytates agreed with findings by Berhanu *et al.*, (2015) for a maize-based food blend. There was correlation between the reduction in antinutrients with formulations made from the method of fermentation and sprouting (Table 4.2). Heat treatment using drum drying of the slurries significantly ($p \leq 0.05$) reduced the phytate content of the formulations. These results demonstrate the viability of the sprouting and fermentation method on phytic acid and it compared well with other research reports employing the same method. Decrease in phytate content (1.44-3.35%) compares with that reported by Alowo *et al.*, (2018) however higher value range (1.1-3.1%) were reported by Hemalatha *et al.*, (2007). Levels within 0 to 5% and are considered safe permissible limits in infant foods (Ikese *et al.*, 2016).

Table 4.2: Phytate content in the raw formulations and drum dried products

	Products	Phytate (mg/100g)
Raw formulations	A	2.57 ± 0.15^{bc}
	B	2.18 ± 0.01^{cd}
	C	1.78 ± 0.06^{de}
	D	3.35 ± 0.09^{a}
Drum dried flours	E	2.18 ± 0.04^{cd}
	F	2.83 ± 0.00^{ab}
	G	2.65 ± 0.50^{bc}
	H	1.44 ± 0.10^{e}

Means with the similar alphabet in the column are not significantly different at $p \geq 0.05$
Values are displayed as mean ± standard deviation
A=Fermented Rice, Sprouted Cowpeas and Sesame seeds
B=Unfermented Rice, Unsprouted Cowpeas and Peanuts
C=Fermented Rice, Sprouted Cowpeas and Peanuts
D=Unfermented Rice, Unsprouted Cowpeas and Sesame seeds
E= Fermented Rice, Sprouted Cowpeas and Sesame seeds (Drum dried)
F= Unfermented Rice, Unsprouted Cowpeas and Sesame seeds (Drum dried)
G= Unfermented Rice, Unsprouted Cowpeas and Peanuts (Drum dried)
H= Fermented Rice, Sprouted Cowpeas and Peanuts (Drum dried)

4.2.9 Bioavailability of iron, zinc and calcium in the formulations and the drum dried products

The bioavailability of minerals is highly essential for a complementary food because of the prevalence of micronutrient deficiency amongst children and infants in developing countries. Bioavailability of minerals in food products are mainly independent on dietary compositions that serve as either mineral inhibitors or mineral absorption enhancers (Sandberg, 2002). The extent to which a processing method lowers nutrient inhibitors directly correlates with the extent of bioavailability of minerals (Chaudhary & Vyas, 2014; Mamiro *et al.*, 2016). The mineral bioavailability of the formulations ranged between (1.58-12.12) in Ca, (1.29-14.08) in Fe and (4.46-15.12) in Zn for the raw formulations to (10.48-20.84) in Ca, (14.20-29.25) in Fe and (19.37-31.30) in Zn for the drum dried products. Formulations with a decrease in phytate had significantly higher mineral bioavailability's (Table 4.3). Products with a combination of fermented rice, sprouted cowpeas with either sesame or peanuts had significantly higher mineral bioavailability than products using unfermented rice, unsprouted cowpeas with either peanuts or sesame. On the other hand, drum drying of the formulations saw significantly higher mineral bioavailability in the products. This is attributed to the reduction in the antinutrients by heat treatment of the slurries (formulations).

Table 4.3: Bioavailability of calcium, iron and zinc from the composite complementary formulations

	Products	% bioavailable Ca	% bioavailable Fe	% bioavailable Zn
Raw formulations	A	12.12 ± 0.15^{d}	14.08 ± 0.30^{d}	15.12 ± 0.07^{d}
	B	4.60 ± 0.09^{f}	4.57 ± 0.37^{f}	5.85 ± 0.35^{e}
	C	14.41 ± 0.65^{b}	13.16 ± 0.27^{e}	26.36 ± 1.39^{b}
	D	1.58 ± 0.03^{g}	1.29 ± 0.04^{g}	4.46 ± 0.41^{e}
Drum dried flours	E	19.90 ± 1.02^{a}	24.69 ± 0.16^{b}	31.30 ± 1.15^{a}
	F	13.17 ± 0.24^{c}	14.20 ± 0.03^{d}	20.01 ± 0.35^{c}
	G	10.48 ± 0.27^{e}	17.17 ± 0.17^{c}	19.37 ± 0.01^{c}
	H	20.84 ± 0.09^{a}	29.25 ± 0.09^{a}	26.19 ± 0.77^{b}

Means with the similar alphabet (superscript) in the column are not significantly different at $p \geq 0.05$
Values are displayed as mean ± standard deviation
A=Fermented Rice, Sprouted Cowpeas and Sesame seeds
B=Unfermented Rice, Unsprouted Cowpeas and Peanuts
C=Fermented Rice, Sprouted Cowpeas and Peanuts
D=Unfermented Rice, Unsprouted Cowpeas and Sesame seeds
E= Fermented Rice, Sprouted Cowpeas and Sesame seeds (Drum dried)
F= Unfermented Rice, Unsprouted Cowpeas and Sesame seeds (Drum dried)
G= Unfermented Rice, Unsprouted Cowpeas and Peanuts (Drum dried)
H= Fermented Rice, Sprouted Cowpeas and Peanuts (Drum dried)

4.2.10 Invitro protein digestibility (IVPD) of the formulations and drum dried products

Invitro protein digestibility (IVPD) signifies the quality and availability of proteins in food (Joye *et al.*, 2019). It is an essential determinant for the amino acids in the food for the body's utilization (Marinangeli and House, 2017). The IVPD of the formulations ranged from 61.37-72.98% for the raw formulations and 74.88-88.60% in the drum dried flours (Table 4.4). Formulations made using fermented rice, sprouted cowpeas with either sesame or peanuts had significantly higher digestibility than their corresponding products with unfermented rice and unsprouted cowpeas. This indicates that fermentation or sprouting have effects on the digestibility of proteins. This may be as a result of the reduction in antinutrients. Drum drying also improved the IVPD of the products compared to the raw formulated flours. Studies have reported that thermal processing such as drum drying improves protein digestibility (Giami, 2001; Abdel-Aal, 2002). Heat changes the protein structure of proteins which makes them easily accessible to proteases which consequently improves the IVPD of food products (Swaisgood and Catignani, 1991). Apart from product E, the IVPD for all the products were lower than 84.6-92.0% reported for a complementary food made from sorghum and legumes using technologies of fermentation and sprouting (Asma *et al.*, 2006) and 87.86-95.51% reported for complementary food using wheat flour and defatted sesame flour (Fathelrahma *et al.*, 2015). Heat treatment promotes structural variations on globulin proteins and enables enzymes like proteases to act on it (Luo and Xie, 2013).

Table 4.4: Protein digestibility's of the formulations and drum dried products

	Products	In vitro protein digestibility (%)
Raw formulations	A	71.09 ± 1.78^{bc}
	B	61.37 ± 0.40^{cd}
	C	65.88 ± 0.08^{de}
	D	72.98 ± 1.41^{a}
Drum dried flours	E	88.60 ± 2.60^{cd}
	F	80.43 ± 0.12^{ab}
	G	74.88 ± 0.79^{bc}
	H	76.81 ± 0.01^{e}

Means with the similar alphabet (superscript) in the column are not significantly different at $p \geq 0.05$
Values are displayed as mean ± standard deviation
A=Fermented Rice, Sprouted Cowpeas and Sesame seeds
B=Unfermented Rice, Unsprouted Cowpeas and Peanuts
C=Fermented Rice, Sprouted Cowpeas and Peanuts
D=Unfermented Rice, Unsprouted Cowpeas and Sesame seeds
E= Fermented Rice, Sprouted Cowpeas and Sesame seeds (Drum dried)
F= Unfermented Rice, Unsprouted Cowpeas and Sesame seeds (Drum dried)
G= Unfermented Rice, Unsprouted Cowpeas and Peanuts (Drum dried)
H= Fermented Rice, Sprouted Cowpeas and Peanuts (Drum dried)

4.3 Functional properties of the raw formulations and drum dried products

4.3.1 Water absorption capacity (WAC)

The water absorption index (WAI) measures the volume occupied by the starch after swelling in water (Yousf *et al.*, 2017). The values for WAC for the raw formulations at 30˚C were between the ranges of 122.06-650.25% and the WAC at 70˚C were between the ranges of 301.03%-723.34% (Table 4.5). The WAC at 30˚C were significantly lower than WAC at 70˚C. Formulations that contained sesame showed significantly ($p \leq 0.05$) higher WAC than formulations that had peanuts. The observed variation in water absorption amongst these formulations may be due to the differences in their macronutrient composition, particularly that protein content and type; which vary in conformation and the degree of water interactions (Butt and Batool, 2010). Houssou and Ayernor, (2002) explained that proteins are mainly responsible for water uptake in foods even though to some extent there is also contribution by the carbohydrates. The values in this study were greater than 150-180% reported by Olapade *et al.*, (2015) using plantain and cowpeas and 95-133% by Brou *et al.*, (2013), using millet, maize and soybeans for their complementary food blend. The differences are as a result of the different composition used and the processing methods. Formulations that contained fermented rice, sprouted cowpeas with either sesame or peanuts showed significantly higher WAC values at both 30˚C and 70˚C than formulations that were using unfermented rice, unsprouted cowpeas with either sesame or peanuts. This indicates that fermentation and or sprouting had significant effects on the WAC of the formulations. Elkhalifa and Bernhardt (2010) reported that 3 days germination of sorghum caused a rise in the water absorption capacity. There was dramatic increase in the WAC of the drum dried products from formulations containing either sesame or peanuts. Majzoobi *et al.*, (2011) explained that, this is linked to the pre-gelatinization of the starches in the process of drum drying, bringing about increased ability to imbibe water easily even at room temperature.

4.3.2 Swelling power (SP) and solubility index (SI)

SP is a sign of how the starches increase in volume after imbibing water (Kaur *et al.,* 2011). It is of great significance for the quality of food and texture because it helps with their stability against effects such as syneresis (Baker *et al.*, 1994). The SP ranged between 7.20-8.93 g/g for the raw formulations and between 10.17-11.20 g/g for the drum dried products (Table 4.5). Formulations made using fermented rice, sprouted cowpeas and sesame recorded significantly higher SP values than those made using unfermented rice, unsprouted cowpeas with sesame. Incorporation of peanuts, instead of sesame did not significantly alter the SP. Increased SP in products with fermented rice and sprouted cowpeas was probably due to modification of starch granules (in both cowpeas and rice) during sprouting and fermentation respectively. However, higher SI values were observed with formulations that included peanuts those that contained sesame. The lower SI observed for products formulated with sesame is due to the high fat and protein content. These compositions have been reported to be linked to lowering the SP of flours (Leach, 1965). Comparatively lower SP values were obtained for complementary food using blends made using malted and unsprouted acha, soybean and defatted sesame 1.10 – 1.50 g/g (Ikujenlola and Adurotoye, 2014) and another blend made from groundnuts, soybeans and fruit bread 0.15 – 0.21 g/g (Adepeju *et al.*, 2014). These variations are due to the ingredient used in the formulations and the processing methods utilized. On the other hand, drum dried products with either sesame or peanuts had significantly higher SP than their respective raw formulations. The observed increase in SP for the drum dried products may be due to the gelatinization of starches during the process of drum drying, resulting in high water uptake and consequently increased SP (Majzoobi *et al.*, 2011). Okorie *et al.*, (2011) reported that infants are able to digest food with relatively lower swelling capacity and this is even helpful to reduce the incidence of choking.

SI is the percent measure of soluble solids (Singh *et al.*, 2005). The SI of the raw formulations was between 7.83 to 10.62% and 11.77 to 18.29% for the drum dried products (Table 4.5). There was no significant difference ($p<0.05$) in the SI for products formulated using fermented rice, sprouted cowpeas with either peanuts or sesame seeds and that formulated using unfermented rice, unsprouted cowpeas with either peanuts or sesame. There were however numerical differences in the values (Table 4.5). The difference could be associated with the amylases activities and comparative increment in the degrees of shorter chain polysaccharide or soluble sugars due to the results of germination (Almeida-Dominguez *et al.*, 1993; Nefale & Mashau, 2018). The relatively high SI may suggest easier digestibility as proposed by other authors (Nguyen *et al.*, 2010; Lentze, 2008) On the other hand, the drum dried products recorded higher SI values than the raw formulations. Colonna *et al.*, (1983) explained that drum drying degrades starch to make them more soluble. There were no significant differences in SI in products containing sesame and that with peanuts.

4.3.3 Bulk density

Bulk density is the mass of particles in a product per unit volume. This parameter is impacted by the porosity and air spaces in the flour particles. Lower bulk is desired in infant food to avoid diluting the food in a lot of water which may tend to reduce the nutrient density (Bazaz *et al.*, 2016). The bulk densities were between 0.65 to 0.75 for the raw formulations and between 0.55-0.58 in the drum dried products (Table 4.5). There were no significant differences between formulations made using fermented rice, sprouted cowpeas with peanuts to products made using unfermented rice, unsprouted cowpeas with peanuts. But significant differences were seen in formulations made using fermented rice, sprouted cowpeas and sesame to those made using unfermented rice, unsprouted cowpeas and sesame. The reduction in bulk density may be as a result of the fermentation and sprouting. The values obtained are comparable with to that reported by Ikujenlola and Adurotoye, (2014) (0.50–0.75 g/cm3) and Ijarotimi *et al.*, (2012) (0.66–0.73 g/cm3). Since theirs were likewise unprocessed the distinction is credited to the differences in the ingredients utilized in the infant food. The drum dried flours had significantly lower bulk in products formulated using either sesame or peanut. Similar observation was made by Laryea *et al.*, (2018). Bulk density is an important parameter in food determination as it affects how consumers perceive food in the mouth and informs processors the packaging options (Wilhelm et al. 2004).

4.3.4 Oil absorption capacity (OAC)

OAC is the measure of how fat binds to the product (mostle through fat-proteins interactions). Protein and starch content as well as the particle size influence oil absorption capacity in food products (Chandra & Samsher, 2013). It is critical in food processing as fats serve as flavour enhancers and how food feels in the mouth (Elkhalifa and Bernhardt, 2018). The OAC of cereal-legume flours are also very important in the textural and flavour characteristics of food products. The OAC of the raw formulations were between 1.04 to 1.13 and from 1.23 to 1.39 for the drum dried products. Formulations made using fermented rice and sprouted cowpeas with either sesame or peanuts recorded significantly higher OAC values compared to products made using unfermented rice, unsprouted cowpeas with either sesame or peanuts. This may be due to high protein and fat contents in the product, which entrapped more oil. The mechanism of OAC is mainly due to the physical entrapment of oil by capillary attraction (Kinsella, 1976; Yuliana *et al.*, 2014). Findings from the study showed that OAC were generally lower (1.42-1.76 mL/g) than functional properties of a complementary food made using maize, sorghum and mungbean malt by Onwurafor *et al.*, (2017). The difference could be as a result of the different combinations used in their study. Conversely, the drum dried products had significantly higher OAC values compared to the raw formulations. This could also be as a result of the porosity of the starches after drum drying which may have resulted in the uptake of oil. Significant differences were not seen in products containing peanuts and products containing sesame.

4.3.5 Emulsifying capacity (EC)

The EC of the raw formulation were between 56.24 to 71.60% and between 82.26 to 88.40% in the drum dried products (Table 4.5). Products formulated using fermented rice, sprouted cowpeas with either sesame or peanuts had significantly ($p \leq 0.05$) higher EC than products formulated using unfermented rice, unsprouted cowpeas with either sesame or peanuts. The reason could be linked to the higher fat content in the products formulated using fermented rice, sprouted cowpeas with either sesame or peanuts. According to Ocheme *et al.*, (2015) the increase in emulsion capacity with increasing germination time could be as a result of increased soluble proteins. Sikorski (2002) also reported that the emulsification of food materials may be due to soluble and insoluble proteins and polysaccharides. On the other hand, there were significant differences in EC between products containing sesame and peanuts. These differences may be as a result of the different fat compositions. Drum dried products also has significant differences in EC relative to the formulations.

Table 4.5: Functional properties of the raw formulations and drum dried products

		Functional Properties						
	Products	30◦C WAC (%)	70◦C WAC (%)	Bulk density (g/mL)	OAC (%)	Swelling power (g/g)	Solubility index (%)	Emulsifying capacity (%)
Raw formulations	A	158.01 ± 2.53^{e}	344.99 ± 4.99^{d}	0.65 ± 0.01^{b}	1.10 ± 0.00^{cd}	8.34 ± 0.03^{c}	9.75 ± 3.01^{a}	71.60 ± 2.21^{c}
	B	130.73 ± 7.59^{f}	301.03 ± 5.62^{f}	0.74 ± 0.01^{a}	1.04 ± 0.01^{e}	8.74 ± 0.07^{c}	7.83 ± 1.28^{a}	56.24 ± 3.65^{d}
	C	151.96 ± 6.24^{e}	403.19 ± 3.12^{c}	0.71 ± 0.06^{a}	1.13 ± 0.05^{c}	8.93 ± 0.08^{c}	10.62 ± 8.09^{a}	66.55 ± 2.46^{c}
	D	122.06 ± 3.47^{f}	328.28 ± 4.81^{e}	0.75 ± 0.01^{a}	1.05 ± 0.05^{de}	7.20 ± 0.25^{d}	7.95 ± 4.17^{a}	56.77 ± 2.50^{d}
Drum dried flours	E	541.20 ± 5.06^{d}	723.34 ± 0.80^{a}	0.57 ± 0.01^{c}	1.39 ± 0.01^{a}	10.78 ± 0.98^{ab}	11.77 ± 5.33^{a}	84.67 ± 1.13^{ab}
	F	606.96 ± 5.71^{b}	631.87 ± 2.78^{b}	0.58 ± 0.01^{c}	1.32 ± 0.03^{a}	10.17 ± 0.56^{b}	18.29 ± 10.91^{a}	88.40 ± 2.71^{a}
	G	650.25 ± 3.52^{a}	725.59 ± 6.94^{a}	0.56 ± 0.00^{c}	1.38 ± 0.00^{a}	10.24 ± 0.40^{b}	14.86 ± 1.61^{a}	80.90 ± 4.21^{b}
	H	575.45 ± 6.58^{c}	731.30 ± 6.84^{a}	0.55 ± 0.01^{c}	1.23 ± 0.02^{b}	11.28 ± 0.22^{a}	16.27 ± 1.04^{a}	82.26 ± 2.28^{b}

Means with the similar alphabet (superscript) in the column are not significantly different at $p \geq 0.05$
Values are displayed as mean ± standard deviation
A=Fermented Rice, Sprouted Cowpeas and Sesame seeds
B=Unfermented Rice, Unsprouted Cowpeas and Peanuts
C=Fermented Rice, Sprouted Cowpeas and Peanuts
D=Unfermented Rice, Unsprouted Cowpeas and Sesame seeds
E= Fermented Rice, Sprouted Cowpeas and Sesame seeds (Drum dried)
F= Unfermented Rice, Unsprouted Cowpeas and Sesame seeds (Drum dried)
G= Unfermented Rice, Unsprouted Cowpeas and Peanuts (Drum dried)
H= Fermented Rice, Sprouted Cowpeas and Peanuts (Drum dried)

4.3.6 Viscosity of the drum dried products

The consistency of infant foods is important for the acceptability as well as the amount the child can eat at a given time. This in turn influences the amount of energy (or nutrients) the child will obtain from the food. Most carbohydrate slurries have been determined to follow non-Newtonian flow behaviour and have been modelled on the power law equation;

$$\sigma = K\gamma^{n-1}$$

Where;

σ is shear stress

γ is shear rate

K and n are constants known as the consistency index and the flow behaviour index respectively.

Since the flow behaviour of the drum dried products were of more significance, the flow parameters were determined for only the drum dried products. The ‘n’ values indicate whether the fluid is a Newtonian or non-Newtonian fluid. Newtonian fluids have been demonstrated to have n=1, while non-Newtonian fluids take values above or below 1. The results (table 4.6) show that all samples had ‘n’ values less than 1 which implies that they exhibited characteristics of non-newtonian, shear thinning (pseudoplastic) flow behaviour (Mrokowska and Krztoń-Maziopa, 2019).

Products formulated using fermented rice, sprouted cowpeas with either sesame or peanuts had higher apparent viscosity at constant solids content than products formulated using unfermented rice, unsprouted cowpeas with either sesame or peanuts (Table 4.6). This is an indication that fermentation or sprouting may have had an increasing effect on the viscosity of the products. Saalia *et al.,* (2012) made similar observation for complementary food made using maize dough and millet malt. In their study, fermentation of the maize for 6 hours caused an increase in the viscosity of the porridge. However, the viscosity decreased after millet malt addition. On the other hand, products made using sesame were thinner (lower apparent viscosity) than products made using peanuts at 15% and 20% solids. These observations have important implications for complementary food acceptability. A preliminary study conducted by Saalia *et al.*, (2012) indicated that mothers or caretakers usually prepare their porridges using a solid content of 15%. Thus, the results of this study might suggest that at 15% solids content, mothers would most likely prefer the sesame product to the peanut product due lower viscosity.

Table 4.6: Apparent viscosity and the degree of non-newtonianity of the drum dried products

Products	10%		15%		20%	
	n	k	n	k	n	k
E	0.34±0.00	845.96±2.89^{b}	0.51±0.00	26224.06±0.00^{b}	0.62±0.00	276057.79±0.01^{b}
F	0.19±0.01	167.65±0.60^{d}	0.29±0.00	4323.645±2.11^{d}	0.66±0.00	188018.25±0.00^{c}
G	0.32±0.01	416.29±0.81^{c}	0.40±0.00	9549.93±3.11^{c}	0.56±0.00	144877.19±0.00^{d}
H	0.40±0.00	1031.67±0.54^{a}	0.60±0.00	50559.18±0.00^{a}	0.63±0.00	364082.66±0.00^{a}

Means with same superscripts in the column are statistically indifferent at $p \leq 0.05$
n= power law
k= apparent viscosity
E= Fermented Rice, Sprouted Cowpeas and Sesame seeds (Drum dried)
F= Unfermented Rice, Unsprouted Cowpeas and Sesame seeds (Drum dried)
G= Unfermented Rice, Unsprouted Cowpeas and Peanuts (Drum dried)
H= Fermented Rice, Sprouted Cowpeas and Peanuts (Drum dried)

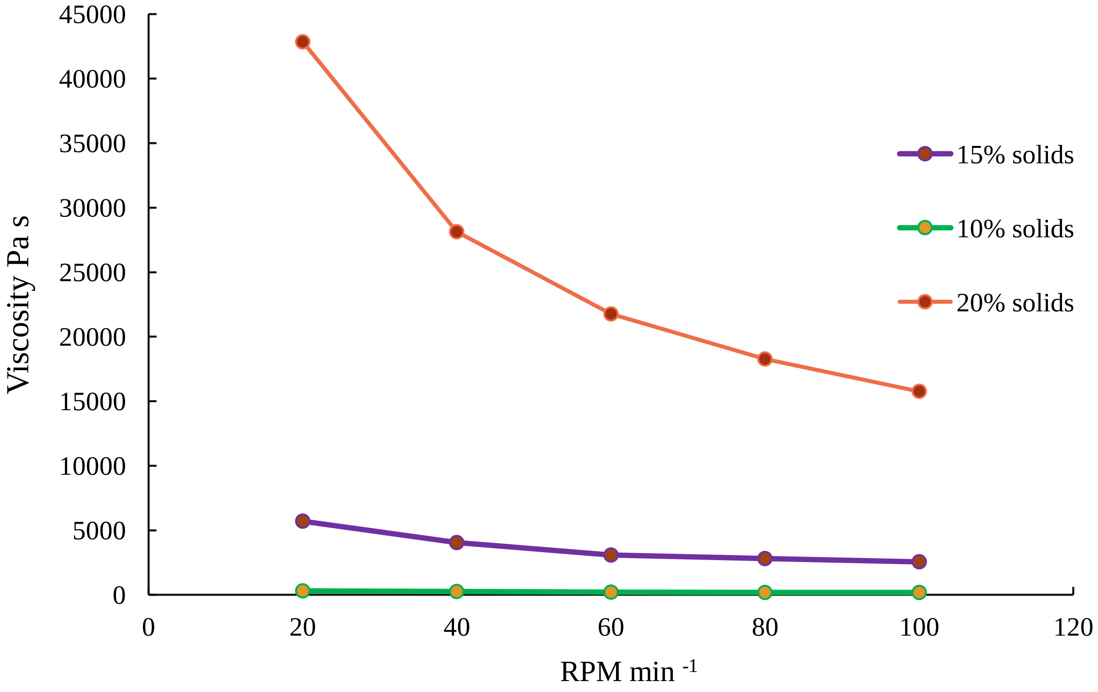


Figure 1.1a: Viscosity against RPM for Sample E

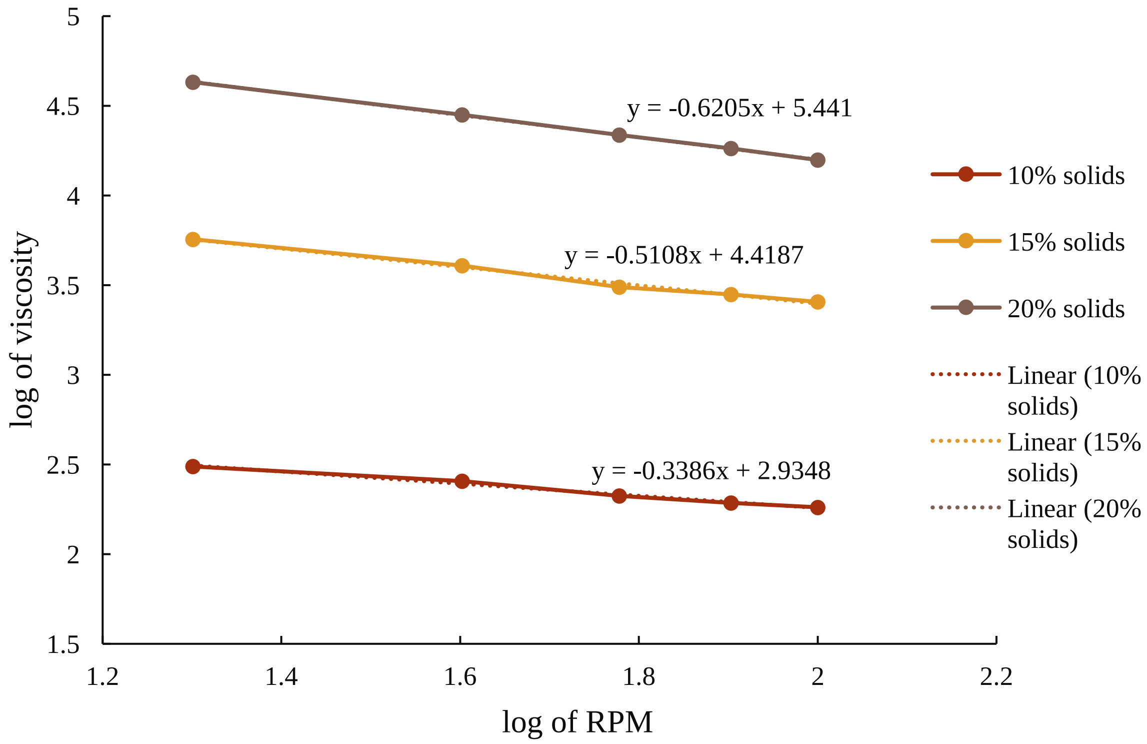


Figure 4. 1b: log of viscosity against the log of RPM for sample E

4.3.7 Resistant (RS) & non-resistant starches of the formulations and drum dried products

RS are starches that are difficult to break down by the digestive enzymes during digestion inside the small intestines, thus arriving at the large intestines non-digested. Upon reaching the large intestines, microorganisms break them down to short-chain unsaturated fatty acids (SCFAs) (Lockyer and Nugent, 2017). It has been suggested that the levels of RS in baby food is important in helping with the development of the baby's digestive tracts. (Bird *et al.*, 2000).

The RS of the raw formulations ranged between 0.35-0.49, which increased after drum drying to between 0.84-4.45. Products formulated using fermented rice, sprouted cowpeas and either peanuts or sesame had significantly lower ($p \leq 0.05$) RS than formulations made using unfermented rice, unsprouted cowpeas with either peanuts or sesame. This indicates fermentation of rice (starch) and or sprouting of cowpeas had a reducing effect on the RS development probably due to the weakening of the starches as a result of fermentation and sprouting. Sprouting may have resulted in the degradation of endosperm starches of the cowpeas by the release of amylases and phosphorylases (Gaikwad and Sharma, 2012). However, there was no significant difference between the sesame and peanut products. It has also been suggested that moist heat treatment such as in drum drying could cause starches to solidify and hence become glassy. Finding agrees with Yadav *et al.*, (2009) on the effect of repeated heating on RS formation in cereals, legumes and tubers. They reported higher RS in the heat treated products and linked it to the formation of starch glasses in the products.

Table 4.7: Resistant starch and non-resistant starch composition of the raw formulations and drum dried products

	Products	Resistant starches (g/100g)	Non-resistant starches (g/100g)
Raw formulations	A	0.37 ± 0.01^{f}	69.71 ± 0.03^{c}
	B	0.48 ± 0.01^{e}	70.73 ± 0.03^{bc}
	C	0.35 ± 0.01^{f}	71.01 ± 0.17^{b}
	D	0.49 ± 0.01^{e}	67.93 ± 0.14^{de}
Drum dried flour	E	1.03 ± 0.03^{c}	68.12 ± 0.72^{d}
	F	4.45 ± 0.04^{a}	66.99 ± 0.23^{ef}
	G	0.84 ± 0.02^{d}	74.86 ± 0.10^{a}
	H	1.18 ± 0.00^{b}	66.48 ± 1.09^{f}

Means with the similar alphabet (superscript) in the column are not significantly different at $p \geq 0.05$
Values are displayed as mean ± standard deviation
A=Fermented Rice, Sprouted Cowpeas and Sesame seeds
B=Unfermented Rice, Unsprouted Cowpeas and Peanuts
C=Fermented Rice, Sprouted Cowpeas and Peanuts
D=Unfermented Rice, Unsprouted Cowpeas and Sesame seeds
E= Fermented Rice, Sprouted Cowpeas and Sesame seeds (Drum dried)
F= Unfermented Rice, Unsprouted Cowpeas and Sesame seeds (Drum dried)
G= Unfermented Rice, Unsprouted Cowpeas and Peanuts (Drum dried)
H= Fermented Rice, Sprouted Cowpeas and Peanuts (Drum dried)

4.4 Physical properties of the drum dried products

4.4.1 Colour profile of the raw formulations and drum dried products

Appearance is a central parameter consumer’s look out for in assessing food quality. Colour is mostly used in this assessment (Pathare *et al.*, 2013) because, colour is fundamentally an appearance property credited to the different light spectrum as perceived by assessors (Jha, 2010).

The L* value specifies the lightness of the product. It is usually scored on a range of 1 to 100; dimness region (1-50) and lightness area (50-100) (Falade and Olugbuyi, 2010). The

L* values of the raw formulations ranged between 80.39-86.27 and between 78.00 to 81.75 in the drum dried products (Table 4.8). Products formulated using fermented rice, sprouted cowpeas with either sesame or peanuts scored higher L* values than products formulated using unfermented rice, unsprouted cowpeas with either sesame or peanuts. There was significant reduction in the L* values of the products after drum drying for either sesame or peanuts. In the presence of reducing sugars and proteins (or primary amino acids) non-enzymatic (or Maillard) browning is promoted by heat leading to the reduction of L* values (Dao, 2015). During fermentation, simple sugars are broken, and this could mean that products with fermented rice had lower amounts of reducing sugars than unfermented rice. Consequently, products with less reducing sugars (i.e. fermented products) showed less browning and had higher L* values.

The b* (yellowness) values ranged between 12.57-15.94 in the raw formulations and between 11.94-15.29 in the drum dried products (Table 4.8). Formulations using peanuts scored higher b* values than formulations using sesame. This may be due to the transfer of yellow pigment colour from the peanuts. Products formulated using fermented rice, sprouted cowpeas with either sesame or peanuts had significantly lower b* values than products formulated using unfermented rice, unsprouted cowpeas with either peanuts or sesame.

The redness (a*) index of the formulations ranged between 1.21-1.68 and between 0.34-1.55 in the drum dried products (Table 4.8). Products formulated using fermented rice, sprouted cowpeas with either sesame or peanuts had lower a* values than formulations made using unfermented rice, unshrouded cowpeas with either peanuts or sesame. This is an indication that fermentation or sprouting may have had an effect on the redness indices of the formulations. However, products formulated using peanuts had significantly higher a* values than formulations with sesame. Drum drying also lowered the redness (a*) of the product irrespective of the legume type (peanuts or sesame). This may be due to maillard reactions between the reducing sugars and free amino acids (Hallén *et al.*, 2004).

Total colour difference (ΔE) is the difference between two colours taking into consideration the three tristimulus difference of L*, a* and b*. A greater colour change (ΔE) was observed when formulation A was drum dried to produce E and when formulation B was drum dried to obtain G. These formulations were those that were made using unfermented rice, unsprouted cowpeas with peanuts and sesame. The higher ΔE values may be due to the higher soluble sugars compared to products that used fermented rice and sprouted cowpeas that has lower soluble sugars due to the process of fermentation. The high sugar content may have caused the greater total change in the products due to maillard reactions.

Table 4.8: Colour changes observed in the raw formulations and drum dried products

	Products	L*	a*	b*	ΔE
Raw formulations	A	86.27±0.12^{a}	1.21±0.02^{e}	12.57±0.03^{e}	
	B	80.39±0.58^{e}	1.52±0.02^{b}	15.94±0.01^{a}	
	C	83.57±0.04^{c}	1.38±0.01^{c}	14.42±0.07^{c}	
	D	84.92±0.05^{b}	1.68±0.01^{a}	13.22±0.04^{d}	
Drum dried flours	E	80.09±0.08^{ef}	0.34±0.06^{g}	12.12±0.14^{f}	6.25±0.20^{a}
	F	81.75±0.49^{d}	1.30±0.04^{d}	11.94±0.05^{g}	3.44±0.43^{b}
	G	78.00±0.09^{g}	1.55±0.01^{b}	12.17±0.03^{f}	4.27±0.23^{b}
	H	79.87±0.58^{f}	0.99±0.01^{f}	15.29±0.10^{b}	3.83±0.58^{b}

Means with the similar alphabet in the column are not significantly different at $p \geq 0.05$
L*= lightness or darkness
a*= redness
b*= yellowness
A=Fermented Rice, Sprouted Cowpeas and Sesame seeds
B=Unfermented Rice, Unsprouted Cowpeas and Peanuts
C=Fermented Rice, Sprouted Cowpeas and Peanuts
D=Unfermented Rice, Unsprouted Cowpeas and Sesame seeds
E= Fermented Rice, Sprouted Cowpeas and Sesame seeds (Drum dried)
F= Unfermented Rice, Unsprouted Cowpeas and Sesame seeds (Drum dried)
G= Unfermented Rice, Unsprouted Cowpeas and Peanuts (Drum dried)
H= Fermented Rice, Sprouted Cowpeas and Peanuts (Drum dried)

4.4.2 Particle size distribution of the formulated flours and drum dried products

Particle size is the most important physical property of particulate samples. Its importance is because it has a direct influence on texture and feel of food ingredients, appearance, flowability as well as packing density and porosity. Particle size of the composite flour samples was estimated as the mean diameter of a food particle that was detained in a known sieve size. It was considered a basic requirement to evaluate how fine the products would feel in the mouth of the baby when consumed. The particle size distribution of composite flour samples and the particle size analysis results were compared between the composite flours (formulations with sesame or peanuts) and with the drum dried flours within each sieve sizes at constant time and amplitude of vibration.

The raw flours (formulations with sesame or peanuts) showed higher percentage of flour of 70% retained in <60µm fraction followed by about 25% retained in 100µm sieve size and about 2% retained in 120-230µm sieve sizes (Table 4.9) The drum dried samples (with either sesame or peanuts) showed lower percentage of flour of about 30% retained in the <60µm sieve size followed by about 40% (100µm) and about 30-40% (120-230µm fraction) (Table 4.9). This indicates that about 80% of all the raw formulations with either sesame or peanuts were retained within the 60-120µm sieve sizes. On the other hand, the drum dried products were grittier than the formulations. (Figure 4.2a). Almost 100% had passed through sieve size 120µm whilst 80% had passed through sieve size 200µm. These differences may be due to the gelatinization of starches during the drum drying process leading to larger particles. It could also be due to the transformation of gelatinized starches into glassy material during the drum drying process, and this is evidenced in the increase in resistant starch content in the products (section 4.3.7 and Table 4.7) From figure 4.2b it is seen that there are differences between the drum dried samples.

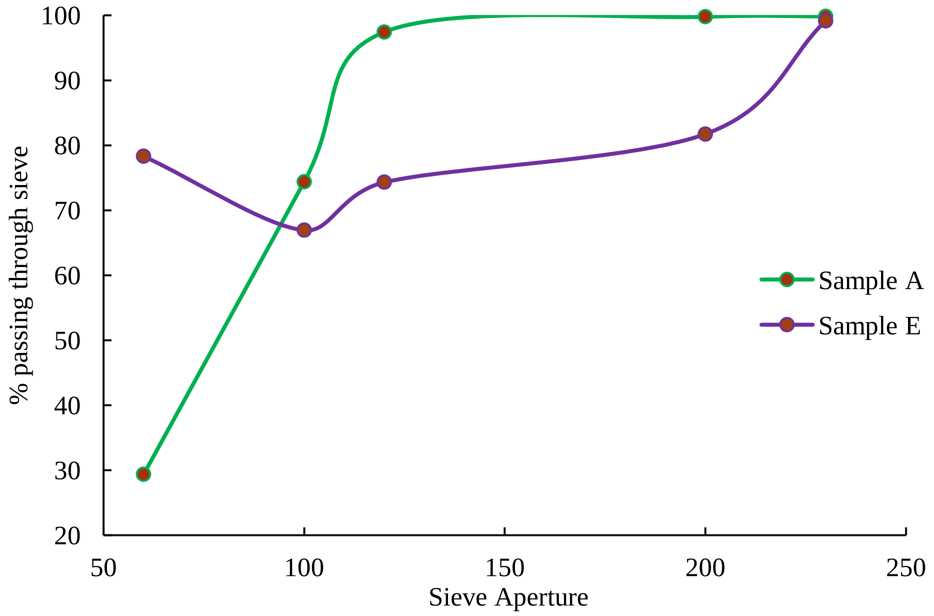


Figure 4 1a: Particle size between formulations against drum drying

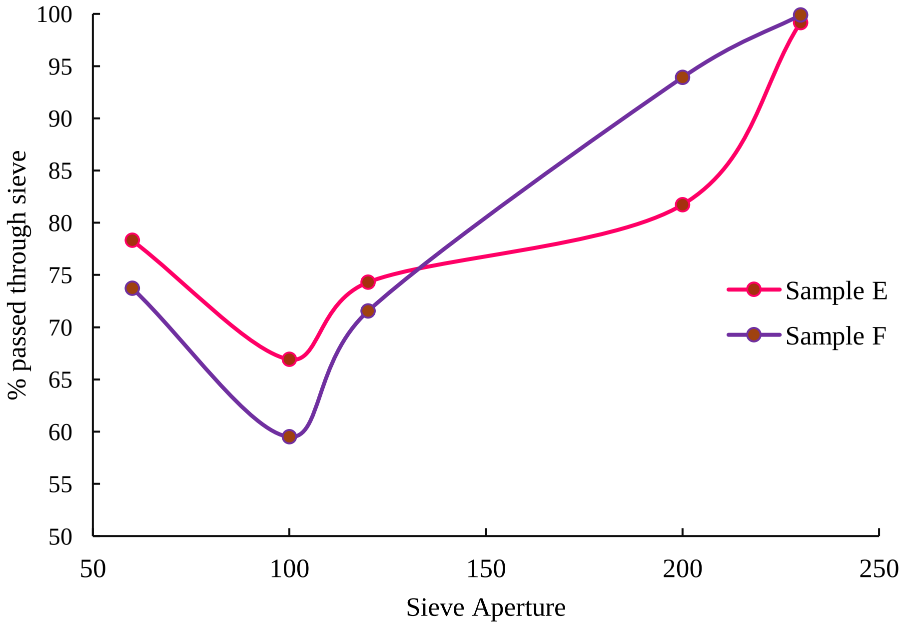


Figure 4.2b: Particle size between drum dried products

Table 4.9: Particle size distribution of raw formulations and drum dried products

Products		% Particle size				
		Sieve aperture (µm)				
		60	100	120	200	230
Raw formulations	A	70.63±1.06	25.61±0.94	2.57±0.20	0.23±0.32	0.17±0.25
	B	77.39±0.00	22.75±0.00	0.06±0.09	0.00±0.00	0.00±0.00
	C	76.23±5.53	21.54±0.35	0.59±0.69	0.24±0.27	0.05±0.07
	D	74.11±1.06	26.18±0.27	0.43±0.53	0.52±0.67	0.00±0.00
Drum dried flours	E	21.69±0.73	33.07±0.89	25.70±1.97	18.27±0.35	0.84±0.49
	F	26.76±0.98	40.50±1.30	28.46±1.05	6.08±1.13	0.12±0.04
	G	29.76±0.78	42.99±1.02	42.99±1.48	3.33±0.39	0.56±0.65
	H	23.71±0.67	37.55±0.11	27.41±0.00	11.29±0.38	0.00±0.00

Means with the similar alphabet (superscript) in the row are not significantly different at $p \geq 0.05$
Values are displayed as mean ± standard deviation
A=Fermented Rice, Sprouted Cowpeas and Sesame seeds
B=Unfermented Rice, Unsprouted Cowpeas and Peanuts
C=Fermented Rice, Sprouted Cowpeas and Peanuts
D=Unfermented Rice, Unsprouted Cowpeas and Sesame seeds
E= Fermented Rice, Sprouted Cowpeas and Sesame seeds (Drum dried)
F= Unfermented Rice, Unsprouted Cowpeas and Sesame seeds (Drum dried)
G= Unfermented Rice, Unsprouted Cowpeas and Peanuts (Drum dried)
H= Fermented Rice, Sprouted Cowpeas and Peanuts (Drum dried)

4.4.3 Moisture sorption isotherm of the formulations and drum dried products

Sorption isotherms describe the relationship between water activity and the equilibrium moisture content of a food product at constant temperature and pressure. They are important applications in the design and optimization of drying equipment, selection of packaging materials, predictions of quality and stability and for calculating product shelf life during storage. Sorption isotherms can reveal phase transition points – water activities at which products cake and clump, deliquesce, or go through glass transition. Several empirical and semi empirical models have been proposed with two or three fitting parameters to describe the moisture sorption behaviour of food products. The most common models are the Langmuir, the BET, the Oswin, the Smith, the Halsey, the Henderson, the Iglesias-Chirife, the GAB and the Peleg models. In this study, the moisture content data were fitted into Oswin, Henderson, GAB, BET and Smith models as reported in Table 4.10. The goodness of fit of the models (as indicated by the R-squared values) varied with each food blend. Figure 4.3a shows an example of how the data for formulation B fits well to model proposed by Oswin. The effects of storage temperature on moisture sorption showed, that the equilibrium moisture decreased with increased storage temperature. Ocheme *et al.*, (2013) explained increase in storage temperature decreases the water molecules' binding strength causing the product to be less hygroscopic. Figure 4.4a shows an example of how the data for the two different temperatures fit for formulation A. It was observed that an increase in temperature decreased the equilibrium moisture content of the products between 23◦C and 30◦C (Figure 4.4a). At a higher temperature, there is a higher adsorption capacity as a result of increase molecular agitation. Consequently, there is a higher mass transfer rate from the product to the bound area at a higher temperature. Another explanation could be that, at higher temperature there is a higher state of excitation of molecules resulting in an increase in the distance between water molecules and the food particles and spreading of the water binding sites. This might cause a reduction in the total number of binding sites available for interaction with water molecules (Souza *et al.*, 2015). A similar observation of decreasing monolayer moisture content with increase temperature was reported by Labuza *et al.*, (1985) for two dehydrated foods. Again, from figure 4.4b it is observed that product made from fermented rice and sprouted cowpeas had higher EMC%. This could be due to the presence of low molecular weight organic acid such as lactic acid which are hygroscopic, and thus entrap more moisture (Badea and Radu, 2018). In addition, the extent of plasticization of starch induced by drum drying influences water sorption sites

(Chuzel and Zakhia, 1991). Consequently, the drum dried product adsorbed less water than the raw formulation (figure 4.4c). This could also be due to the high resistant starch content in the product.

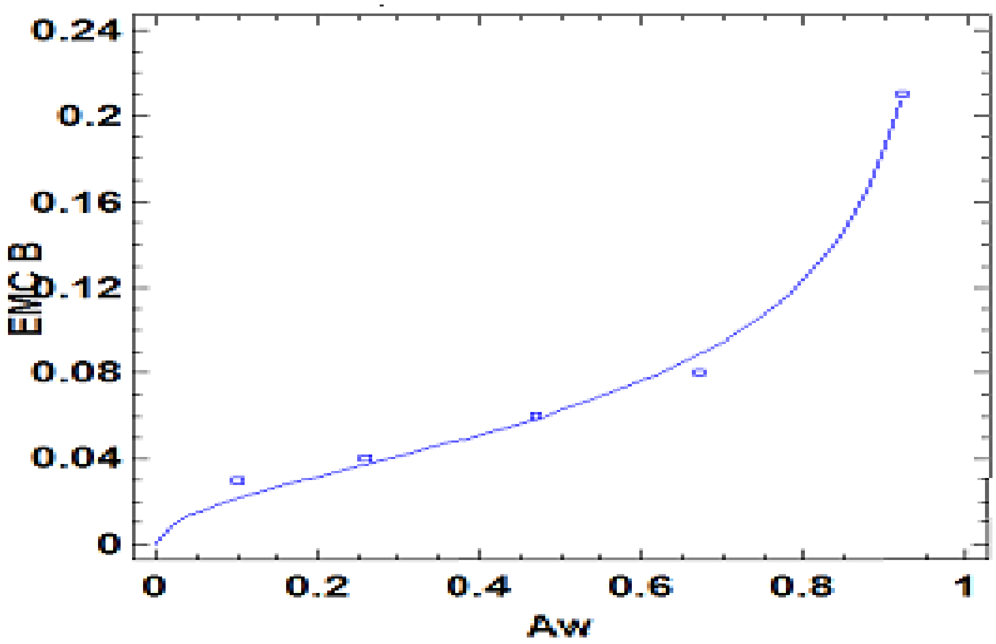


Figure 4.3a: Oswin best fitted model for formulation B at 23◦C

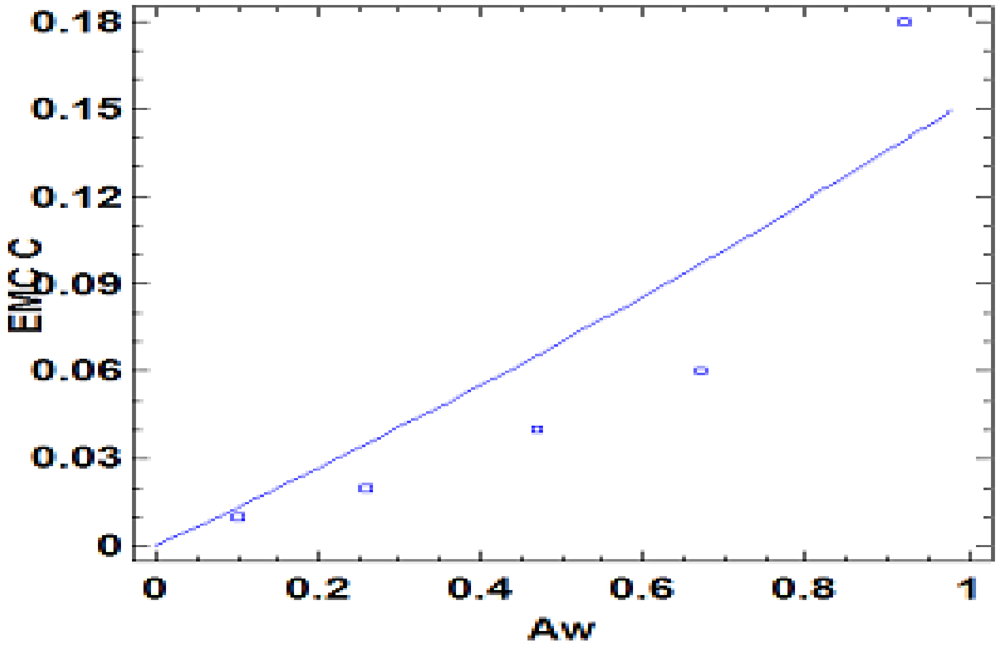
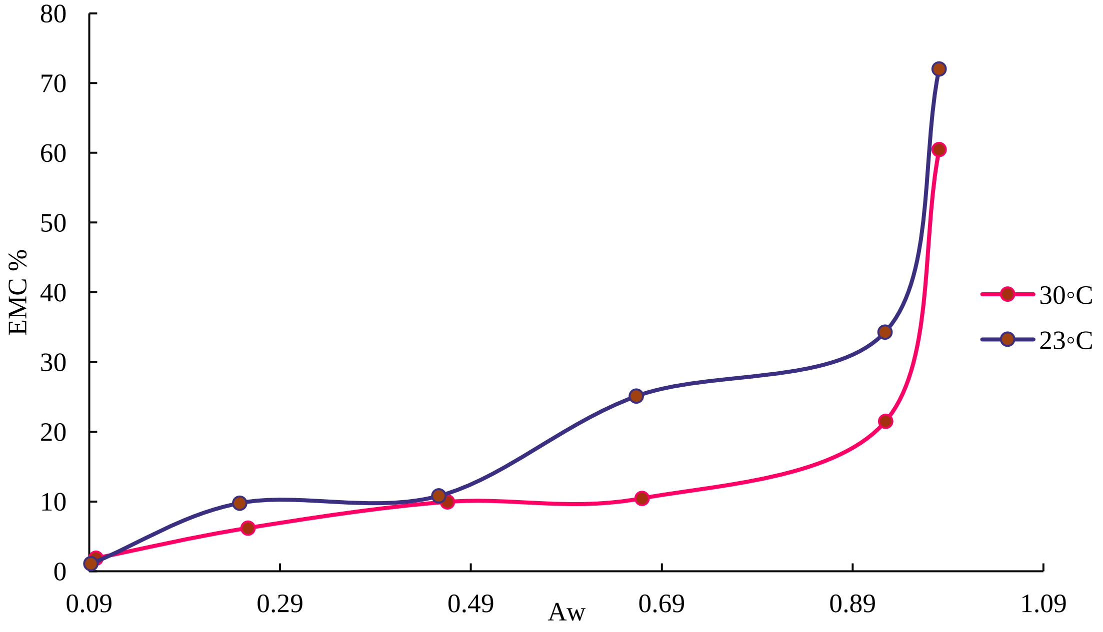
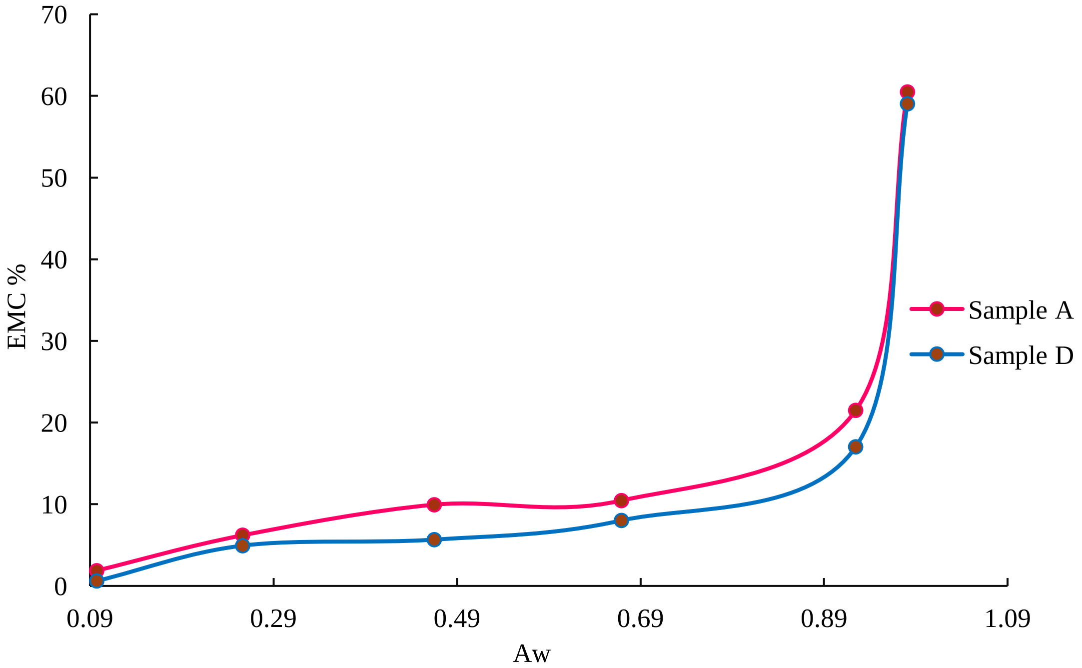


Figure 4.3b: GAB bad fitted model for formulation C at 30◦C



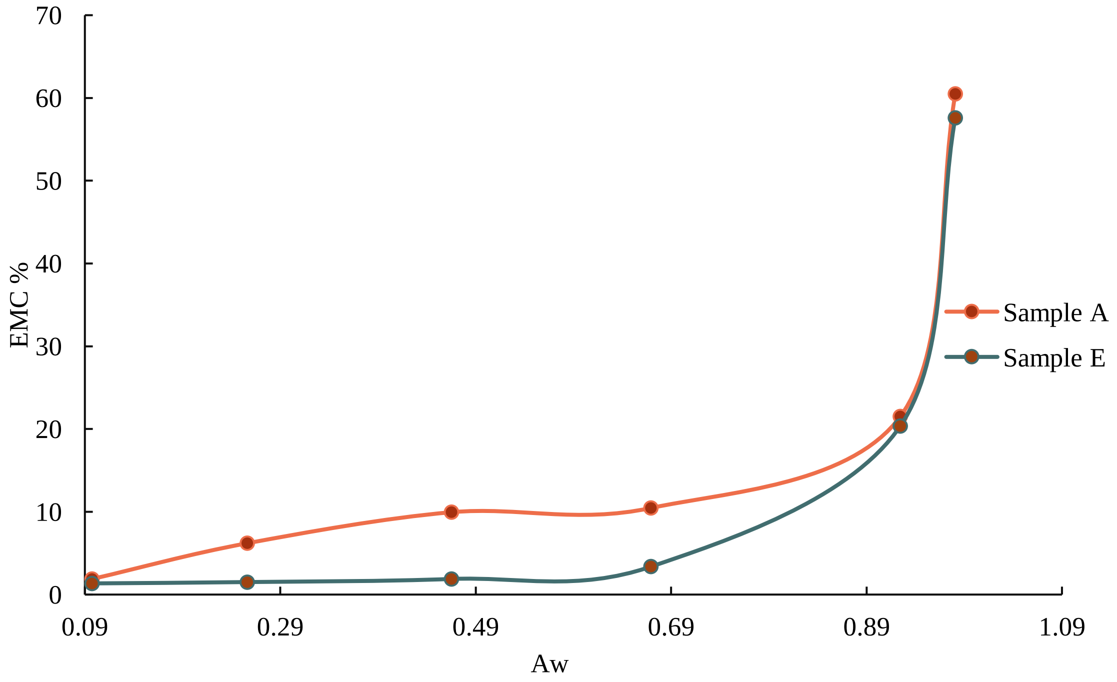
EMC= Equilibrium Moisture Content   Aw= water activity

Figure 4.4a: Equilibrium Moisture Content for formulation A at two different temperatures



EMC= Equilibrium Moisture Content   Aw= water activity

Figure 4.4b: Equilibrium Moisture Content for formulation A & D at 30◦C



EMC= Equilibrium Moisture Content Aw= water activity

Figure 4.4c: Equilibrium moisture content for sample A & E at 30◦C

Table 4.10: Constants and results derived from isotherm models for all raw formulations and drum dried products at two different temperatures

Products	Temperature °C	BET model			GAB model				Oswin model			Henderson model				Smith model		
		Mo	C	R^2	Mo	K	G	R^2	A	B	R^2	A	B	T	R^2	A	B	R^2
A	23	2.091	0.122	88.243	0.491	0.505	1.153	96.400	0.179	0.451	91.350	0.127	0.756	0.756	92.409	0.027	0.206	93.394
B		0.566	0.271	99.293	0.398	0.981	0.366	99.227	0.095	0.742	99.201	0.127	0.753	0.752	98.979	-0.041	0.234	96.003
C		0.468	0.152	99.906	0.607	0.985	0.220	99.006	0.079	0.640	99.140	0.113	0.852	0.852	97.596	-0.010	0.148	96.591
D		0.347	0.281	99.264	0.345	1.000	0.282	99.263	0.032	0.771	99.721	0.112	0.863	0.863	97.973	-0.022	0.150	94.790
E		0.072	0.682	99.280	0.225	1.039	0.272	99.607	0.037	0.742	99.282	0.114	0.832	0.832	90.842	-0.040	0.160	90.492
F		0.902	0.150	98.496	0.851	0.997	0.158	99.423	0.078	0.599	98.797	0.108	0.917	0.917	96.032	-0.000	0.128	96.032
G		0.456	0.233	99.850	0.134	0.923	0.669	99.952	0.063	0.713	99.829	0.109	0.9.06	0.906	96.392	-0.026	0.148	98.273
H		0.136	0.510	99.116	0.242	1.020	0.324	99.270	0.051	0.877	99.066	0.114	0.823	0.823	98.400	-0.013	0.176	98.729
A	30	4.373	0.044	96.999	0.349	0.589	0.738	94.281	0.097	0.418	97.640	0.104	0.963	0.963	91.222	0.029	0.095	96.725
B		1.311	0.087	97.499	0.471	0.256	1.185	85.785	0.063	0.491	99.234	0.094	1.057	1.057	95.815	0.014	0.075	98.045
C		3.186	0.044	94.18	0.870	0.171	0.892	79.126	0.040	0.616	99.933	0.087	1.131	1.131	98.290	0.004	0.071	98.479
D		0.154	0.318	99.729	0.508	0.230	1.106	71.614	0.062	0.743	99.220	0.091	1.096	1.096	93.307	0.014	0.084	94.990
E		0.249	0.274	99.976	0.584	0.209	1.318	74.564	0.042	0.746	99.054	0.098	1.019	1.019	94.989	-0.018	0.105	96.776
F		0.103	0.426	98.201	0.535	0.215	1.242	65.917	0.078	0.454	98.898	0.094	1.058	1.058	88.995	-0.015	0.093	90.418
G		0.108	0.427	99.898	0.391	0.254	1.413	85.654	0.032	0.842	99.904	0.096	1.040	1.040	92.481	-0.028	0.105	96.776
H		0.143	0.373	98.978	0.570	0.207	1.319	68.798	0.036	0.808	98.885	0.097	1.028	1.028	90.985	-0.018	0.102	92.698

A=Fermented Rice, Sprouted Cowpeas and Sesame seeds
B=Unfermented Rice, Unsprouted Cowpeas and Peanuts
C=Fermented Rice, Sprouted Cowpeas and Peanuts
D=Unfermented Rice, Unsprouted Cowpeas and Sesame seeds
E= Fermented Rice, Sprouted Cowpeas and Sesame seeds (Drum dried)
F= Unfermented Rice, Unsprouted Cowpeas and Sesame seeds (Drum dried)
G= Unfermented Rice, Unsprouted Cowpeas and Peanuts (Drum dried)
H= Fermented Rice, Sprouted Cowpeas and Peanuts (Drum dried)

Mo = Monolayer moisture content (gH2O/100g solid), C = BET constant, G and K = GAB constants
A and B = Henderson and Smith constants R2 = coefficient of regression

4.5 Food safety

4.5.1 Aflatoxin levels of the raw material (sesame and peanuts**)**

The occurrence of aflatoxins in peanuts and peanut products is very widespread all over the world. Since aflatoxins have been considered as human carcinogen (Ostry *et al.*, 2017), it was important to analyse for aflatoxins in the products to ascertain their safety particularly as they were to be used as complementary food. The aflatoxin levels of the raw materials were determined to be below regulatory limit or not detectable (Table 4.11) and thus safe for use in the formulation for complementary foods. These levels reflect good sorting of the raw materials.

Table 4.11: Aflatoxin levels of the raw materials used

Raw materials	Aflatoxin type			
	Amount (ug/kg)			
	G1	G2	B1	B2
Sesame	ND	ND	ND	ND
Peanuts	ND	ND	1.31e-01	ND

ND = Not detectable

4.5.2 Microbiological safety of the formulations and drum dried products

Generally, the microbiological load on the formulations were low and within acceptable limits thus safe for consumption (Table 4.12). The criteria set for Total Plate Count (TPC) in complementary foods 2.70 log CFU/g or below, 2.48 log CFU/g for yeast and moulds for ready to eat foods prepared for infants and no detectable count for e. coli in complementary food (CAC, 2008). The lower levels of drum dried products comparative to the flour samples confirms the effect of heat on microbial load. Tang *et al.,* (2003) reported that the drum dryer can operate under a clean and hygienic guideline if Good Manufacturing Practices are observed carefully. Hence, it can be deduced that the instant food prepared are safe for babies.

Table 4.12: Microbial content of the raw formulations and drum dried products

Microbial analysis	Raw formulations				Drum dried flours			
	A	B	C	D	E	F	G	H
Total plate count (cfu/g)	43	75	61	108	160	1.9×10^3	30	12
Coliform bacteria (cfu/g)	0	0	0	0	0	0	0	0
Enterobacteriaceae (cfu/g)	0	0	0	0	0	0	0	0
Yeast and mould	0	0	0	0	0	0	0	0

Values are averages of triplicates
Values are presented as mean ± standard deviation
ND means Not Detected
A=Fermented Rice, Sprouted Cowpeas and Sesame seeds
B=Unfermented Rice, Unsprouted Cowpeas and Peanuts
C=Fermented Rice, Sprouted Cowpeas and Peanuts
D=Unfermented Rice, Unsprouted Cowpeas and Sesame seeds
E= Fermented Rice, Sprouted Cowpeas and Sesame seeds (Drum dried)
F= Unfermented Rice, Unsprouted Cowpeas and Sesame seeds (Drum dried)
G= Unfermented Rice, Unsprouted Cowpeas and Peanuts (Drum dried)
H= Fermented Rice, Sprouted Cowpeas and Peanuts (Drum dried)

4.6 Consumer focus group discussion and sensory evaluation of a sesame or peanut based complementary food

Participants in the focus group discussions (FGD) were between 18 and 50 years old with most of them between 18 – 24 years old. Participants were mostly females with only one male in the FGD. The participants were either traders, stay-at-home mothers or unemployed within the Sekondi/Takoradi metropolis. The characteristics of the participants are shown in Table 4.13.

Table 4.13: Characteristics of FGD participants in the focus group discussion

Characteristics	No. of participants (N=41)
Sex	
Female	40
Male	1
Age	
18-24	2
25-31	11
39-45	13
46-60	5
61-70	10
Occupation	
Nanny/House girl	2
Stay-at-home mom	1
Health worker	1
Trader	18
Seamstress	2
Unemployed	17

4.6.1 Consumer focus group discussion

The consumer focus group discussion based on the panellists' understanding of the desirability of complementary foods and their perception on fermented and sprouted ingredients used in complementary foods. The results for this discussion were coded into a global theme (The Understanding on the desirability of cereal legume blends). The global theme was then broken down into sub-themes (Figure 4.5). Participants were grouped into 4 categories i.e. Parents with children ages 7-24months (parent group 1, parent group 2) and mothers, caretakers or nannies (non-parent group 1 and non-parent group 2). Each group consisted of 8 participants per each category

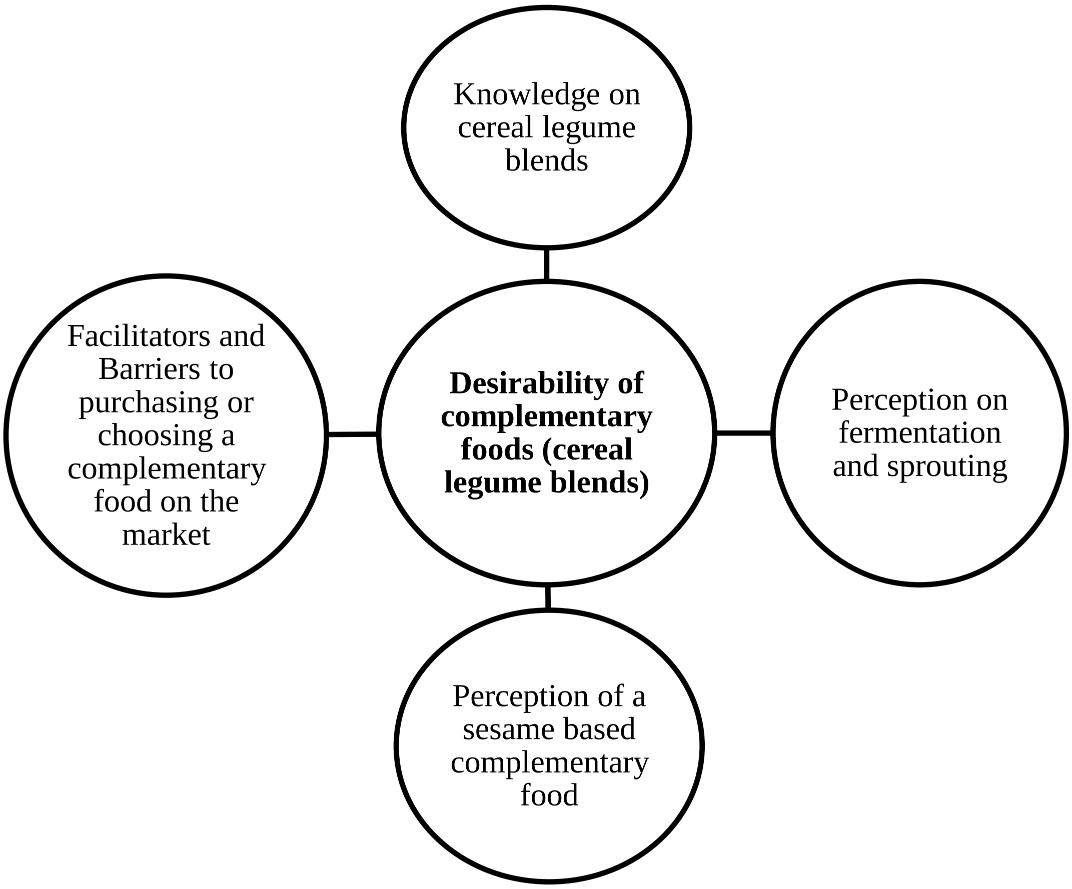


Figure 4.5: Understanding the desirability of complementary food (cereal legume blends)

4.6.1.1 Perception about cereal legume blends (complementary foods)

This subject sought the knowledge of the respondents on cereal legume blends, their perception on these blends for infants and if the panellists understood what really constituted complementary foods and possibly enquire about what they would normally use. It was observed that all the focus group participants seemed to understand what cereal legume blends were and its importance to infants. They pointed out that cereal legume blends are good complements for breast milk after 6 months of age when breast milk is not enough to satisfy them. The focus groups from the non-parent side mentioned that the combination of cereal legume blends is to complement each nutrient to form a more balanced meal. It was generally observed that some points raised in the parent or non-parent group were similar. On the other hand, some focus groups raised unique points out of the discussion. A panellist from Focus Group 2 (mother group) mentioned:

"I think complementary foods are blends of cereals (carbohydrates) and legumes (proteins) to help babies to get more nutrients after 6 months of breastfeeding" **(Parent Focus Group 2).**

In the parent/caretakers group 1, another panellist described complementary food as:

"You see, because after 6 months the baby is growing fast, he or she has to eat well so these foods, complement the breast milk to offer the baby more nutrients to grow well and become healthy. Babies that eat good complementary foods are heavy in weight" **(Non Parent Focus Group 1).**

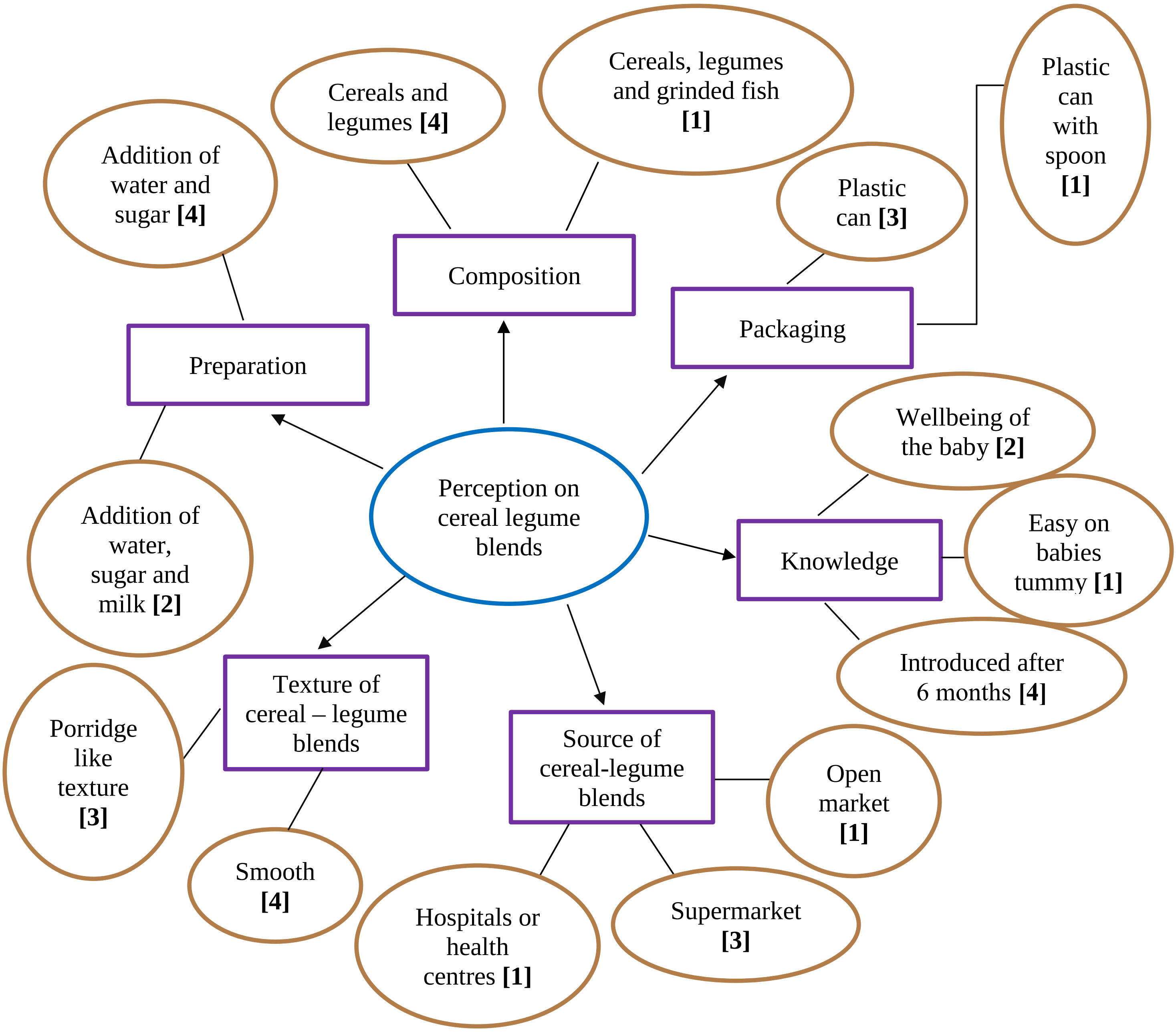
From the focus group discussion on their knowledge about complementary food, it can be deduced that most of them knew what complementary foods (cereal legume blends) are and their importance. This is because the World Health Organization described and recommended the introduction of complementary food after 6 months of exclusive breastfeeding and that it helps to constitute an important milestone in the child's wellbeing.

When asked about their how they prepare their complementary foods. All the groups mentioned that they just add water and then cook to a light and smooth consistency. Other groups also indicated that, they add milk powder to the porridge after cooking and because they believed it helps boost the nutritional content of the mixes.

Three of the focus groups mentioned that the traditional complementary food they buy usually come in plastic container. The lids are tight and come in many colours they said. One group however mentioned they would like to have the products come with its measuring spoon. *"If they have a small spoon to measure the product that would be fine"* **(Parent Focus Group 2**).

The panelists also mentioned that they purchased their products from either the supermarkets (3 Focus groups), open markets or hospitals.

The thematic mapping on the panellists' perceptions on cereal legume blends as complementary foods are presented in Figure 4.6.



Numbers in brackets represent the total number of focus groups with similar themes. Note that the themes may appear in more than one focus group.

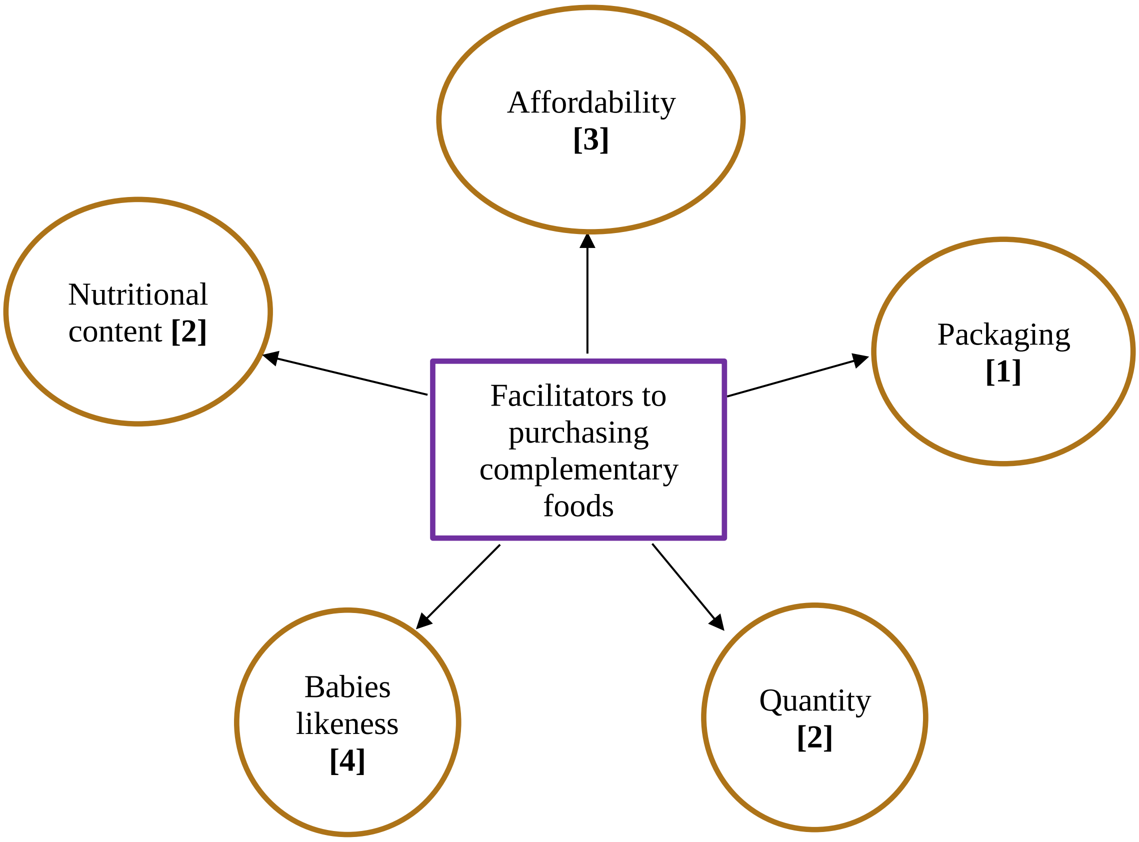
Figure 4.6: Perception on cereal legume blends

4.6.1.2 Facilitators and barriers to purchasing and selecting complementary foods

All focus groups discussed some key facilitators in purchasing complementary foods as well as the barriers that deters them from purchasing. Babies acceptability of the food and product affordability were major facilitators mentioned (Figure 4.7) whilst allergies and safety were the most discussed as a barrier in selecting a complementary food on the market (Figure 4.8). Generally, it was observed that some points raised in the mothers and non-parent groups were quite similar. With regards to what facilitates purchase, examples of some statements made by the panellists during the discussion were:

"*Usually when the baby likes the first try or two obviously, I buy them. For me, it all depends on what products my baby enjoys"* **(Parent Focus Group 1).** Another panellist also stated that;

"I personally look at the cost and how many preparations I can make from a product" **(Parent Focus Group 2).**

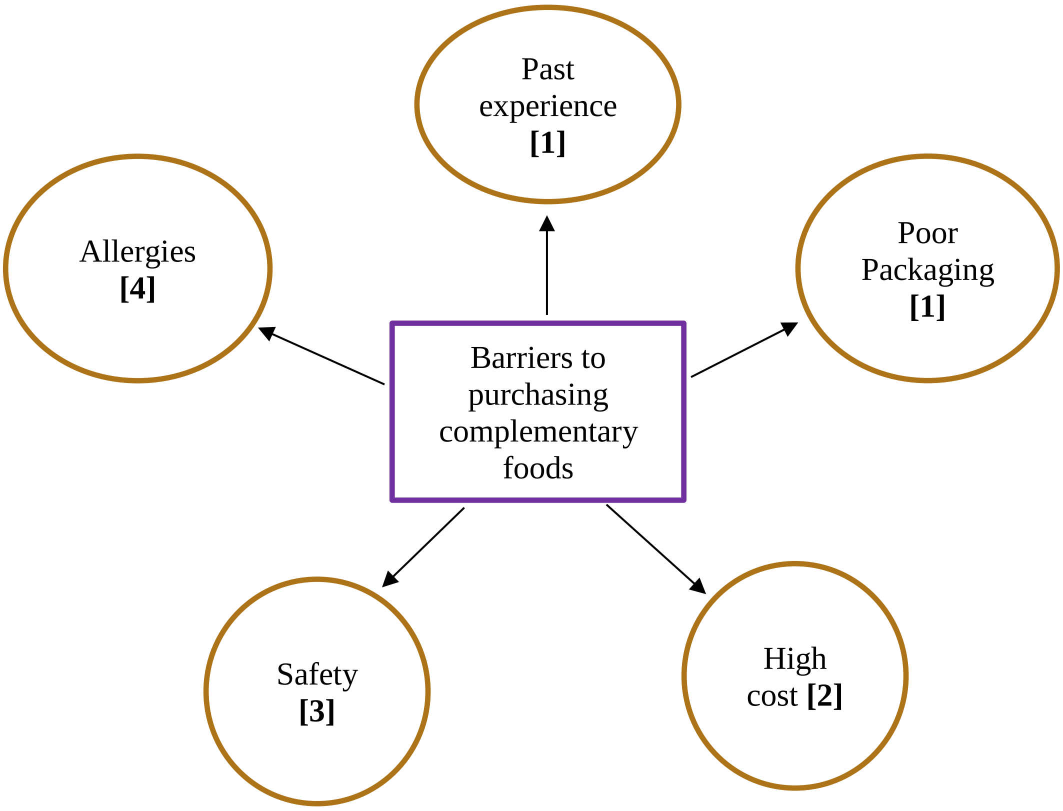


Numbers in brackets represent the total number of focus groups with similar themes. Note that the themes may appear in more than one focus group.

Figure 4.7: Facilitators in purchasing or selecting complementary foods/cereal legume blends

Barriers that deter them from purchasing complementary foods on the market was also discussed (Figure 4.8). From the discussion, a common statement made by the correspondents are;

"Allergies are major reasons why I would not buy a cereal legume blend for my baby. For example, the food may be good alright but immediately you feed the baby with it he/she experiences stomach upsets or fever" **(Parent Focus Group 2).**



Numbers in brackets represent the total number of focus groups with similar themes. Note that the themes may appear in more than one focus group.

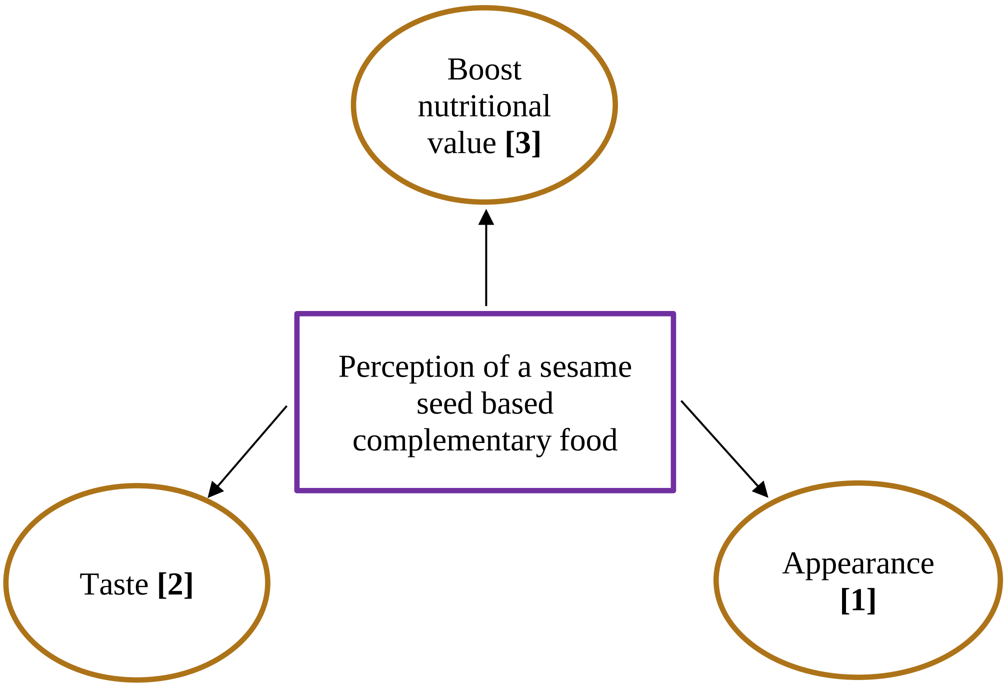
Figure 4.8: Barriers to purchasing or selecting complementary foods/cereal legume blends

4.6.1.3 Perception of a sesame seed based complementary food

The panellists in the focus groups were asked to taste and give their opinion about the food. All the groups were intrigued about the idea of sesame in complementary food as they explained the nutritional content it offers (Figure 4.9). Below are some statements that popped up during the discussion period:

"The sesame seeds, we know are very nutritious so I think it would be good trying to make a complementary food from it. I would like to see and taste how it turns out" **(Parent Focus Group 2).**

"I have only heard about the seeds nutritional benefits from traders in public transports so this would be good because the seeds are nutritious" **(Non Parent Focus Group 2).**



Numbers in brackets represent the total number of focus groups with similar themes. Note that the themes may appear in more than one focus group.

Figure 4.9: Perception of a sesame seed based complementary food (cereal legume blends)

4.6.1.4 Perception on sprouting and fermentation in complementary food

The panellists in the focus groups (parent and non-parent/caretakers groups) were asked about their perception on fermentation and sprouting in complementary food (Figure 4.10). With regards to fermentation, the panellists expressed their knowledge on the term fermentation and the benefits they know about. It was generally observed that the points were similar across the different focus groups even though there were few points raised that were unique to a particular group. A panellist from the parent group 2 said:

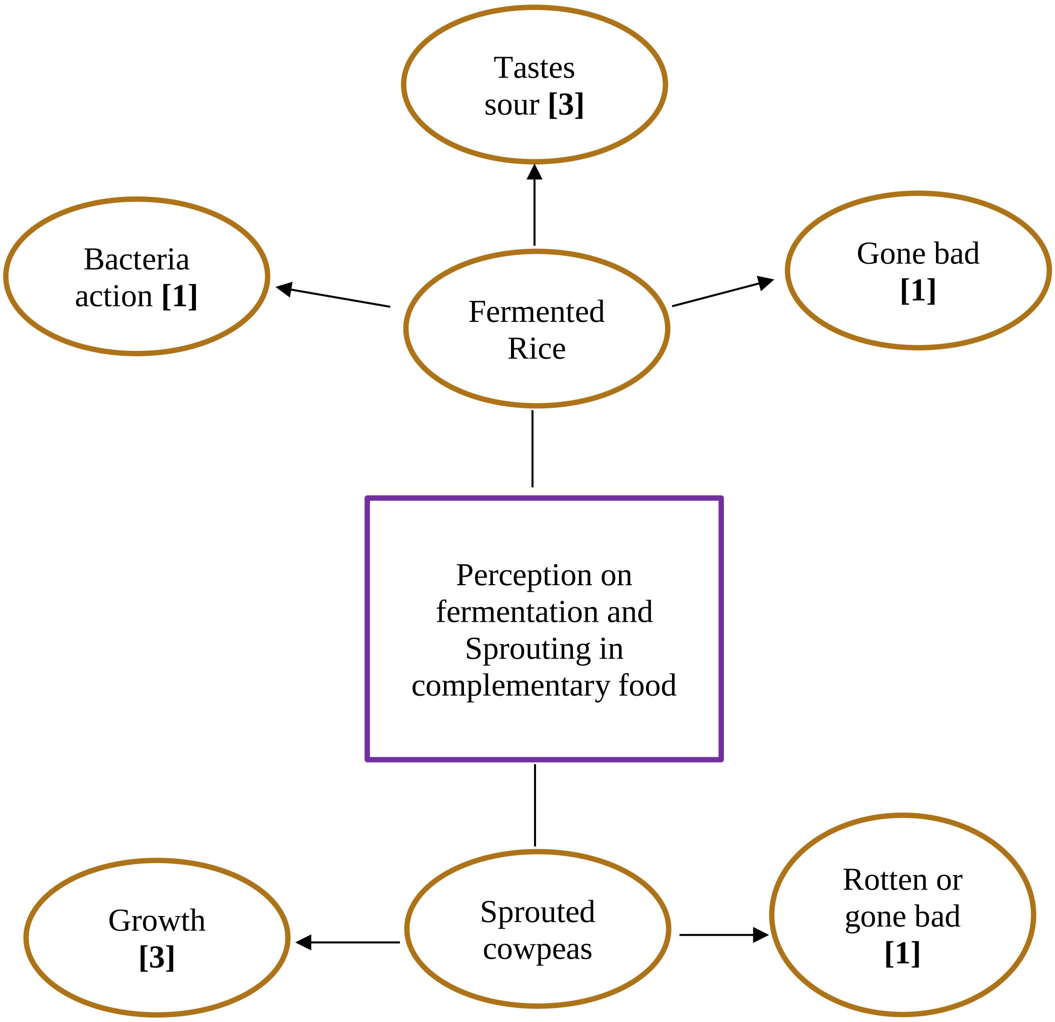
"I think that it is rice that has been made to go bad; due to that the taste becomes sour and when you eat it you feel a tingling sensation in your mouth" **(Parent Focus Group 2).**

From the non-parent/caretakers group 1, another panellist mentioned that:

"It is rice that has been made into a dough like the ones we use to prepare banku" **(Non Parent Group 2).**

Based on responses from the panellists from these focus groups, it can be concluded that they had an idea about what fermentation or fermented rice was since sourness and bacterial action have been mentioned by previous researchers as some characteristics of fermentation.

Sprouting, on the other hand was described by three groups as "something that is growing naturally" by one panellist in the focus groups. Panellists in another group associated sprouting with spoilage and believed that this was not a healthy option for baby's food.



Numbers in brackets represent the total number of focus groups with similar themes. Note that the themes may appear in more than one focus group.

Figure 4.10: Perception on fermentation and sprouting in complementary food

4.6.2 Sensory evaluation of the formulations and drum dried products

The participants were presented with the concept on how the complementary food was formulated and their benefits. All the participants were intrigued about the concept of sprouting of cowpeas in particular and would want to try that at home. Again, they expressed that the idea of drum drying would save them time from cooking.

During the tasting session, participants did not like the taste of the fermented drum dried products irrespective of the use of sesame or peanut but liked the cooked raw formulations better. Comments for the fermented drum dried products were;

"It tastes like burnt banku"

"I have not tried anything like this before, but it does not taste good to me"

In conclusion, all groups suggested they preferred the fermented products using either peanut or sesame in its raw formulated form to cook in the conventional way rather than drum dried, ready to eat form.

For the unfermented products, some participants expressed that flours incorporated with peanuts tasted much better than the sesame seed products.

"I like the peanut one as the sesame product has a bitter aftertaste"

"I like the peanut product because I am more familiar to that than sesame products weanimix".

4.7 Cost analysis for the production of the drum dried products

The initial capital investment, useful life and depreciation needed to begin the project as well as the costs are shown in table 4.13. The capital investment estimated for the plants and machinery used in the processing process was GH₵102,300. The costing of the various items is as shown below.

4.7.1 Capital investment

Table 4.14: Capital investment

Item	**Units**	**Amount (GH¢)**	**Useful Life**	**Depreciation (90%)**	**Annual Depreciation**
Drum Dryer	1	25000	10	2500	2250
Hammer Mill	1	48000	10	4800	4320
Electric Oven	1	1600	8	160	180
Handheld Ph Meter	1	1000	8	100	112.5
Vehicles	2	26000	15	2600	1560
Water Storage Tank	1	400	10	40	36
Electric Measuring Scale	1	150	5	15	27
Thermometer	1	150	4	15	33.75
Total Capital Cost		**102300**		**10230**	**8519.25**

For the estimation of cost for the products that do not require the use of a drum dryer, the cost of the drum dryer was deducted from the capital cost resulting GH₵77,300

4.7.2 Operational cost

The operational cost considered items that were constantly being used in the processing process and had to be replenished periodically (Table 4.14).

Table 4.15: Cost of materials and equipment

Description	**Years**						
	1	**2**	**3**	**4**	**5**	**6 to 9**	**10**
Plastic Bowls	100	100	125	125	150	150	160
Basin	60	60	75	75	90	90	96
Measuring Cups	14	14	17.5	17.5	21	21	22.4
Tap Water	2400	2400	3000	3000	3600	3600	3840
Drying Trays	30	30	37.5	37.5	45	45	48
Plastic Containers	15	15	18.75	18.75	22.5	22.5	24
Napkins	50	50	62.5	62.5	75	75	80
Aprons	40	40	50	50	60	60	64
Hair Net	4	4	5	5	6	6	6.4
Sesame Seeds (1kg)	20800	20800	26000	26000	31200	31200	33280
Cowpeas (768kg)	3490	3490	4362.5	4362.5	5235	5235	5584

Local White Rice (3360kg)	13440	13440	16800	16800	20160	20160	21504
Peanuts (192kg)	1404	1404	1755	1755	2106	2106	2246.4
Gloves	30	30	37.5	37.5	45	45	48
Cheese Cloth	15	15	18.8	18.8	22.5	22.5	24
Colander	25	25	31.25	31.25	37.5	37.5	40
Spatula	10	10	12.5	12.5	15	15	16
Knives	15	15	18.8	18.8	22.5	22.5	24
Electricity	12000	12000	15000	15000	18000	18000	19200
Wooden Spoon	4	4	5	5	6	6	6.4
Communication	3000	3000	3750	3750	4500	4500	4800
Ziplock Bags	1680	1680	2100	2100	2520	2520	2688
Labels	2400	2400	3000	3000	3600	3600	3840
Fuel	12000	12000	15000	15000	18000	18000	19200
Administration							
Managing Director	9600	9600	9600	9600	9600	12000	12000
Production Manager	3600	3600	3600	3600	3600	4500	4500
Marketing Director	3600	3600	3600	3600	3600	4500	4500
Accountant	3600	3600	3600	3600	3600	4500	4500
Drivers	3000	3000	3000	3000	3000	3750	3750
Cleaners	3000	3000	3000	3000	3000	3750	3750
Security	3000	3000	3000	3000	3000	3750	3750
Total Cost	102426	102426	120683	120683	138939	146289	153591
Contingency (Maintenance)	2048.5	2048.5	2413.7	2413.7	2778.7	2925.7	3071.8
Total Operating Cost	104475	104475	123096	123096	141718	149215	156663

The operational total cost of the various products was calculated by subtracting the cost of the materials of the product not included in the product production from the total operational cost. The operational cost of the sesame products and peanut products were GH₵103,042 in the 1st and 2nd year, GH₵121306 in the 3rd to 4th year, and respectively GH₵139569, GH₵147066, GH₵154372 in the 5th, 6th -9th and 10th year.

The operational cost of the peanut products was: GH₵83258 GH₵83258 GH₵96576 GH₵96576, GH₵109894, GH₵117391, GH₵122718 in the years, 1-2, 3-4, 5, 6-9 and 10 respectively.

4.7.3 Revenues from the products

The revenue from the sales the products from sesame and peanut product are as the main component was estimated as shown in table 4.15 and 4.16.

4.7.3.1 Sesame products

Table 4.16: Revenue of sesame products

Description	**Years**						
	1	**2**	**3**	**4**	**5**	**6 to 9**	**10**
Capacity of Production	80	80	80	100	100	100	100
4800kg/4.8tonnes	3840	3840	3840	4800	4800	4800	4320
Units of production	7680	7680	7680	9600	9600	9600	8640
Revenue drum dried (GH¢21 per unit)	161280	161280	161280	201600	201600	201600	181440
Revenue non-drum dried (GH¢20 per unit)	153600	153600	153600	192000	192000	192000	172800

4.7.3.2 Peanut products

Table 4.17: Revenue of peanut products

Description	**Years**						
	1	**2**	**3**	**4**	**5**	**6 to 9**	**10**
Capacity of production	80	80	80	100	100	100	100
4800kg/4.8tonnes	3840	3840	3840	4800	4800	4800	4320
Units of production	7680	7680	7680	9600	9600	9600	8640
Revenue drum dried (GH¢17 per unit)	130560	130560	130560	163200	163200	163200	146880
Revenue non-drum dried (GH¢15 per unit)	115200	115200	115200	144000	144000	144000	129600

4.7.4 Discounted measures of project worth

4.7.4.1 Sesame drum dried products

Table 4.18: Discounted Worth of Drum Dried Sesame Products

Years	**Cost**	**Contingencies (5%)**	**Cash outflow**	**Benefit**	**Cash inflow**	**df**	**Present cost**	**Present benefit**	**Present inflow**
0	102300	5115	107415						
1	103042	5152	210495	161280	-49215	0.8696	183046	140249	-42796.98
2	103042	5152	108195	161280	53085	0.7561	81806	121944	40137.9
3	121306	6065	127371	161280	33909	0.6575	83747	106042	22294.94
4	121306	6065	127371	201600	74229	0.5718	72831	115275	42443.94
5	139570	6978	146548	201600	55052	0.4972	72864	100236	27371.78
6	147067	7353	154420	201600	47180	0.4323	66756	87152	20395.92
7	147067	7353	154420	201600	47180	0.3759	58046	75781	17734.96
8	147067	7353	154420	201600	47180	0.3269	50480	65903	15423.14
9	147067	7353	154420	201600	47180	0.2843	43902	57315	13413.28
10	154372	7719	162091	181440	19349	0.2472	40069	44852	4783.14
TOTAL							**753546**	**914748**	
NPV									**161202.02**
BCR									**1.21**

4.7.4.2 Sesame non-drum dried products

Table 4.19: Discounted worth of non-drum sesame products

Years	**Cost**	**Contingencies (5%)**	**Cash Outflow**	**Benefit**	**Cash Inflow**	**df**	**Present Cost**	**Present Benefit**	**Present Inflow**
0	77300	3865	81165						
1	103042	5152	185495	153600	(31895)	0.8696	161306	133570.56	27735.51
2	103042	5152	108195	153600	45405	0.7561	81806	116136.96	34331.05
3	121306	6065	127371	153600	26229	0.6575	83747	100992	17245.34
4	121306	6065	127371	192000	64629	0.5718	72831	109785.6	36954.66
5	139570	6978	146548	192000	45452	0.4972	72864	95462.4	22598.66
6	147067	7353	154420	192000	37580	0.4323	66756	83001.6	16245.84
7	147067	7353	154420	192000	37580	0.3759	58046	72172.8	14126.32
8	147067	7353	154420	192000	37580	0.3269	50480	62764.8	12284.90
9	147067	7353	154420	192000	37580	0.2843	43902	54585.6	10684.00

10	154372	7719	162091	172800	10709	0.2472	40069	42716.16	2647.34
TOTAL							**731806**	**871188.48**	
NPV									**139382.60**
BCR									**1.19**

4.7.4.3 Peanut drum dried products

Table 4.20: Discounted worth of drum dried products peanut products

Years	**Cost**	**Contingencies (5%)**	**Cash Outflow**	**Benefit**	**Cash Inflow**	**df**	**Present Cost**	**Present Benefit**	**Present Inflow**
0	102300	5115	107415						
1	83259	4163	189721	130560	(59161)	0.8696	164982	113535	51447
2	83259	4163	87421	130560	43139	0.7561	66099	98716	32617
3	96576	4829	101405	130560	29155	0.6575	66674	85843	19169
4	96576	4829	101405	163200	61795	0.5718	57983	93318	35334
5	109894	5495	115388	163200	47812	0.4972	57371	81143	23772
6	117391	5870	123260	163200	39940	0.4323	53285	70551	17266
7	117391	5870	123260	163200	39940	0.3759	46334	61347	15013
8	117391	5870	123260	163200	39940	0.3269	40294	53350	13056
9	117391	5870	123260	163200	39940	0.2843	35043	46398	11355
10	122718	6136	128854	146880	18026	0.2472	31853	36309	4456
TOTAL							**619918**	**740510**	
NPV									**120592**
BCR									**1.19**

4.7.4.4 Peanut non-drum dried products

Table 4.21: Discounted worth of non-drum dried peanut products

Years	**Cost**	**Contingencies (5%)**	**Cash Outflow**	**Benefit**	**Cash Inflow**	**df**	**Present Cost**	**Present Benefit**	**Present Inflow**
0	77300	3865	81165						
1	83259	4163	164721	115200	- 49521	0.8696	143242	100178	-43064
2	83259	4163	87421	115200	27779	0.7561	66099	87103	21003
3	96576	4829	101405	115200	13795	0.6575	66674	75744	9070
4	96576	4829	101405	144000	42595	0.5718	57983	82339	24356
5	109894	5495	115388	144000	28612	0.4972	57371	71597	14226
6	117391	5870	123260	144000	20740	0.4323	53285	62251	8966
7	117391	5870	123260	144000	20740	0.3759	46334	54130	7796

8	117391	5870	123260	144000	20740	0.3269	40294	47074	6780
9	117391	5870	123260	144000	20740	0.2843	35043	40939	5896
10	122718	6136	128854	129600	746	0.2472	31853	32037	184
TOTAL							**598178**	**653391**	
NPV									**55214**
BCR									**1.09**

4.7.5 Comparison of the various products

In general, all the products indicated positive outcomes. The NPV of all the products were positive implying that, it is worth the investment. They products also possess BCRs which were greater than one indicating that the products are worth the investment. However, the product with highest NPV was the sesame drum products with a value of GH₵161202 followed by the Sesame Non-Drum Dried Products with NPV of GH₵139383 whiles the peanut drum dried and non-drum dried products have NPVs of GH₵120592 and GH₵55214 respectively. From the above values its recommended to invest in sesame drum dried products since it has the highest NPV. For the defined period of the project, the sesame drum dried products will yield GH₵161,202 whiles the peanut non drum dried products will only yield GH₵55,214.

The BCR of all the products were also greater than one, this satisfy the decision rule to invest in the products. The BCR of Sesame Drum Dried Products as 1.21 whiles the Sesame Non Drumdried products was 1.19 the same as the Peanut Drum Dried Products. The Peanut Non-Drum Products had the lowest BCR of 1.09. It is therefore recommended that, the investment be directed towards the Sesame Drum Dried Products since the generate a higher return on investment than the other products. These are the benefits(returns) for every 1 cedi spent in the production of the products. That is. if GH₵1 is spent on the sesame drum dried products we generate a revenue of 1.21 whiles a GH₵1 spent on peanut non drum dried will generate a revenue of GH₵1.09.

CHAPTER FIVE

5.0 Conclusion and recommendation

5.1 Conclusion

A least cost formulation, with optimum macronutrient content complementary food product, was developed using rice, cowpeas with either sesame or peanuts. Sprouting of cowpeas, fermentation of rice flour and drum drying improved the nutritional and functional properties of the cereal legume blend. Formulations with sesame had higher protein digestibility and protein content than those with peanuts. Drum drying of the formulations increased resistant starch content with implications for bowl transit time and prebiotic functionality. Sprouting of cowpeas lowered phytate content, improved protein digestibility and appeared to increase mineral bioavailability. Similarly, fermentation of the rice flour and sprouting of the cowpeas improved the mineral bioavailability. Drum drying of the products increased the average particle size and influenced the product consistency. Moisture sorption isotherms using the GAB and Oswin models were mostly ideal in predicting the best fit for the models. They demonstrated that drum drying made the products more hygroscopic and would require good moisture barrier packaging material to extend shelf life.

Mothers and caretakers preferred drum dried non-fermented products over drum dried fermented products. On the other hand, mothers would prefer the fermented flour products irrespective of the legume type to cook in the conventional way rather than pre-cooked, drum dried products. Thus, processed cereal (fermented rice) and legume (sprouted cowpeas) with sesame or peanuts can be utilized to prepare highly acceptable nutrient and energy dense complementary foods. In terms of cost, all the products indicated a positive outcome. However, the sesame drum dried samples showed positive signs to generate highest investment returns than the peanuts product as it recorded the highest net present value.

5.2 Recommendations

1. Field work for nutritional intervention studies to ascertain the efficacy of the product for infants.
2. Micronutrient fortification of all the products developed should be considered.
3. Exploring different fermentation time to ascertain the acceptability of the fermented products.
4. Amino acid and fatty acid profiles need to be determined for the products.

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APPENDICES

Appendix 1: MATLAB Script for the complementary food formulation

```
% PUT YOUR NAME HERE
% AND A DESCRIPTION OF THE CODE OF ASSIGNMENT

clear all
clc

% PRODUCT 1 which only has rice cowpea and sesame.
energy1=[349,319,577]/100; %the order of the vector is rice cowpea and sesame.
protein1=[6.9,19.2,18.2]/100;
fat1 = [0.6,1.5,48.9]/100;
carbs1=[78.3,52.0,10.0]/100;

% PRODUCT 2 which only has rice cowpea and peanuts
energy2=[349,319,578]/100; %the order of the vector is rice cowpea and peanuts.
protein2=[6.9,19.2,22.4]/100;
fat2 = [0.6,1.5,45.9]/100;
carbs2=[78.3,52.0,14.6]/100;

global c1 c2;


%Define the Maximum (or Minimum) value

b=[440 11 12 69]; %Nutrient Constraint (energy protein fat and carbohydrate)
c1=[0.49 0.76 2.00]/100; % Cost per gram of ingredients for product1
c2=[0.49 0.76 0.72]/100; % Cost per gram of ingredients for product2


% Define the function
f1= [c1(1) c1(2) c1(3)];
f2= [c2(1) c2(2) c2(3)];

% matrix of inequality constraint for product 1
A1= [energy1(1) energy1(2) energy1(3)
    protein1(1) protein1(2) protein1(3)
    fat1(1) fat1(2) fat1(3)
    carbs1(1) carbs1(2) carbs1(3)];
% matrix of inequality constraint for product 2
A2= [energy2(1) energy2(2) energy2(3)
    protein2(1) protein2(2) protein2(3)
    fat2(1) fat2(2) fat2(3)
    carbs2(1) carbs2(2) carbs2(3)];

lb1= [0,0,0]; % lower bounds
lb2= [0,10,0]; % lower bounds
ub = [100,25,25]; % upper bounds
```

```
Aeq1= [1 1 1]; % equality constraints for product 1
Aeq2= [1 1 1]; % equality constraints for product 2

beq1=100; % bounds for the inequality for product 1
beq2=100; % bounds for the inequality for product 2


% Solving the linear programming
[x1, f1val] = linprog(f1,A1,b,Aeq1,beq1,lb1,ub) % the units of rice, peanut and sesame per gram of product1
[x2, f2val] = linprog(f2,A2,b,Aeq2,beq2,lb2,ub) % the units of rice, cowpea and sesame per gram of product2


% Computing the values of the energy, protein, fat and carbs of the product
%%% for product 1
Constraints1 = A1*x1
%%% for product 2
Constraints2 = A2*x2
```

```
Optimization terminated.
x1 = 71.0102
     25.0000
     3.9898
f1val = 0.6177

Optimization terminated.
x2 = 79.5290
     10.0000
     10.4710
f2val = 0.5411
```

Appendix 4: ANOVA Tables

ANOVA Table for Lightness (L*) versus Products

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Products	7	110.622	15.8031	144.98	0.000
Error	8	0.872	0.1090		
Total	15	111.494			

ANOVA Table for redness (a*) versus Products

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Products	7	2.65239	0.378913	787.35	0.000
Error	8	0.00385	0.000481		
Total	15	2.65624			

yellowness (b*) versus Products

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Products	7	33.4868	4.78383	808.25	0.000
Error	8	0.0474	0.00592		
Total	15	33.5342			

Change in E versus Products

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Products	3	7.8803	2.6268	13.99	0.014
Error	4	0.7510	0.1877		
Total	7	8.6313			

Protein versus Products

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Products	3	1.7313	0.57710	7.29	0.042
Error	4	0.3167	0.07917		
Total	7	2.0480			

Fat versus Products

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Products	3	0.52954	0.176512	42.66	0.002
Error	4	0.01655	0.004137		
Total	7	0.54609			

Fibre versus Products

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Products	3	0.463400	0.154467	114.42	0.000
Error	4	0.005400	0.001350		
Total	7	0.468800			

Carbohydrates versus Products

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Products	3	4.5622	1.52075	31.15	0.003
Error	4	0.1953	0.04881		
Total	7	4.7575			

Energy versus Products

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Products	3	71.4082	23.8027	99.12	0.000
Error	4	0.9605	0.2401		
Total	7	72.3688			

Phytate versus Products

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Products	7	4.7134	0.67334	12.32	0.001
Error	8	0.4371	0.05464		
Total	15	5.1505			

Invitro Protein versus Products

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Products	7	996.05	142.292	89.84	0.000
Error	8	12.67	1.584		
Total	15	1008.72			

Water Absorption at 30 versus Products

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Products	7	834689	119241	4169.10	0.000
Error	8	229	29		
Total	15	834918			

Water Absorption at 70 versus Products

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Products	7	539296	77042.2	3203.31	0.000
Error	8	192	24.1		
Total	15	539488			

Bulk Density versus Products

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Products	7	0.120175	0.017168	68.67	0.000
Error	8	0.002000	0.000250		
Total	15	0.122175			

Oil Absorption versus Products

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Products	7	0.299400	0.042771	57.03	0.000
Error	8	0.006000	0.000750		
Total	15	0.305400			

Swelling versus Products

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Products	7	26.663	3.8091	19.54	0.000
Error	8	1.559	0.1949		
Total	15	28.223			

Solubility versus Products

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Products	7	202.2	28.88	0.83	0.592
Error	7	242.9	34.70		
Total	14	445.0			

Emulsifying Capacity versus Products

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Products	7	2216.00	316.571	40.83	0.000
Error	8	62.03	7.754		
Total	15	2278.03			

Viscosity versus Products

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Products	7	0.076494	0.010928	349.69	0.000
Error	8	0.000250	0.000031		
Total	15	0.076744			

Non Resistant Starches versus Products

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Products	7	97.402	13.9145	55.46	0.000
Error	7	1.756	0.2509		
Total	14	99.158			