KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI

COLLEGE OF SCIENCE

DEPARTMENT OF FOOD SCIENCE AND TECHNOLOGY

FORMULATION AND CHARACTERIZATION OF SWEETPOTATO-BASED COMPLEMENTARY FOOD

BY

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in partial fulfilment of the requirements for the degree of

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DECLARATION

I hereby declare that this submission is my own work towards the MPhil. and that, to the best of my knowledge, it contains no material previously published by another person, nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

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Abstract

To promote the utilization of orange-fleshed sweetpotato (OFSP) and to aid with the eradication of vitamin A deficiency in Ghana, a sweetpotato-based complementary food was developed. Four blends of complementary flours made up of OFSP, millet and soyabean flours were formulated based on the nutrient strength of the individual flours. The functional, pasting properties and colour of the flour blends before and after drum drying was determined. The most preferred formulation determined through sensory evaluation was assessed for some nutrients and microbial safety. Colour intensity (ΔE) and saturation (ΔC) of formulated products increased after drum drying. Water absorption capacity (WAC) of formulations ranged from 152.5 to 216.7%, swelling index (SI) from 6.65 to 7.73, bulk density (BD) from 0.787 to 0.827 g/ml and solubility from 17.78 to 20.32%. Drum drying conditions used reduced the WAC, SI, BD and solubility of the formulations. Though the drum drying conditions used did not reduce the pasting temperature, it was able to reduce the peak time and further reduce the peak viscosity, breakdown and setback viscosities. The most preferred formulation was the blend with 50% OFSP, 15% Millet and 35% Soyabean flours. It had significantly ($p<0.05$) higher protein (16.96%) and β-carotene (0.53 mg/100g) content than the control complementary foods, which are maize-based. Ash and fat were comparable to that of a commercial complementary food. In addition, it had a significantly higher iron and potassium content compared with two commercial complementary foods. Yeast and mould was <3 $\log_{10}$ cfu/g, Total Plate Count, <5 $\log_{10}$ cfu/g, while *E. coli* and *S. aureus* had no counts. This complementary food when promoted and utilised could support efforts to reduce vitamin A deficiency in Ghana and also enhance the use of OFSP to help achieve food and nutrient security.

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CHAPTER ONE

1.0 INTRODUCTION

Complementary foods are foods and liquids other than breast milk or infant formulas required during the second part of the first year of life for both nutritional and developmental reasons and also to enable transition from milk feeding to family foods (Koletzko *et al*., 2008). After 6 months of age, breast milk is not enough to meet the macro- and micronutrient requirements of infants (Koletzko *et al*., 2008; Ijarotimi and Keshinro, 2013). Infants also develop the ability to chew, hence begin showing interest for foods other than milk, therefore the need to introduce healthy complementary foods. According to Codex Alimantarius Commission, CAC (2008), complementary foods should be of appropriate nutritional quality and energy to complement the nutrients obtained from breast milk for infants and family foods for younger children.

A number of complementary foods have been developed. In Africa, especially in Ghana, most of these complementary foods are cereal-based (Amagloh *et al*., 2012a). They are mostly formulated with maize as the major ingredient and complemented with soyabean, cowpea and/or groundnut. The legumes are added in an attempt to improve upon the fat and protein content of the food. However, over the years the problem with malnutrition, especially micronutrient deficiencies of vitamin A, iodine and iron, have led to the supplementation of complementary foods (Bhandari *et al*., 2001; Nestel *et al*., 2003; Lutter *et al*., 2008). Vitamin A and iron deficiency are amongst the world's most prevalent nutritional problems (Lutter *et al*., 2008; Amagloh *et al*., 2012a).

Sweetpotato as a complementary food has been identified as a viable product both for supplementing the nutritional needs of babies in developing countries while enhancing the utilisation of the crop. A number of studies by Ijarotimi and Ashipa (2006), Sanoussi *et al*. (2013) and Haque *et al*. (2013) have thus been conducted in this wise.

Some varieties have high amount of β-carotene which is a precursor of vitamin A (Picha and Padda, 2009; Burri *et al*., 2011); hence could be used to reduce vitamin A deficiency amongst children. Notwithstanding the high energy content of sweetpotato and other micronutrients such as vitamin A, C, potassium, iron and zinc, it is low in protein and fat contents, hence the need to complement it with legumes and/or cereals when being used in complementary foods. Sweetpotato in Ghana is being promoted but there are limited diversified products from the crop, which could encourage its consumption. It is characterized by high moisture content hence high perishability. The roots unlike other staples in Ghana are sweet, and this has been a challenge in its acceptance especially when processed into already existing food forms. There is therefore the need to diversify Orange Fleshed Sweetpotato (OFSP) into forms that are acceptable especially for children due to the high β-carotene (a provitamin A) content of the roots and its sugar content, to reduce sugar added to complementary foods. This is because vitamin A deficiency is a public health problem in Ghana with prevalence around 35.6% (Egbi, 2012).

The major drawback in the research works on sweetpotato-based complementary foods including those by Ijarotimi and Ashipa (2006), Sanoussi *et al*. (2013) and Haque *et al*. (2013) was the viscous nature of the resultant complementary foods. Amagloh *et al*. (2013) employed three processing methods (extrusion, roller drying and oven toasting) to resolve this drawback. These processes also improved the nutrient composition of the complementary foods. However, to further improve the nutrient composition of sweetpotato-based complementary food and to enhance the suitability of sweetpotato in the baby food industry, studies into the use of the orange-fleshed sweetpotato, which has higher β-carotene compared with the cream flesh used by previous researchers, is needed. Moreover, soyabean, which has been used as the protein and fat source in complementary foods has been reported to lack methionine and cysteine (Edema *et al*. 2005). These amino acids are abundant in cereals such as millet or maize.

Therefore a blend of cereals such as millet and legumes, such as soyabean, in the formulation of a complementary food, may enhance the protein quality and nutritional composition of the sweetpotato-based complementary food.

Therefore the objective of this study is to formulate a sweetpotato-based complementary food from an orange-fleshed sweetpotato (*Bohye* variety), millet and soyabean. The characteristics of the complementary food formulated before and after drum drying will be studied, as well as the acceptability, nutrient and microbial levels.

1.1 Problem Statement

Although sweetpotato is being promoted in Ghana, there are limited diversified products from the crop, which will encourage its consumption. Sweetpotato is characterized by high moisture content hence high perishability. The roots unlike other staples in Ghana are sweet, and this has been a challenge in its acceptance especially when processed into already existing food forms. There is therefore the need to diversify Orange Fleshed Sweetpotato (OFSP) into forms that are acceptable especially for children due to the high beta-carotene (a provitamin A) content of the roots. This is because vitamin A deficiency is a public health problem in Ghana with prevalence around 35.6% (Egbi, 2012).

Millet also has limited uses in Ghana compared with maize, despite its characteristic texture for porridge and nutritional advantages. Its use in addition to soyabean in developing a sweetpotato-based complementary food has not yet been studied.

In addition, studies have been done to reduce viscosity in sweetpotato-based complementary foods through processing methods, however, there is limited information on the use of the orange-fleshed sweetpotato variety, which has higher β-carotene, in such studies.

1.2 Justification

Development of orange-fleshed sweetpotato-based complementary food will help diversify the uses of sweetpotato and will provide an alternate healthy and nutritious food for most infants in Ghana. Due to its high vitamin A, it will also help with efforts to reduce vitamin A deficiency in Ghana. The diversification and utilization of orange-fleshed sweetpotato will help efforts to achieve Food and Nutrient security in Ghana. An alternative use of millet will also be provided while the characteristics of sweetpotato-based complementary food blend with millet and soyabean will be known.

1.3 Main Objective

To formulate and characterize a complementary food from a blend of sweetpotato, millet and soyabean

1.3.1 Specific Objectives

The specific objectives of this research are:

1. To assess the proximate composition of the sweetpotato, millet and soyabean flours and formulate complementary blends

2. To determine the colour, some functional and pasting properties of the flour blends before and after drum drying

3. To determine the most preferred complementary food (drum dried product milled into flour) and assess its nutrient (proximate, mineral and β-carotene) composition and microbial levels

CHAPTER TWO

2.0.0 LITERATURE REVIEW

2.1.0 About Sweetpotato

Sweetpotato is one of the major roots and tubers and in 2004 was reported to be the 7th most important food crop in the world (Kays, 2004). In 2010, according to the International Potato Centre (CIP), it became the 6th most important food crop after rice, wheat, potatoes, maize and cassava (CIP, 2013). In developing countries, it is the 5th most important crop. About 105 million Mt of sweetpotato is produced globally each year with developing countries contributing about 95% (CIP, 2013). Asia is currently the largest sweetpotato-producing region in the world; producing about 90 million tonnes annually (Peters, 2004; CIP, 2013). The importance of sweetpotato as a food crop is growing rapidly in some parts of the world and in sub-Saharan Africa it is outpacing the growth rate of other staples. Sweetpotato is used for human consumption and as a healthy cheap source of animal feed. It is considered an excellent food security crop in sub-Saharan Africa. It requires less agro-chemical inputs and survives/grows in diverse conditions (CIP, 2013).

Sweetpotato is grown across all regions in Ghana except the Western region. The major growing region is the Upper East region which contributes 34.9% of the 131,990 Mt of sweetpotato produced in Ghana. This region also has the largest area of cultivation of sweetpotato (57.7% of the 9,622 Ha production areas). This region is followed by Eastern region (26.4% Mt; 10.7% Ha production area) and Upper West (14.8% Mt; 12% Ha production area). The region with the least production of sweetpotato and area of cultivation are the Greater Accra and Ashanti regions. Within the major production region, the Bawku Municipal was the District with the major production and largest production area of sweetpotato (MoFA and SRID, 2012).

The entire village of Fiaso in the BrongAhafo region cultivates sweetpotato. Some intercrop with yam and farm sizes range from 1 to 15 acres. The farmers have formed an association (made up of 25 members; 7 females) which is currently being supported by the Ministry of Food and Agriculture and has been in existence for the past 9 years (Aidoo *et al*., 2014).

This indicates that sweetpotato cultivation cuts across the country and seems to be a sustainable venture from the associations being formed and assistance from the Ministry of Food and Agriculture. Therefore in order to avoid postharvest losses and to maximize the utilization of sweetpotato, there is the need to develop new products from it, thereby adding value to the crop and providing more income for the farmers, who would intend increase their yield. This could go a long way to help with the attainment of food and nutrient security in Ghana.

2.1.1 Sweetpotato value addition and its importance

Most farm produce are perishable due to their short shelf life; as a result many experience a lot of postharvest losses. Roots and tubers such as sweetpotato are amongst farm produce that experience a lot of postharvest losses. They have very high moisture content and as a result are unable to last longer after harvest (Hagenimana *et al*., 2001). There is therefore a need to develop them into more stable forms like flours and other products. Sweetpotato is bulky and perishable (Hal, 2000) and according to Nungo *et al*. (2005) value addition can help reduce the bulkiness, improve shelf life and result in the development of new and diversified product.

Through the process of developing new and diversified products from the produce, more value is being added to the crop, therefore fetching more money for the producer and also broadening the value chain of the produce. Value addition of farm produce is a very important aspect of the food value chain.

Besides broadening the utilization base of the farm produce and providing more income, it also helps to have food available all year round and as a result help with the problem of food and nutrient insecurity. Nungo *et al*. (2005), in their research on value addition of orange fleshed sweetpotato indicated that it was necessary to develop new products from the orange fleshed sweetpotato for commercialization to diversify products to enable farmers obtain more income.

There have been lots of improvements on the value of sweetpotato. Some of these include commercial processing of sweetpotato into chips or flour, which could be stored for a long time. It could also be used in *ugali*, bread and cakes, or processing into fermented and dried products like *fufu*. It has also been used for sweetpotato noodles, wines, etc. (Tilman *et al*., 2003).

The challenge with value addition or new products developed from raw materials such as sweetpotato is its adoption. The utilization of the crop may be broadened through the new products developed. But if these products are not adopted into the existing value chain of the communities, the benefits and impact of the value addition will not be felt by farmers and the various actors of the chain; as well as the community.

Aniedu *et al*. (2012) assessed the impact and adoption of value added innovations in root and tuber crops among farmers in Nigeria. This research sought to make known to some farmers innovations and processing technologies available to help curtail perishability and add value to the roots and tubers. It was observed that the adoption rate of cassava products was higher compared with that of cocoyam and sweetpotato; although consumers were very much aware or knew the products developed. This could be as a result of general consumer preference of cassava to cocoyam and sweetpotato.

However, Aniedu *et al*. (2012) explained that the cocoyam and sweetpotato were newly introduced to the farmers unlike that of cassava which had already been reinforced through training to the farmers. Therefore constant education to create awareness of products developed can help with its adoption into the society. Improving the value addition of sweetpotato can create new economic and employment activities for farmers and rural households, and can add nutritional value to food systems.

2.1.2 Sweetpotato varieties

Generally, sweetpotato roots can be differentiated or classified by the colour of their flesh. They could be white, cream, pale yellow, yellow, pale orange, orange and purple fleshed. The colour of the flesh of sweetpotato roots can also give an indication as to the amount of βcarotene it contains; or whether it contains a higher β-carotene content compared to another. Listing in order of increasing β-carotene, there is the white, cream, pale yellow, yellow, pale orange and orange flesh (Hagenimana *et al*., 1999). The purple flesh on the other hand has more anthocyanins and higher antioxidant activity (Teow *et al*., 2007; Steed and Truong, 2008; Philpott *et al*., 2004). Due to its high β-carotene content, the orange-fleshed sweetpotato roots has received a lot of attention to release enough varieties to help curb vitamin A deficiency in sub-Sahara Africa.

In 1996, the International Potato Centre after realizing the nutritious and economic importance of sweetpotato instituted a project to improving human health and income generation. This could be realized through the development and adoption of new sweetpotato varieties with enhanced postharvest characteristics, and the application of virus cleanup techniques for production of healthy planting material in low-input subsistence farming systems (CIP, 2013). As a result, numerous varieties of sweetpotato have been produced.

In Ghana, the Crops Research Institute of the Council for Scientific and Industrial Research (CSIR-CRI) has developed several varieties of sweetpotato since 1998. Four varieties were produced in 1998 (*Sauti*, *Okumkom*, *Faara* and *SantomPona*). These varieties have already been widely adopted by farmers in Ohawu in the Akatsi District in the Volta region and also in some parts of the Central and Western regions. They are high-yielding, early-maturing, and disease-resistant and have a high content of protein (GNA, 2002).

In 2005, Hi-Starch, *Ogyefo*, *Otoo* and *Apomuden* were also released. These are high yielding, resistant to pests and diseases and good for food and industrial products. *Apomuden* had the highest mean fresh tuber yields followed by *Otoo*, *Ogyefo* and High-Starch (CSIR-CRI, 2005). The *Apomuden* variety is an orange-fleshed variety of sweetpotato which has more βcarotene compared with the other varieties. However, the challenge associated with itis the high moisture content. Thus, it not economically feasible for the production of flour but could be used for puree or non-alcoholic beverages.

As a result, in 2012 a new variety of sweetpotato was released by the CSIR-CRI known as *Bohye*. This variety is an orange fleshed sweetpotato with much higher β-carotene and dry matter compared with *Apomuden* (personal communication). This will enable the processing of an orange fleshed variety of sweetpotato into flour while obtaining or retaining enough of the β-carotene. In producing a sweetpotato-based complementary food blend (a flour product) for infants and young children, between the ages of 6months and 3 years, using the *Bohye* variety will therefore be a very good choice. The high β-carotene content will help combat vitamin A deficiency, while the increased dry matter – compared with the *apomuden* variety – could bring down the economic cost of producing orange fleshed sweetpotato flour. Generally, the sweetpotato flour is more shelf stable compared with puree or any other form of sweetpotato which is not dried into flour; due to the lower moisture content in the flour produced (Hal, 2000).

2.1.3 Nutrient and health benefits of Sweetpotato

Sweepotato like the other roots and tubers is mainly made of carbohydrates. Total carbohydrates, which are mainly starch (Mazzei *et al*., 1995; FAO, 2002), make up about 19%

to 28% of the root. While the 86% (on dry basis) of total soluble sugars are glucose, the remainder are fructose and sucrose (Zhang *et al*., 2002), besides the fact of having a significant fiber content. Protein content is 1% to 2% and it has high biological value due to its high lysine content, whereas lipid level is low (0.1 to 0.4%) (Mazzei *et al*., 1995; FAO, 2002). Sweetpotato root is therefore a major source of energy due to its high carbohydrate content.

In addition to these nutrients, sweetpotato is well known for its β-carotene content and other minor components such as vitamins B, C, E and phenolic acid, as well as potassium, calcium, iron, zinc and phosphorus (Martí, 2000; Hal, 2000; Aina *et al*., 2009; Picha and Padda, 2009; Burri *et al*., 2011). Moreover, it has been considered as a highly functional, low calories food, with anti-diabetic effects. Due to these, it is often recognized as a health food (Padmaja, 2009). Yamakawa and Yoshimoto (2002) reported the presence of functional components such as polyphenols, dietary fibre and anthocyanins in sweetpotato which are beneficial to the health of consumers. Moreover these anthocyanins act as antioxidants in situ and in vitro within the purple fleshed sweetpoato roots (Philpott *et al*., 2004).

According to Bovell-Benjamin (2007), sweetpotato leaves and roots could have protein contents ranging from 4-27% and 1-9%, respectively. They also contain β-carotene and anthocyanins which are health beneficial and could serve as a potential source of natural health promoting compounds for the functional food market. Moreover, due to their concentrated anthocyanin and β-carotene contents in addition to the high stability of colour extract, this crop could provide a promising and healthier alternative to the synthetic colouring agents.

Sweetpotato is ranked highest in nutritional value amongst other roots and tubers. The consumption of the roots relieves the symptoms of stomach ulcer, inflamed conditions of the colon, haemorrhoids and cancer prevention in glands and organs with epithelial tissue. Sweetpotato roots and leaves are also used in folk remedies to treat illnesses such as asthma, night blindness and diarrhoea. The roots are easily digestible and are good for eliminative system; it also detoxifies the system because it is believed to bind heavy metals (Padmaja, 2009).

Reports indicate that phytochemicals present in sweetpotato, especially polyphenols, have high free-radical scavenging activity, which helps to reduce the risk of chronic diseases, such as cardiovascular disease, cancer and age-related degenerative diseases (Ames *et al*., 1993; Scalbert *et al*., 2005). Miyazaki *et al*. (2005) also reported that the consumption of white skinned sweetpotatoes is an effective alternative to the prevention and improvement of the symptoms of diabetes because it stimulates human immunity.

Given all these nutritional and health benefits of sweetpotato, promoting its consumption will help improve the health of consumers. Due to the highly acclaimed β-carotene content in the roots, it could help curb the problem of vitamin A deficiency in Ghana and Africa as a whole. Therefore incorporating sweetpotato into a complementary food will enrich it; providing enough dietary vitamin A for babies and young children.

2.1.4 Utilization of sweetpotato and its products

Sweetpotato has diverse uses in various parts of the world. The roots are consumed in India either as fresh vegetables or boiled and baked in the diet of rural and tribal people (Ray and Balagopalan, 1997). In Nigeria, it is often boiled and eaten with stew. It is sometimes boiled and pounded with either boiled or fermented cassava as *foofoo*. More so, it could be dried and milled for sweetening of gruels or *ogi* porridge.

Lastly, it is sometimes sliced into chips, dried and fried in vegetable oil (Tewe *et al*., 2003). In Liberia, it is baked into cookies and puffs, used as a soup thickener, foliage for animals, and leaves for stew. In Senegal, it is also used as a soup thickener, milled into flour, serves as foliage for animals fried as chips. In Ghana, it is boiled and eaten with stew in various local homes. It is also fried and eaten as snack with pepper which is enjoyed by people of all ages. The leaves have also been used for stews and tea (personal communication).

In spite the local uses of sweetpotato, some processing methods have been developed to process sweetpotatoes into purees and dehydrated forms to be used as functional ingredients in several food products (Truong and Avula, 2010). Purees from the orange-fleshed sweetpotatoes have been commercially produced in cans or in frozen form in the U.S. (Kays, 1985; Walter and Schwartz, 1993).

Sweetpotato roots can also be processed into dehydrated forms such as dried chips or flour that remains in good condition for a long time and can be used in food preparations (Peters and Wheatley, 1997). The flour can add natural sweetness, colour and flavour to processed food products. The processing of sweetpotato involves washing, peeling, slicing/shredding, blanching, soaking, pressing, and drying (Woolfe, 1992; Hal, 2000; Oke and Workneh, 2013). In addition, spray-dried sweetpotato powder has been reported by Grabowski *et al*. (2008).

A variety of products such as doughnuts, biscuits, muffin, cakes, cookies, extruded products, fried chips, ice cream, porridge, brownies, pies, breakfast foods, and weaning foods have been made from sweetpotato flour (Toyokawa *et al*., 1989; Greene *et al*., 2003; Lee, 2005). For sweetpotato roots to produce good quality flour, they should be low in total free sugar content, reducing sugar content, ash content, amylase and polyphenol oxidase activities, and have high dry matter (Bovell-Benjamin, 2007).

Sweetpotato, either fresh, grated, cooked and mashed, or made into flour, could replace the expensive wheat flour in making buns, *chapatis* (flat unleavened bread) and *mandazis* (doughnuts) (Hagenimana *et al*, 1998). Sweetpotato-based pasta has been developed by Singh *et al*. (2004). The flour is used as a dough conditioner for bread, biscuit, and cake processing (it may substitute for up to 20% of wheat flour), as well as in gluten-free pancake preparation (Adebowale *et al.*, 2006). Shih *et al.* (2006) developed gluten-free pancakes from rice and sweetpotato flours and assessed some physicochemical properties. They observed that though some textural properties such as cohesiveness, hardness and chewiness reduced with increasing sweetpotato levels in the product (10, 20 and 40% Sweetpotato replacement), the nutritional content of the product in terms of protein, dietary fibre, carbohydrate were improved upon and compared with the control sample which was wheat flour based glutenfree pancakes. The major nutritional increment was found to be β-carotene which increased from 5.2 to 236.1 μg/g.

Many studies have reported the feasibility of using sweetpotato flour as an alternative to wheat, especially in bakery products (Singh *et al.*, 2007). Commercial bakeries in Peru produced widely accepted bread supplemented with up to 30% sweetpotato (Huaman, 1992; Palomar *et al.*, 1981). According to Srivastava *et al*. (2012), sweetpotato is rich in dietary fibre but low in protein content. As a result if composited with wheat flour for bakery products will provide a product with better nutritional and functional properties than wheat flour bakery products. In their research they observed that substituting wheat flour with 40% sweetpotato flour resulted in cookies with similar characteristics as that of wheat flour cookies but with better nutritional and textural values.

Substitution levels as high as 65% sweet potato flour has resulted in bread with acceptable loaf volumes, flavour and texture as that of bread made of wheat flour (Greene *et al.*, 2003; Green and Bovell-Benjamin, 2004).

Despite report by Hal (2000) that consumer acceptable bread could be achieved with substitutions between 10-15%. The variation in results could be due to the type of bread produced. "Golden bread" produced by Low and Jaarsveld (2008), by substituting 38% of wheat flour with sweetpotato puree had a better consumer acceptability compared to whole wheat flour due to its heavier texture and attractive appearance. This resulted in profit margins of bakers increasing 54-92%. The orange fleshed sweetpotato was employed in the "Golden bread" development and that may have resulted in its attractive colour and will also impact on the β-carotene content of the bread. This type of bread could be used to help with alleviating vitamin A deficiency in Africa. Idolo (2011) also reported that substituting wheat flour with sweetpotato flour up to 25% in a local bread product in Nigeria (*Madiga*) improved the nutrient compositions, in terms of protein, fat, ash, carbohydrate and crude fibre, as well as vitamin A, B, C and magnesium. It also improved upon sensorial attributes determined.

Extruded ready-to-eat breakfast cereal containing 75-100% sweetpotato flour are promising products to be included in human diets (Dansby and Bovell-Benjamin, 2003). Fonseca *et al*. (2008) and Zhang *et al*. (1998) reported optimal extrusion conditions for β-carotene retention in extruded sweetpotato flour and sweetpotato/peanut blends. Sweetpotato flour from *Jalomas* and *Telong* varieties have good potential as raw material for the production of extruded snack food and ready-to-eat breakfast food (Lee, 2005). The single screw extruder was used in these studies, and the effect of screw speed, feeder flow rate and moisture content on the extrudate quality were investigated in these studies. The severe heat treatment received by sweetpotato extrudates rendered them applicable in soup bases, flour mixes and breakfast foods (Iwe, 2000).

Conversion of drum dried sweetpotato flour to ethanol was studied by Reddy and Basappa (1997). A wine like product containing ethanol up to 8.6% (w/v), with desirable aroma and colour was developed by treating drum-dried flour with pectinase, α-amylase and glucoamylase. The inoculated flour was fermented for 3 days. *Lactobacillus plantarum* MTCC 1407 was used for direct fermentation of sweetpotato flour to lactic acid under semi- solid fermentation (Panda and Ray, 2008).

In Ghana, several studies have been conducted in the Food Science & Technology and Biochemistry & Biotechnology Departments in KNUST to investigate the nutritional qualities, physicochemical properties as well as the potential of product diversities from different varieties of sweetpotato. One of such products is non-alcoholic drink from sweetpotato. Sweetpotato tubers were processed into non-alcoholic beverage flavoured with citrus lime and ginger. Two varieties namely *faara* and *sauti* were used. pH, total sugars, total solids, brix, total titrable acidity, vitamins C and A were determined and sensory evaluation was conducted on the products to assess the acceptance preference. Values for pH ranged from 3.81 to 4.34 and that for degree brix was from 12.00 – 13.13°. The result of Total Titrable Acidity (TTA) ranged between 0.45 – 1.6 with lime flavoured having higher TTA than the ginger flavoured. Total solids varied significantly and ranged from 12.57 – 13.78% with *faara* having higher values than *sauti*. Vitamin C content was low because of heat treatment and hence the beverage was fortified with vitamin C. Vitamin A content was also low and ranged from 3.28 – 10.11 µg/100 g (32.8 – 101.08 μgL^{-1}) with *faara* variety having higher vitamin A equivalent (Wireko-Manu *et al.*, 2010).

2.1.5 Challenges associated with the use of sweetpotato

Despite its uses and products developed from it through several research works, sweetpotato as a root and its utilization comes along with some constraints or challenges. The bulkiness and perishable nature of the sweetpotato roots are a major constraint on the marketing and availability of the crop. At maturation, sweetpotato roots are subject to deterioration which lowers quality and quantity adversely if they are not harvested timely (Owori and Agona, 2003). Also, pest and disease attack, improper handling during harvest and lack of adequate storage facilities, all make production of the root not cost effective.

There is also low extraction rate of starch from sweetpotato, thus causing much waste of raw material. Cost of production of starch from sweetpotatoes is higher than that of the corn. Sweetpotato starch is therefore relatively low priced resulting in low sales amount (Lui, 2008).

Sweetpotato processing is not well developed. Only small scale chips making and cooking of sweetpotato is made. Processing methods as well as processing facilities that can induce consumption and also increase shelf life of the root are limited (Emana and Gebremedhin, 2007).

One major constraint associated with sweetpotato is the browning reaction which takes place when the roots are exposed to air during processing. This results in an undesirable discolouration, a major obstacle in some products that incorporate sweetpotato flour (Owori and Agona, 2003). Oiliness has also been found to be one of the most important problems affecting the acceptability of sweetpotato crisps (Owori and Agona, 2003). Thus, sweetpotato crisps tend to be soggy (too oily because crisps absorb more oil) when fried and this may be due to the nature of proteins and carbohydrates present and their interaction with the oil.

In Nigeria, sweetpotatoes are not extensively grown and utilized for food because they are sweet and moist when cooked. Sweetpotatoes are widely accepted as a daytime snack in schools and offices but have difficulty crossing over to be considered a viable staple food or main dish component (Bergh *et al*., 2012). Consumption of sweetpotato is also limited at household level because of the little know-how on the different ways of utilizing sweetpotato (Emana and Gebremedhin, 2007).

Sweetpotato is known for its β-carotene; especially the yellow and orange varieties which have higher β-carotene contents. Producers promoting sweetpotato often depend on its potential to provide consumers with vitamin A (Tumwegamire *et al*., 2004). As a result, retaining the β-carotene is important in processing the tubers into new products or adding value to them. However, β-carotene is sensitive to heat and is reduced when most processing conditions are applied to them (Fonseca *et al*., 2008). This has been a constraint in adding value to the crop, as most methods being used would include the application of heat.

One major way of adding value to the tuber is through the processing of the tubers into flour and its use in bakery products (Low and van Jaarsveld, 2008; Srivastava *et al*., 2012; Greene and Bovell-Benjamin, 2004). The drying conditions and processing into bakery products reduce the b-carotene content of the product produced.

Moreover the flour from the tuber is not suitable for bread baking as it lacks gluten. Due to its bulky nature, composition (no gluten but starch) and colour, most research work recommend a consumer acceptable bread to have a substitution of 10-15% flour (Hal, 2000). In addition, some of the vitamin A rich varieties have low dry matter content; hence producing them into flour would not be economically viable (Hagenimana *et al*., 2001).

One of the issues associated with adopting sweetpotato flour as a substitute for wheat flour in bakery products is to ensure the price of the sweetpotato flour is competitive with wheat flour and be of good quality (Hal, 2000). However, some research work at the Crops Research Institute, Fumesua has resulted in some β-carotene rich varieties with relatively higher dry matter than previous ones developed. One of such variety is the *Bohye* variety which is being employed in this work to develop a Sweetpoato-based complementary food.

Trypsin inhibitor activity has also been observed in some sweetpotato genotypes which have a possibility of being heat stable (Zhang and Corke, 2001). This could pose a problem in the nutrition of consumers patronizing those varieties. Though sweetpotato as a crop may have all these challenges as reported in some research works, its nutritional advantages far outweigh the challenges; especially with the high β-carotene of some varieties such as the *Bohye* variety and other added vitamins and minerals coupled with its high energy content. In order to help with the alleviation of vitamin A deficiency, processing sweetpotato into products and making it accessible to consumers, especially those in the most vulnerable group (babies, young children and mothers) is a very prudent exercise.

2.2.0 Millet and its varieties

Millet is one of the common cereals produced mostly in the Northern part of Ghana. There are about 9 species of millet grown worldwide but only four varieties are significantly grown in Africa (Obilana, 2003). The four major types are Pearl millet (*Pennisetum glaucum*), which comprises 40% of the world production, Foxtail millet (*Setariaitalica*), Proso millet or white millet (*Panicum miliaceum*), and Finger Millet (*Eleusine coracana*). Pearl millet produces the largest seeds and it is the variety most commonly used for human consumption (Mariac *et al*., 2006; ICRISAT, 2007). Millet is a major source of energy and protein for about 130 million people in sub-Sahara Africa (Obilana, 2003).

Minor millets include: Barnyard millet (*Echinochloa* spp.), Kodo millet (*Paspalum scrobiculatum*), Little millet (*Panicum sumatrense*), Guinea millet (*Brachiaria deflexa* or *Urochloa deflexa*), Browntop millet (*Urochloa ramose*, *Brachiaria ramosa* or *Panicum ramosum*), Teff (*Eragrostis tef*) and fonio (*Digitaria exilis*) are also often called millets, as more rarely are sorghum (Sorghum spp.) and Job's tears (Coixlacrima-jobi) (ICRISAT, 2007; FAO, 2009; Adekunle, 2012).

2.2.1 Nutritional benefits of millet

Millets are unique among the cereals because of their richness in calcium, dietary fibre, polyphenols and protein (Devi *et al*., 2011). Millets generally contain significant amounts of amino acids particularly the sulphur containing amino acids i.e. methionine and cysteine

(Obilana and Manyasa, 2002). The amino acid profile of the different varieties of millet per 100 grams with respect to essential amino acids show that Pearl millet has high isoleucine content (5.1g) compared to Foxtail (4.59g), Finger (4.3g) and Proso (4.1g) millet varieties.

In terms of Leucine content, Pearl millet has the highest content (14.1g) compared to Foxtail (13.6 g), Proso (12.2g) and Finger (10.8g) millet varieties. Finger millet has a Lysine content of 2.2 g compared to Foxtail millet (1.59 g), Proso millet (1.5 g) and Pearl millet (0.5 g). Foxtail millet has a Methionine content of 3.06 g compared to Finger millet (2.9 g), Proso millet (2.2 g) and Pearl millet (1.0 g). Pearl millet has the highest Phenylalanine content (7.6 g) compared to Foxtail millet (6.27 g), Finger millet (6.0 g) and Proso millet (5.5 g) (Obilana and Manyasa, 2002).

Finger millet has the highest Threonine content (4.3 g) compared to Foxtail millet (3.68 g), Pearl millet (3.3 g) and Proso millet (3.0 g). Again, Finger millet has the highest Valine content (6.3 g) compared to Foxtail millet (5.81 g), Proso millet (5.4 g) and Pearl millet (4.2 g). Finger millet has the highest Histidine content (2.3 g) compared to Foxtail millet (2.11 g), Proso millet (2.1 g) and Pearl millet (1.7 g) (Bagdi *et al*., 2011; Devi *et al*., 2011; Kamara *et al*., 2009; Saldivar, 2003).

Millet as an alternative to the more common grains is rich in phytochemicals, including phytic acid, which is believed to lower cholesterol, and phytate, which is associated with reduced cancer risk (Coulibaly *et al*., 2011). These health benefits have been partly attributed to the wide variety of phytochemicals, including antioxidants present in high amounts in millet (Izadi *et al*., 2012). It is also useful for people who are suffering from atherosclerosis and diabetic heart disease (Gélinas *et al*., 2008) due to its fibre content and appreciable magnesium levels.

Millets extract from the seed coat were reported to have shown high antibacterial and antifungal activity compared to whole millet flour extract due to high polyphenols content in seed coat

(Viswanath *et al*., 2009; Xu *et al*., 2011). They have high content of calcium and are suitable for diabetic patients due to low glycemic index. Millet is gluten-free and safe to eat for those who suffer from Celiac disease or for those who experience gluten sensitivity. It is a healthy alternative to gluten containing grains such as wheat. More so, it is most recognized nutritionally for being a good source of the minerals namely, magnesium, manganese and phosphorus. Research has linked magnesium to a reduced risk for heart attack and phosphorus is important for the development of body tissue and energy metabolism (Veenu and Patel, 2012).

According to Nambiar *et al*. (2011) millet contains appreciable levels of the B-vitamins, thus vitamin B1, B2 and B5 and also vitamin A and C. It has also been reported to contain some appreciable levels of folic acid.

Some health benefits associated with the consumption of millet include increased Hb levels, helps with constipation, has anticancer property (thus inhibit tumour development) and probiotic treatment (contains Lactic acid bacteria). It is capable of all these due to its high iron content (8 mg/100g), high zinc content (3.1 mg/100g), high fibre content (1.2 g/100g), high flavonoids, low glycemic index, gluten free and contains appreciable levels of phenolics and omega-3 fatty acids as reported by Nambiar *et al*. (2011).

Cereals and legumes are known to complement each other in terms of the amino acid content, thus the quality of protein. Legume proteins often lack methionine and cystine which have been reported to be present in adequate levels in cereals (Edema *et al*., 2005). Thus, an improved diet in terms of protein quality could be formulated using a combination of legumes and cereals. Hence, the use of millet in this study, coupled with its production, availability and commercial potential.

2.2.2 Millet utilization and its products

Millet has been used in the development of a variety of products. About 80% of the world's millet is used as food, with the remaining being used for stock feed (2%), beers (local and industrial), other uses (15%) and bird seed (ICRISAT and FAO, 1996). Foods prepared from millets are several and differ from country to country and occasionally from region to region. In West Africa, the main food dishes from pearl millet is country dependent. The stiff or thick porridges (*Tuwo* or *Tộ*) are the most popular, commonly consumed in all the Sahelian countries across the region.

The steam cooked product *Couscous*, as well as bouilles, is commonly consumed in the Francophone countries including Senegal, Mali, Guinea, Burkina Faso, Niger and Chad (Obilana, 2003). In Nigeria and Niger the thin porridge *Fourra* is very popular while *Soungouf*; *Sankhal* and *Araw* are very popular in Senegal.
Fermented thick porridges are popular in Niger, Sudan and Southern Africa, while fermented thin porridges are commonly consumed in West Africa especially Nigeria and Ghana (*ogi, koko*, *akamu*, *kunu*) and East Africa mostly in Kenya and Uganda (*uji*) where souring (with lemon) is used instead of fermentation (Obilana, 2003).

2.2.3 Challenges associated with Millet production

Pearl millet is grown mainly in the three Administrative regions of Northern, Upper East Upper West (covering 29% total land area) of Ghana, (SRID, 2011). According to Policy Planning Monitoring and Evaluation Division of the Ministry of Food and Agriculture (PPMED, 1991), in 1990 an estimated 244,000 ha of land put to millet production yielded 80,000 tonnes of grain. In 2010 (20 years later), the actual cropped area declined to 177,000 ha but grain yields increased to 219,000 tonnes (SRID, 2011). This increase in yield could be attributed to prudent and efficient management practices adopted by farmers and not as a result of farmers using improved seed (SRID, 2011).

Despite these increments, millet seems to have limited uses; with very common uses being *fura*/*fula*, *tuozaafi*, gruels and beverages. According to Saleh *et al*. (2013) the utilization of millet grains as food is still limited to populations in the rural areas at the household level.

Moreover, it is generally still being regarded as the poor man's food and does not find place in the food purchase list of "elites" (Nambiar *et al*. 2011). In addition, the onset of problems such as climate changes, water scarcity, increasing world population, rising food prices and other socioeconomic impacts in this 21st century, are expected to generate a great threat to agriculture and food security worldwide, most especially for the poorest people who live in arid and sub-arid regions (Saleh *et al*., 2013).

Given its limited use but great nutritional potential, employing it in a complementary food may help broaden the utilization of millet. This will also help make available the various nutrients such as the B-vitamins, vitamin C, A and folic acid for infant nutrition.

2.3.0 Soyabean and varieties

Soyabean is a very common legume used as a protein source in most diet; especially in diet of infants or babies. Some released varieties of soybean in Ghana are: *Ahoto*, an early maturity genotype, of medium seed size, rounded and yellow seed colour, with mean 100 seed dry weight of 13.60 g. It is resistant to pod shattering, good cereal-*Striga* management and promiscuous nodulator with the native *Rhizobia.* Grain yield is 1.9 – 2.9 tons per hectare. It matures in about 95 days, and was released by CRI in 2005 (MoFA and CSIR, 2005).

Anidaso, a medium maturity genotype, small seed size, rounded and yellow seed colour, with mean 100 seed dry weight of 13.0 g and matures in 110 days resistant to pod shattering, fairly good cereal-*Striga* management and promiscuous nodulator with the native *Rhizobia.* Grain yield is 1.2 – 1.8 tons per hectare. It was released in 1992 by CRI (MoFA and CSIR, 2005). *Nangbaar* is an early maturity dwarf type genotype with large seed size of mean 100 seed dry weight of 16.0 g. The seeds are oval and creamy-yellow in colour. It is also resistant to pod shattering, fairly good cereal-*Striga* management and very promiscuous nodulator with native *Rhizobia*. Grain yield is 1.5 – 2.5 tons per hectare. It matures in 90 days, and was also released in 2005 by CRI (MoFA and CSIR, 2005). It is also used to fortify various traditional foods such as *gari*, sauces, stew, soups, *banku* and *kenkey* to improve their nutritional levels (MoFA and CSIR, 2005).

2.3.1 Amino acid Profile of Soyabean

Soyabean can produce at least twice as much protein per acre than any other major vegetable or grain crop (Abbey *et al*., 2001). About 35 – 38% of the calories in soyabeans are derived from protein, compared to 20 – 30% in most other legumes (Abbey *et al*., 2001). Soyabean protein contains enough of all the essential amino acids to meet biological requirements when consumed at the recommended level of protein intake (Pennington, 1994; WHO, 2007). The table below indicates the amino acids present in soyabean in its raw and dried form.

The highest amino acid contents in soyabean are Glutamic acid and Lysine (100.58 g/kg), as shown in Table 1. The least amount of amino acid in soyabean is tryptophan (5.91 g/kg) (Table 1). These values for amino acids may however vary with varieties and climate conditions. As indicated by Edema *et al*. (2005), legume protein such as soyabean lacks methionine and cystine as can be seen in the amino acid profile in Table 1. However in the complementary food being developed, these amino acids will be made up for by the cereal being included in the formulation; which is millet.

2.3.2 Nutrient Benefits of Soyabean

Soyabean is of particular interest as a vegetable protein source because of its cholesterol lowering abilities in patients with type II hyperlipoproteinaemia (Lovati *et al*., 2000). Apart from proteins, soybeans also contain carbohydrate (32%), fat (20%), minerals/vitamins (5%) and fiber (3%). A lot of work has been reported on the chemical composition, cultivation and processing of Soyabean. However, more studies need to be carried out to elucidate its nutritional value. Soyabean may hold many advantages over animal products due to its relatively low saturated fatty acids and it being cholesterol free.

Table 1: Amino acid composition of soyabean (whole bean, dried, raw)

Amino Acid	Composition (g/kg)
Glutamic acid+Lysine	100.58
Histidine	10.97
Threonine	17.66
Isoleucine	19.71
Leucine	33.09
Phenylalanine	21.22
Tryptophan	5.91
Valine	20.29
Glycine	18.80
Serine	23.57
Aspartic acid	51.12
Alanine	19.15
Tyrosine	15.39
Proline	23.79
Arginine	31.53

(Source: USDA National Nutrient Database for Standard Reference, 2010)

Soyabean is a legume and cultivated in many areas of the world, from tropics to temperate regions. For centuries, it has played a major role in the diet of the population of Eastern Asia particularly China where soyabean was termed sacred “grain”. Now most countries have recognized the importance of soybean as a potential source of high quality protein and oil. Its high fibre and low carbohydrate content in diet generally improves the control of diabetes. It has been reported that soyabean has a buffering effect on gastric acidity and ameliorates induced ulcers (Alada *et al*., 2004). Soya protein seems to be a better food source for people suffering from allergies. They clear up rashes, pimples, eczema, and other skin troubles (American Academy of Pediatrics, 1998) because they render unnecessary use of animal protein such as meat and eggs lessen the inflammatory activities of the skin.

Soyabean contain adequate amount of vitamin A, which is present as antioxidants as well as vegetable oil (Alada *et al*., 2004). It is a common protein source and legume used to improve the protein content and quality of several foods developed (Anuonye *et al*., 2010; Ndife *et al*., 2011) including complementary foods (Martin *et al*., 2010; Anigo *et al*., 2010; Bisimwa *et al*., 2012) and even sweetpotato-based complementary foods (Akaninwor, and Okechukwu, 2004; Ijarotimi and Ashipa 2006; Nandutu and Howell, 2009; Amagloh *et al*., 2012a).

2.4.0 Complementary foods developed from sweetpotato

There have been several complementary foods developed. In Africa, especially Ghana, most of these complementary foods are cereal based (Amagloh *et al*., 2012a). However according to Ugwu (2009), roots and tubers (including sweetpotato), due to their high energy content could be used in the development of complementary foods. However due to the low protein and fat contents of these roots and tubers, it is required that they should be formulated with either legume and/or cereal source. This will make such a complementary food complete in terms of fat and protein content as well as other micronutrients.

Some work has been done using sweetpotato in the development or formulation of a complementary food; either as the major component or as a supplement due to its β-carotene content. Akaninwor and Okechukwu, (2004) compared nutrient and anti-nutrient levels in commercial and formulated weaning mixtures. They reported the tannin content of sweetpotato to be 0.3 mg/100g and its phytate content 119.98mg/100g; that of processed soyabeans was 0.8 mg/100g and 171.25 mg/100g, respectively. They however did not provide enough details on the processing of the soyabean as it was procured from a company. Therefore there is no way of determining whether the soyabean they used was dehulled or otherwise.

Dehulling could get rid of most of these anti-nutrients while helping to decrease the fibre content of the complementary food; which according to Codex Alimentarius Commission guidelines on formulation of complementary food, CAC, (2011) should be limited to 5% of the food composition. They also go on to advice on using the method of dehulling to achieve this requirement. Moreover, no processing methods were employed in order to reduce the phytic acid and tannin contents of the complementary food developed.

Akaninwor and Okechukwu (2006) also reported on the evaluation of processed sweetpotatocrayfish-soyabean and sweetpotato-crayfish-bambara groundnut weaning mixtures. In this work the red skinned variety of sweetpotato was used. The formulations for this work were based on a total calories range of 353-391 kCal/100kg. These formulations in addition to a control brand (Nutrend®) were fed to rats. They reported increase in organ (heart and liver) weight after the diets were consumed. This work was a continuation of the work done in 2004, where the nutrient and anti-nutrient contents of formulated complementary foods and commercial complementary foods were compared.

Ijarotimi and Ashipa (2006) researched on developing a home-based complementary food using low cost locally available food materials. They substituted sweetpotato flour with soyabean flour in a range of 10-50% at an interval of 10. The increase in soyabean flour increased the protein, fat and energy of the food blend, while decreasing the carbohydrate content. The mineral contents determined (P, Zn, Fe, Mg, Ca, K and Na) were also improved.

The peak viscosity of the flours reported was in the range of 180-365 BU; this increased in the range of 420-720 BU when cooled to 50°C. They reported that supplementing sweetpotato flour with soyabean at 30% was able to meet the dietary allowance of children in the ages of 1-3 years. Phytate, an anti-nutrient present in soyabean flour was not determined in this work. According to Amagloh *et al*. (2012a), the presence of this anti-nutrient is responsible for the micronutrient deficiencies in Africa.

The food formulated as indicated by the pasting properties was viscous and therefore needed to be diluted before given to infants. Local processing methods such as oven-toasting (Amagloh *et al*. 2012b) could have been used to solve this problem; since this work was based on developing a low cost complementary food.

The work of Ahmed and Ramaswamy (2006) on sweetpotato complementary food assessed the viscoelastic properties of commercial sweetpotato puree infant food manufactured by Heinz, Canada. They determined the pH and total soluble solids of the puree and then studied the dynamic rheological measurement of the foods. In this research, sweetpotato was not used in the development of a new product or improving upon an existing product.

Nandutu and Howell (2009) reported on the nutritional and rheological properties of sweetpotato-based infant food and its preservation using antioxidants. The orange-fleshed sweetpotato (SPK 004) was used in this work. The formulation was done using the Micro diet program version 1. Two recipes were produced and in both cases sweetpotato was the major ingredient. Soyabean flour was added to both recipes. The formulated blends were compared with two commercial complementary foods (Cerelac® and Heinz baby food) used in Uganda. It was also reported that the formulated food was within the accepted consistency (<500Pa) after heating and cooling. The digestibility of the formulated products was also assessed and it ranged from 64.9% for Cerelac® to 69.5% for one of the recipes developed.

Adenuga (2010) reported on the nutritional and sensory profiles of sweetpotato-based infant complementary food fortified with cowpea and peanut. Sweetpotato was the major ingredient ranging from 60-70% while cowpea and peanut ranged from 15-25% and 15-20%, respectively. The food developed was compared with that of a commercial weaning food. He reported that the addition of cowpea and peanut though increased protein also affected the sensory qualities of the weaning food.

Adenuga (2010) however stated that the sensory characteristics of the sweetpotato-based products were comparable to that of the commercial product "Nutrend®". In his work it was observed that the formulation of the weaning food may not have considered the requirements of a complementary food as indicated by the FAO/WHO standards programme in the Codex Alimentarius Commission report in 2011; though in his conclusions he reported that the energy content as required by WHO/FAO guidelines was met. The choice of formulation may therefore have been impulsive. This could have resulted in the complementary food developed not meeting the nutrient requirements of infants. Moreover since sweetpotato is starchy, it would have helped if some processing methods such as oven toasting, drum drying or extrusion was applied to make the carbohydrates present more digestible to the infants. This would also decrease the viscosity of the product to avoid dilution of the food, hence dilution of nutrients. In place of cowpea, soyabean could have been used; this may have helped to provide a more acceptable product. In his work, formulations with 60% sweetpotato, less than 25% cowpea and 15% peanut flour was acceptable.

Khan *et al*. (2011) also developed a complementary food using sweetpotato. However their work was skewed towards making use of agro-industrial waste, rice bran, in developing a complementary food. As a result, the complementary food developed was a rice bran-based complementary food and not sweetpotato-based. Sweetpotato therefore served as an ingredient. However, in their work, drum drying was employed and starchy ingredients pregelatinized to reduce bulk. Light golden colour with good paste consistency and uniform texture formulations were produced. The nutrient content of product was able to meet standards for complementary infant foods.

Amagloh *et al*. (2012a) provided a review and a proposed solution to complementary food blends and malnutrition among infants in Ghana. In their review they made mention that malnutrition among children in Ghana can be attributed to the commonly used household plant-based complementary foods which are unfortified. Most Ghanaian complementary foods are cereal-based (mainly maize) and sometimes complemented with soyabean, cowpea and/or groundnut. However these diets are very low in some micronutrients such as vitamin A and with the high phytate (antinutrient that limits the absorption of iron, calcium and zinc) content of such diets, has partly accounted for micronutrient deficiencies among Ghanaian infants. They therefore proposed another complementary formulation and processing method that is capable of improving on the micronutrients content (especially vitamin A) of the food while decreasing the phytate content of the food. Their vitamin A source was sweetpotato while protein was being provided for by soyabean flour. The processing methods proposed was roller drying and extrusion cooking and that could help limit the phytate content while improving upon the nutrient content of the complementary food.

Amagloh *et al*. (2012b) developed sweetpotato-based complementary food for infants in low income countries using the cream fleshed variety of sweetpotato, full-fat soybean flour, soybean oil, iodized salt, sugar, skim milk powder and fish powder (only for the home-based processing; oven toasting). Sweetpotato was the major ingredient in the proportion of 72%. He employed industrial processing methods (extrusion cooking and roller drying) and a home-based processing method (oven toasting). These were compared to a control complementary food which was weanimix in its enriched form. The fructose contents increased on all formulations except for the enriched weanimix whilst phytate was reduced due to the processing methods employed. No significant difference was however observed in the phytate content of the three processing methods (extrusion cooking, roller drying and oven-toasting). The energy, protein and fat contents reported on their formulations were comparable to that stated in Codex Alimentarius Commission guidelines for complementary foods for infants.

Although sweetpotato contains vitamin A, it varies in terms of the varieties. The flesh colour is an indication of the level of vitamin A content. Therefore in order of increasing vitamin A content, they can be listed as white fleshed, cream fleshed, pale yellow, yellow, pale orange and then orange fleshed variety (Hagenimana *et al*., 1998). The orange-fleshed variety has the highest β-carotene content (a pre-cursor of vitamin A) and therefore should be a suitable candidate when it comes to developing a sweetpotato-based complementary food for infants. This will also go a long way to help with the alleviation of vitamin A deficiency in Ghana and sub-Sahara Africa. There has also been a revised Codex Alimentarius Commission guideline for complementary foods formulation for older infants and young children. This document was made possible by a joint FAO/WHO food standards programme on the Codex Committee on nutrition and foods for special dietary uses, thirty third sessions in Germany and prepared by electronic working group chaired by Ghana.

Haque *et al*. (2013) reported on the nutritional composition and sensory attributes of weaning food prepared from sweetpotato and soyabean. In their work they formulated a complementary food blend using sweetpotato flour, soybean flour, wheat flour, whole milk powder and sugar. The major component of the complementary food in this formulation was wheat flour (45%) and this component was constant in all four formulations developed. The sweetpotato flour ranged from 10-25%. Soyabean flour (10-25%) was the protein source of the food blend. The formulation of the blend was based on the assumption that a child consumes an average of 100 g/day but not based on the CAC (2011) guidelines on formulation of complementary food. Retinol component of the food blends was higher in the control sample (Cerelac®; a brand of complementary food) than that of the formulations developed; though none was able to meet the RDA of 400 µg/100g recommended by FAO.

It is a possibility that if the orange fleshed variety of sweetpotato was used and in larger quantities, the RDA recommendation of vitamin A or retinol would have been met.

In their work Haque *et al*. (2013) applied $NaHCO_3$ in order to reduce the anti-nutritional content of the soyabean during the soyabean processing. Dehulling of the soyabean was however not mentioned. The variety of sweetpotato used was also not specified. This product may be viscous and would require dilution before being fed to infants. A processing method to reduce the viscosity as prescribed by Amagloh *et al*. (2012b) could have been applied to improve the nutrient quality of the food blend. Though the fibre content of the product was not determined, it could be inferred that the fibre content of the product could be higher than what was recommended by CAC (2011), since whole soyabean flour was used and again sweetpotato could be another source of fibre. The fibre content is an important aspect of infant diet and should have been determined. Since infants do not need so much fibre (5% or less), as recommended by CAC (2011).

Another sweetpotato-based complementary food was developed by Sanoussi *et al*. (2013). Their research was aimed at adding value to sweetpotato in order to help achieve food security in Benin. The yellow-fleshed and orange-fleshed sweetpotato were used in this study. Sweetpotato was blended with soyabean at 25 and 50%. Mixture design in the Minitab software was used to optimize the formulations in order to achieve a protein range of 16.9 to 22 g/100g and fat content of 6 to 10 g/100g recommended by FAO and WHO Commission and Codex Alimentarius Commission guidelines in 1991. From the study, there was no significant difference in colour in terms of L*, a* and ΔE but a significant difference in b* values were observed. Therefore the yellowness of the formulations differed from one another. The 50:50 orange-fleshed sweetpotato and soyabean formulation was the only formulation that was observed to be consistent to the FAO/WHO standards.

The formulations however had relatively lower protein, fat and carbohydrate content compared with a commercial cereal-based complementary food (VIE VITAL VITE). The formulations were found to have met the microbial safety levels (Total aerobes, yeasts and moulds, faecal coliforms and *E. coli*).

In this research work by Sanoussi *et al*. (2013), the levels of soyabean in order to meet the nutritional guidelines provided for by the FAO/WHO was high. Soyabean is known to contain phytate and this may interfere with nutrient absorption or does not make nutrients available for the infants. No processing method to help reduce the phytate content in soyabean was reported. $NaHCO_2$ or processing methods such as drum drying, roller drying or extrusion as employed by Amagloh *et al*. (2012b) could have been used to reduce the antinutrient levels (phytate) in the product. Moreover, soyabean lacks some amino acids (methionine and cystine) as indicated by Edema *et al*. (2005). These amino acids are however present in cereals. As a result, complementing legumes with cereals is a more effective way of providing infants with all needed amino acids. In this study by Sanoussi *et al*. (2013), the legume (soyabean) was not complemented with cereals.

Bonsi *et al*. (2014) made use of the orange-fleshed sweetpotato to enhance the nutrient content of some complementary foods. In their work, orange-fleshed sweetpotato was added to an already known cereal-legume weaning food (roasted maize-soy blend and fermented maize-soy blend). This was intended to improve on the nutrient content (vitamin A) of the food blend in order to help with the alleviation of vitamin A deficiency. The orange-fleshed sweetpotato provided vitamin A to the products developed. The higher the orange-fleshed sweetpotato content, the higher the vitamin A content; 25% sweetpotato portion resulted in the complementary food obtaining a β-carotene content of 66.47 μg/g while 50% resulted in almost twice the amount (115.55μg/g).

This proves that sweetpotato is a very good dietary source of β-carotene (a precursor of vitamin A) and if used in complementary foods would help with the alleviation of vitamin A deficiency in Ghana. However, the problems enumerated by Amagloh *et al*. (2012a) were not addressed in this research; thus, phytate content and viscosity of the product resulting in nutrient dilution.

This work therefore seeks to develop a new blend of orange-fleshed sweetpotato-based complementary food (making use of sweetpotato, millet and soyabean). The formulation of the blend will be based on the CAC (2011) guidelines on developing complementary foods for older infants and young children. The mixture design using STATGRAPHICS Centurion, will also be employed in the formulation process. Drum drying as used by Khan *et al.* (2011) and similar to roller drying used by Amagloh *et al*. (2012b) in his work will be used to improve upon the nutrient content of the food blend, as well as make it instant. Antinutrients will be reduced through this process.

2.5.0 The drum dryer and quality parameters of some drum dried products

The drum dyer is an old food processing equipment that was developed in the early 1900s. Its main purpose was for drying most liquid food materials until the invention of the spray dryer. It could dry slurries, liquid or dough materials into thin sheets which could then be made into flakes or powders (Tang *et al*., 2003). Specifically, the drum dryer could be used to dry thick liquids, pulps, pastes or slurries, mashed potatoes, carrots, soups, baby cereals, etc. (Bonazzi and Dumoulin, 2011). It has also been used to dry sweet whey and used as a sugar replacer in

French-type bread and butter cookies with good sensorial and nutrient attributes (Mustafa *et al*. 2014).

There are two forms of the drum dryer: single drum dryer and double drum dryer. However another type exists which is similar to the double drum dryer, called the twin drum dryer. But the drums of the twin drum dryer moves in opposite directions to each other.

The vacuum drum dryer is another type which is used to dry food materials sensitive to heat. All drum dryers have common parts such as the feeding system, a scraper, motor to rotate drums, pressure gauges, etc. Some may have an automated system included to control the screw speed and pressure of steam (Tang *et al*., 2003). The temperature of steam for drum drying could be as high as 200 ºC, at which most of the moisture of the food material is removed. Time for drying could take a few seconds or dozens of seconds to obtain moisture content of about 5% (Tang *et al*., 2003). The space between drums determines the thickness of dried product. Energy consumption may range from 1.1 kg steam per kg of evaporated water and 1.6 kg steam per kg of evaporated water, corresponding to energy efficiencies of about 60-90%. Rate of production of products could be between 5 kg/h/m^2 and 50 kg/h/m^2. This depends on the initial moisture of feed, the final moisture content to be achieved, steam temperature, type of food, type of dryer, etc (Tang *et al*., 2003).

The drum dryer is easy to operate and maintain, flexible and appropriate for multiple but small quantity production. Products may have good porosity, hence good rehydration due to boiling evaporation. Drum drying may however affect flavour and colour of product due to direct contact with high dry heat (Tang *et al*., 2003).

The physico-chemical properties, macromolecule structure (starch granules) and other nutrients are affected by the process of drum drying. Colonna *et al*. (1983) reported that drum drying degrades starch very slightly compared with extrusion cooking; which together with shear (due to the screws) degrades starches better to make them more soluble. It was again reported that extruded samples (90-180 ºC barrel temperature), except for one processed at pasta-like conditions, exhibit cold water swelling and higher solubility than drum dried starches (Doublier *et al.*, 1986). More so, it was observed that extrusion cooking led to much thinner pastes than drum drying. This could be influenced by conditions of processing like feed moisture, extrusion temperatures, etc (Doublier *et al.*, 1986).

Arrage *et al*. (1992) reported on the protein quality of whole wheat as affected by drumdrying and extrusion. Wheat flour was made into simulated whole wheat spaghetti by extrusion cooking at 93 ºC and flake product by drum drying at 152 ºC. Both processes were found to have had greater than or equal to 5% reduction in several essential amino acids. Extruded product had 16% less lysine, 10% less threonine, 6% less leucine and 5% less valine when compared to whole wheat. The drum dried flakes had 20% less isoleucine and 16% less methionine. However the available lysine content was significantly increased in drum drying than extrusion. Protein digestibility were improved upon by both processing methods, but the drum drying process had the highest (1.66) compared with the extruded product (1.42). This signifies that the drum drying process at temperatures of 152 ºC could improve the protein digestibility and make more amino acids available.

Desobry *et al*. (1997) has also reported that drum drying was able to stabilize carotenoids in pure β-carotene which was encapsulated in 25 Dextrose Equivalent maltodextrin, than spray and freeze-drying. Stability of β-carotene was studied at 11 – 32% relative humidity and 25 – 45 ºC but no significant influence of these parameters on its retention was observed. This indicates that the effect on β-carotene retention was influenced by the processing methods irrespective of relative humidity and temperature. With respect to functional properties (bulk density) drum dried tamarind powder was observed to be between 0.478 (at 140 ºC) and 0.816

(at 120 ºC) g/ml. It was also observed from their work that the higher the temperature, the lower the bulk density. Pua *et al*. (2010) also reported that the quality and acceptability of drum dried product is greatly and significantly affected by steam pressure and rotation speed of drums.

In another work by Majzoobi *et al*. (2011), who sought to modify wheat starch, using the process of drum drying observed that the process destroyed native starch granules. It also degraded molecular structure and reduced the degree of crystallinity of starch.

The pregelatinized starch was able to show cold water viscosity at 25 ºC unlike the native starch. Water absorption and swelling of the starch increased, but the intrinsic viscosity was greatly reduced by the drum drying process.

The drum dryer could therefore be used for the development of baby cereals or complementary food. Due to the various modifications it applies on the starches being drum dried, it could be used to produce instant complementary foods. It is also safe to use. As a result the Sweetpotato-based complementary food being drum dried will produce an instant complementary food while improving on the quality of the food; in terms of digestibility and nutrient availability.

2.6.0 Pasting and functional properties of complementary foods

Pasting properties are an important index in determining the cooking and baking qualities of flours. The properties include peak viscosity, breakdown viscosity, setback viscosity, final viscosity, pasting temperature, peak time, etc. These help in determining the nature of flour and its use in the food industry. It also helps to ascertain the cooking properties of formulated flour blends which include complementary foods (Oladunmoye *et al*., 2014). The Brabender or Rapid viscoamylograph could be used in determining these pasting properties.

Functional properties of flours have also been linked with some important qualities of products produced from these flours (Ponzio *et al*., 2008). Some functional properties include; water absorption capacity, oil absorption capacity, least gelation concentration, bulk density, foaming properties (capacity and stability), swelling power/capacity, water solubility index, emulsifying capacity or emulsion activity/stability.

Several research works have reported the pasting and functional properties of complementary foods. Olapade *et al*. (2015) determined the pasting and functional properties of complementary food developed from a blend of plantain and cowpea flours.

It was observed that the water absorption capacity was in the range of 150-180%, while bulk density was in the range of 0.835 to 0.886 g/ml. Bulk density reported by Adepeju *et al*. (2014) was much lower (0.31-0.40 g/ml). Their food materials were however different (breadfruits, soyabean and groundnut). Since no processing was involved in any of the two works, the differences may be due to the food materials. The pasting temperature was found to be between 84.4 to 85.2 ºC. No significant differences were observed in all formulations in terms of their pasting temperatures. Pasting temperatures reflect the amount of energy needed to cook the food. The higher the pasting temperature, the more energy, hence the more the cost involved in processing the food (Adeniji *et al*., 2010).

Complementary food also developed from sorghum, pigeon pea and soybean was found to have solubility index ranging from 1.1 to 3 g/g while swelling capacity was between 1.1 and 2.6 g/g (Addis *et al*., 2013). These values were lower than solubility index (3.27-4.9 g/g) and swelling power (15.33-20.67%) reported by Adepeju *et al*. (2014).

Adebayo-Oyetoro *et al*. (2012) also reported the pasting temperature of complementary food developed from sorghum and walnut to be in the range of 74.16 to 77.16 ºC. Breakdown and setback viscosities ranged from 25.57 to 66.30 and 23.75 to 64.57 RVU, respectively. Peak viscosity ranged from 90.40 to 212.65 RVU. The Rapid viscoamylograph was used for the determinations hence the unit RVU (Rapid Viscoamylograph units). If the Brabender viscoamylograph was used, it would have been reported in BU (Branbender units).

A much higher pasting temperature (73.82-84.60 ºC) was obtained for fermented maizecardaba banana complementary food. The peak viscosity was between 110 and 375 BU, while Breakdown and Setback viscosities were in the range of 11 to 326 and 38.5 to 174.58 BU. It can be therefore be observed that the pasting and functional properties of complementary foods depends on the formulations used in their formulation.

Therefore the behaviour of individual flours used imparts the pasting and functional properties of the formulated complementary foods.

Food Product Development

Food product development is a process of developing new food products or improving upon existing ones for consumption. It has been a very important process in the Food Industry for over 40 years (Earle *et al*., 2001). It is an integral part of the food industry and has been linked to the business and managerial aspects (Earle *et al*., 2001). According to Stewart-Knox and Mitchell (2003), it is a necessity, if a food industry will want to survive in the current food market competitions. To the food industry, its absence 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 has led to changes in consumer choice of food and preferences (Winger and Wall, 2006). These and other reasons such as health and environmental issues, convenience, company profitability and technological developments has led to the development of new products or improving upon existing ones through the process of food product development (Woods and Demiralay, 1998; Earle *et al*., 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. Due to this the companies resort to new food product development or improving upon existing products already on the market. Over the years women in the working force have increased and more meals are eaten away from the homes (Earle *et al*., 2001). This has led to the development of new convenient food products and improvements 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. They may be formulated with reduced fat and salt and increased vitamins and minerals. The process of using orange-fleshed sweetpotato in the development of a complementary food will help with vitamin A deficiency in Ghana. This will help meet a consumer health need.

According to Rudder *et al*. (2001), the process of food product development consists of stages that include ideas and concept generation, screening, research, development, product testing and marketing launch activities. These stages may be followed systematically to obtain an efficient process of product development or overlapped to make it less tedious with less time consumption (Stewart-Knox and Mitchell, 2003). Despite these various stages, a consumer-driven product is more likely to survive on the market (Costa and Jongen, 2006). Carpenter *et al*. (2000) have also reported that sensory analysis is one key aspect of food product development. 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.

In the development of the orange-fleshed sweetpotato complementary food, the drum dryer will be used to make the product instant to provide convenience for consumers. Sensory evaluation will also be used to select the most preferred product out of the different formulations developed in order so the product meets consumer sensorial attributes.

CHAPTER THREE

3.0.0 MATERIALS AND METHODS

3.1.0 Source of raw materials

The *Bohye* variety of Sweetpotato was obtained from the farms of the Crops Research Institute (CSIR-CRI), Fumesua. The Pearl millet and Soyabean were obtained from the open market in Accra. A commercial complementary food, which was used as a control sample, was obtained from the supermarket in Accra and weanimix (made up of maize, soyabean and groundnut), another control sample and a common household complementary food was processed as commonly done in the household level; thus, a larger proportion of the mixture is maize flour, while soyabean and groundnut formed a small part of the whole mixture.

3.2.0 Preparation of flour from the Sweetpotato, Millet and Soyabean

Sweetpotatoes weighing 78.25 kg were sorted, peeled, chipped and dried in a hot air oven at 60 °C for 12 h. Weight of chipped sweetpotatoes before drying was noted to be 49 kg. The dried sweetpotato chips were then milled in a hammer mill into flour. Millet weighing 27 kg was sorted, sieved, washed and dried at 60 °C for 2 h and then milled into flour using the hammer mill (500 micron sieve size). Soyabean weighing 24 kg was also sorted and roasted for 15 min. It was then dehulled and milled into flour. All the flours were packed into high density polyethylene bags and stored in a cool dry room ready for formulation and analysis.

3.3.0 Proximate analysis of samples

These analysis were conducted in the chemistry laboratory of the Food Research Institute (CSIR-FRI), Accra. All experiments were conducted in triplicates.

3.3.1 Moisture Determination

Moisture cans were washed, rinsed and dried in the oven at 103 ºC for 20 min and then allowed to cool in a desiccator, to room temperature. The balance was calibrated using a 30 g standard weight. Moisture cans were labelled and weighed, and then 3 g of sample was weighed into the moisture cans.

Weighed moisture cans and samples were put in a dessicator and then transferred into the oven and dried at 103 ºC ± 2 ºC for 4 h. After the drying process, the dried samples were allowed to cool in a dessicator and then weighed (AOAC, 1990).

3.3.2 Ash Determination

Crucibles were washed, dried and preheated in an oven at 105 ºC ± 10 ºC for 30 min and then cooled in a dessicator before use. They were labelled, weight taken and then 3 g of sample was weighed into the crucibles. They were then put into a muffle furnace. The samples were ignited at 550 ºC ± 10 ºC for 6 h (AOAC, 1990).

3.3.3 Fat Determination

The soxhlet extraction method was used for this experiment. The round bottom flask used was washed, rinsed and dried at 103 ºC ± 2 ºC for an hour. It was cooled to room temperature and weight noted. 5 g of sample was weighed into a filter paper, folded and put into a thimble which had already been stuffed with an adsorbent cotton wool. The thimble was again stuffed with more adsorbent cotton wool and then placed in the extracting chamber of the soxhlet extractor. About 240 ml of petroleum ether was poured into the 250 ml round bottom flask and then fixed to the extractor. The condenser was also fixed. The burner, on which the extractor was positioned, had a temperature that allowed about 10 - 15 drops of petroleum ether from the condenser to the extractor containing the thimble. Extraction was then done for 15 h. After the extraction process, the petroleum ether was distilled from the solution of petroleum ether and fat in the round bottom flask. But before, thimble containing defatted sample was removed from the extraction chamber. The petroleum ether was poured into a Winchester bottle.

Evaporation of petroleum ether took place untill fat was left in the round bottom flask. It was further dried in a hot air oven, cooled in a dessicator and then weighed (AOAC, 1990).

3.3.4 Crude Fibre Determination

2.5g of sample was weighed into a beaker and washed with petroleum ether about 3 times. The petroleum ether was then allowed to evaporate in the fume chamber. Sample obtained was transferred into a 750 mL Erlenmeyer flask and approximately 0.5 g of asbestos added. 200 mL of boiling 1.25% H_2SO_4 was added and immediately the flask was set on a hot plate and connected to a condenser. The flask was removed after 30 min and immediately filtered using linen cloth in a funnel and washed with boiling water until the residue washing was no longer acidic. The filterate and asbestos were washed back into the flask with 250 mL boiling

1.25% NaOH solution. The flask was then connected to the condenser and boiled for 30 min. It was filtered through a linen cloth and washed with boiling water until the residue was no longer basic. The residue was washed with approximately 15 mL alcohol and transferred into Gooch crucible quantitatively with water. The crucible and its content was dried for 1 h at 100 °C, cooled in a dessicator and weighed. It was then ignited in the furnace for 30 min cooled and re-weighed. Crude fibre was expressed as weight loss in weight percent (AOAC, 1990).

3.3.5 Protein Determination

3.3.5.1 Digestion

2 g of sample was weighed and transferred into a digestion tube. A blank was prepared alongside; that is, an empty digestion tube without sample. Concentrated H_2SO_4 (20 mL) was poured into each sample including the blank after 10 mL of distilled water was added.

Sample was prepared in triplicate. A catalyst (Kjeltab) in the form of tablets (1 tablet) was added, and then taken to the digestion chamber for digestion. Digestion was done for 3 h.

3.3.5.2 Distillation

After digestion, the digestion tubes were allowed to cool, contents diluted with a small quantity of distilled water and made up to 100 mL. 10 mL of the 100 mL digest was pipetted into distillation flasks with the addition of 90 mL distilled water. To the solution, 20 mL of 40% NaOH was also added. A conical flask containing 10 mL of boric acid solution with a few drops of mixed indicator was added to the distillation apparatus which aided in the collection of the ammonia. At least 100 – 150 ml of distillate was collected.

3.3.5.3 Titration

Drops of the mixed indicator (methyl blue, methyl red and 95 % ethanol) was added to the distillate and titrated against 0.1 N HCl. A colour change (from green to light blue) was observed and titre values noted (AOAC, 1990). The conversion factor used was 6.25.

3.3.6 Carbohydrate Determination

The carbohydrate content of all samples was determined by difference, that is, by subtracting the percentage proximate components of all the samples from 100 % (AOAC, 1990).

3.4.0 Mineral Determination

Minerals in the samples were determined using AOAC (2005) methods. Into a digestion tube 1 g of the sample was weighed, 15 ml of concentrated Nitric acid (HNO_3) added to each sample and digested for 30 min at 150 °C in a digester in a fume chamber. The sample was digested until the solution was pale yellow, and allowed to cool. 10 mL of concentrated perchloric acid (70 % $HClO_4$) was added and the digestion continued at 200 °C until the solution was colourless. After complete digestion, the solution was cooled slightly and 80 ml of distilled water added. The mixture was boiled for about 10 min and filtered through Whatman No. 42 filter paper into 250 ml volumetric flask. The solution was then made to the mark with distilled water.

3.4.1 Determination of Ca, Mg, K, Zn and Fe

The concentrations of Ca, Mg, K, Zn and Fe were determined using Atomic Absorption Spectrometer (Spectra AA220FS Model). The mineral contents in the samples were then calculated and results expressed in mg/kg.

3.5.0 Formulation of complementary food

Based on the macronutrients of the individual flours with reference to the levels of macronutrients required of complementary foods as developed by Codex Alimentarius Commission (2011), material balance was used to estimate the minimum amount of each portion of flour to meet the standard (Fig 1). A range for the various proportions was therefore developed and mixture design (from the Statsgraphics Centurion software) used to formulate the complementary food blends. The formulations are as shown in Table 2.

Table 2**: Formulations for the complementary food blend**

Runs	**Flour compositions (%)**			**Other ingredients (g/100g of flour sample)**		
	Sweetpotato flour	**Millet flour**	**Soyabean flour**	**Sugar**	**Salt**	**Powdered milk**
1	60	10	30	5	0.5	5
2	60	15	25	5	0.5	5
3	50	15	35	5	0.5	5
4	55	10	35	5	0.5	5

Formulations obtained from the statgraphics centurion from the range determined through material balance reference to the CODEX, 2011 requirement for complementary foods

3.6.0 Processing of the complementary food blends

The flour blends produced from the formulations were drum dried. To 2.5 kg of flour blend, 2.37 L of water was added; therefore 95% of water per weight of flour blend was added to each of the samples and kneaded into dough. The dough was then introduced onto the drums. The pressure of steam used was 2.5 bar and temperature, 126.9 ºC while revolution of drums was at 0.1911 rev/min. Thin dry films were produced from the drum drying and these were then milled into flour and packaged for further analysis.

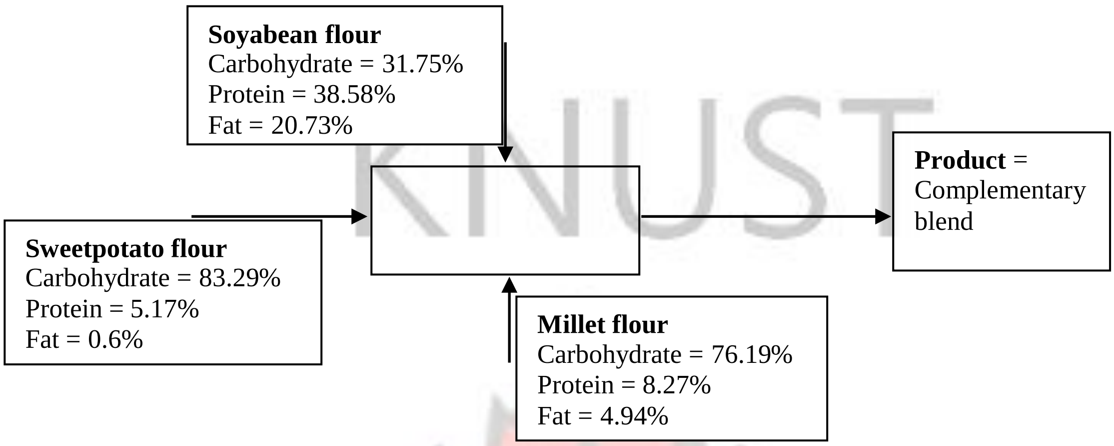

Figure 1: Design of material balance used for flour amounts for the blend

3.7.0 Colour determination of the flour samples

A hand held chromameter CR-310 (Minolta Co. Ltd., Osaka, Japan) was used to determine the colour of flour samples. The chromameter was first calibrated with a white tile. The sample flour was poured to fill a petri dish and then covered. The lens of the chromameter was placed on the petri dish at three different parts. The colour measurements were then taken and recorded as *L*= darkness/lightness (0 = black, 100 = white), *a* (-*a* = greenness and +*a* = redness), and *b* (-*b* = blueness, +*b* = yellowness) (Greene and Bovell-Benjamin, 2004).

3.8.0 Determination of pasting and functional properties of the flour samples

3.8.1 Determination of the pasting properties of flours

The pasting properties of the raw mixed flours and drum dried processed flours were determined using a Brabender viscoamylograph (Brabender, Duisberg Germany) which is equipped with 700-cmg sensitivity cartridge. 10% slurry (dry matter basis) of each of the flour samples was made with 500 mL distilled water and poured into the collection chamber.

The suspension/slurry was then heated at a rate of 1.5 ºC per minute from room temperature to 95 ºC. This temperature was then held for 15 min and then cooled again to 55 ºC. The pasting temperature, peak viscosity, peak time, breakdown viscosity and setback viscosity were all deduced from the graph produced by the Brabender viscoamylograph (Shuey and Tipples, 1982). The experiment was carried out in duplicate.

3.8.2 Swelling power and solubility

A gramme of sample flour was weighed and poured into a previously weighed 50 mL capacity centrifuge tube and 40 mL of distilled water added. The suspension obtained was uniformly and gently stirred using a stirring rod, avoiding excess force that might rupture the starch granules in the flour. It was then heated in a thermostatically controlled water bath at 85 ºC for 30 min, with constant stirring. The tubes were then cooled rapidly in ice cubes and then centrifuged at 2200 rpm for 15 min. The supernatant was poured into a weighed petri dish and evaporated to dryness in an oven at 105 ºC. The petri dish was then cooled in a desiccator and weighed in order to calculate the solubility. The swelling power was obtained through calculation when the sediment paste obtained after centrifugation was weighed

(Leach *et al*., 1959).

3.8.3 Bulk density

A calibrated centrifuge tube was weighed and filled with flour sample to the 5 mL mark, with constant tapping until there was no further change in volume. The tapped centrifuge tube was then weighed and the weight of the content noted. The bulk density of the sample was then calculated as the weight of sample noted per noted volume (5 mL) (Narayana and Rao, 1982).

3.8.4 Water Absorption Capacity

Into a graduated centrifuge tube was weighed 1 g of sample. 10 mL of distilled water was added and tube shaken for 5 min to obtain dispersion. The resulting dispersion was then centrifuged at 3500 rpm for 30 min. The volume of supernatant was measured while the sediment and centrifuge tube weighed. The water absorption capacity of sample was then calculated per weight of initial dry sample (Adebowale *et al*., 2005).

3.9.0 Sensory Evaluation

3.9.1 Preparation of samples and sensory evaluation

3.9.1.1 Weaning mix (control sample)

A well-known maize-based complementary food (weanimix) was used as the control sample in this study and as such included in the sensory evaluation. Into a cooking utensil on fire was added 500 mL of water. 100 g of weanimix flour was mixed with 250 mL of water to form slurry. The slurry was then poured into the boiling water which already had 0.5 g of salt. The resulting slurry was then stirred using a wooden ladle consistently until a paste was formed. The food was cooked for 15 min and after, 20 g of sugar added.

3.9.1.2 Sweetpotato-based complementary food preparation and sensory evaluation Five hundred millilitres of water at 85 ºC was added to 100 g of the processed sweetpotatobased complementary food flour and stirred with a wooden ladle consistently until a paste was formed. These food samples were served in disposable cups in a random order for panellists to assess. The sensory evaluation was carried out in a sensory lab in the Department of Food Science and Technology, KNUST. The sensory lab had adequate lighting from daylight or sunlight and panellists were seated in individual booths. The evaluation was carried out for 3 days between 10:00am to 3:00pm. Thirty-five untrained panellists (28 breastfeeding mothers and 7 non-breastfeeding mothers who have fed babies before) were asked to assess the coded complementary food samples in terms of colour, thickness, consistency, sweetness, aftertaste and overall acceptability using a 5-point hedonic scale (1dislike very much and 5-like very much). Water was provided for panellists to rinse their mouth in-between tasting of the complementary foods.

3.10 β-carotene determination of complementary foods and orange-fleshed sweetpotato flour

The β-carotene content of the most preferred complementary food, control samples (a commercial complementary food and Weanimix) and the orange-fleshed sweetpotato flour was determined using the method described by Imungi and Wabule (1990). 2g of flour sample was weighed into a beaker and then transferred into a mortar. It was then grinded with 50 mL cold acetone. This was filtered with suction through a Buchner funnel. The mortar, pestle, funnel and residue were rinsed with small amounts of acetone, receiving the washings in the suction flask through the funnel. The process was repeated until the residue was devoid of colour. Into a 500 mL separation funnel with teflon stop-cock was put 40 mL of petroleum ether, after which acetone was added. Two hundred millilitres of distilled water was added slowly along the walls of the funnel. The two phases were allowed to separate and the lower aqueous phase discarded. It was washed 4 times, using 200 mL of distilled water each time in order to remove residual acetone. The petroleum ether phase was collected into a volumetric flask by making solution pass through a small funnel containing anhydrous sodium sulphate to remove residual water. The separation funnel was washed with petroleum ether, collecting each washing in the volumetric flask by passing it through the funnel with sodium sulphate. This was further evaporated to dryness by passing it under a stream of nitrogen gas. It was reconstituted with a known volume of mobile phase. 20 µl of the reconstituted solution was injected into Shimadzu HPLC equipment. The Shimadzu HPLC equipment was made up of an LG6 pump, a UV-Visible detector, a CR6 recorder, ODSRESERVED PHASE column and a Ryhodyne 1725 injector. Mobile phase was made up of acetonitrile 70%, 20% dichloromethane and 10% methanol. The flow rate was also 1mL/min and wavelength 450nm. Before sample solution was injected a standard β-carotene was dissolved in petroleum ether and absorbance read at 540 nm. Since the absorption read was 0.432, which was between 0.2 and 0.8, it was injected into the Shimadzu HPLC equipment and the elution time noted. This was to help note the peaks for the sample injections, which was then used to calculate the β-carotene content of the samples.

3.11.0 Microbial determination of complementary food

3.11.1 Staphylococcus aureus enumeration

Sixty grams of Baird Parker Agar was suspended in 1 L of distilled water. The solution was heated with frequent agitation and boiled for 1 min to completely dissolve the medium. It was then autoclaved at 121 ºC for 15 min. After cooling, 50 mL of Egg Yolk Tellurite supplement (#7983) was added and mixed thoroughly before dispensing. 1g of sample was dissolved in 10 mL of peptone water and serial dilutions made into test tubes. After which 1 mL of sample was transferred into each of the plates containing Baird Parker Agar. The distribution of sample of the surface of the agar was done using a bent glass rod. The inoculum was then allowed to absorb to the surface of the media and then plates inverted. They were incubated at 37 ºC for 48 h. Colonies were then counted on a colony counter after incubation

(Vanderzant and Splittstoesser, 1992).

3.11.2 Enumeration of coliforms (E. coli)

To prepare the medium, 37 g of Rapid' E. coli 2 Agar was dissolved in 1L of distilled water. It was then mixed until a homogenous mixture was obtained. It was then heated gently while agitating frequently and then boiled until powder was completely dissolved. It was then autoclaved at 121 ºC for 15 min. 1g of sample was weighed into 10 mL Butterfield's Phosphate Buffer diluents. It was homogenised in a blender at high speed to dissolve sample. Serial dilutions were made. After, 1 mL of the sample solutions was pipette into a sterile Petri dish and 15 mL melted medium rapidly poured into it. Petri dish was swirled to mix the contents and then left to solidify. Petri dishes were then inverted and incubated at 44 ºC for 24 h for enumeration of *E. coli*. The colonies formed after incubation was counted using a colony counter.

3.11.3 Enumeration of yeast and mould

Yeast and mould was enumerated using a conventional method. 25 g of sample was dissolved in 225 mL of sterile distilled water. A serial dilution of this solution was then prepared by pipetting 1 mL of solution in 9 mL of distilled water in a test tube. 1 mL of each dilution prepared was transferred into their corresponding sterilized Petri dishes. The potato dextrose agar was melted in a water bath and 15 mL poured into the Petri dishes. It was swirled to disperse medium and sample solution evenly. It was then allowed to solidify and then incubated at 28 ºC for 72 h. The colonies formed were then counted using a colony counter.

3.11.4 Enumeration of Total Plate Count

Total Plate Count was enumerated using the conventional method. 1 g of sample was dissolved in 10 mL of distilled water. A serial dilution of the solution was prepared by pipetting 1 mL of solution in 9 mL of distilled water in a test tube. 1 mL of each dilution prepared was transferred into their corresponding sterilized Petri dishes. Plate Count Agar was melted in a water bath and 15 mL poured into the Petri dishes. It was swirled to disperse medium and sample solution evenly. It was then allowed to solidify and then incubated at 37 ºC for 24 h. Colonies formed were then counted using a colony counter.

Statistical Analysis

All data collected were in triplicate, with the exception of the sensory evaluation and pasting properties. Data was expressed as mean and standard deviation and one-way analysis of variance and Tukey's HSD test was used to ascertain any statistical differences at 95% confidence interval. Pearson's correlation was also used to establish any relationships between the sensory attributes.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1.0 Flour yields of sweetpotato, millet and soyabean

Weight of sweetpotato, millet and soyabean after drying and milling were 12.5 kg, 25 kg and 20 kg, respectively. This resulted in a yield of 16% for sweetpotato, 92.6% for millet and 83.3% for soyabean. Millet had the highest yield of 92.6% followed by Soyabean (83.3%) and Sweetpotato (16%) (Fig 2). Sweetpotato had the least yield due to the peeling process and its large amount of water typical of most roots (Ogunlakin *et al*., 2012). Freshly sweetpotato could have a moisture content of about 80% (Kamal *et al*., 2013). Cereals and legumes on the other hand are usually dried before storage and sale; therefore there was not much water to lose before milling.

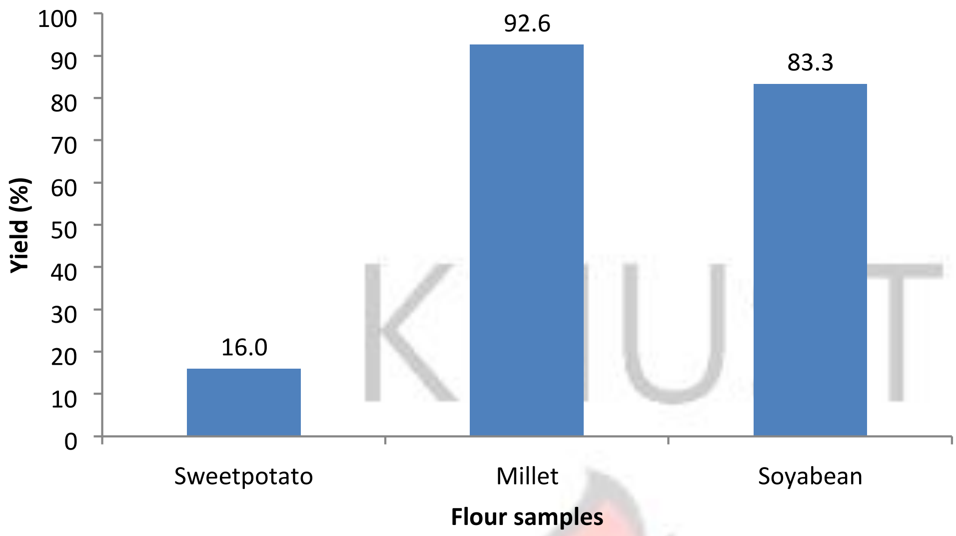

Figure 2: Yield of flours processed from Sweetpotato, Millet and Soyabean

Soyabean had a lesser yield compared to millet due to the dehulling process. Dehulling of soyabean is necessary in the development of an infant food because the seed coat is mainly made up of fibre. Fibre levels in infant food should be limited as much as possible (less than 5%), since infants at that stage are unable to digest them effectively (CAC, 2011).

4.2.0 Proximate composition of the flours produced

Moisture content was highest in millet flour compared to the other two flours. This may have been due to the source of materials and different processing method. Soyabean, being a legume and a good source of protein and fat, had the highest contents of protein and fat. It also contained the highest amount of ash; making it a relatively higher source of minerals. Sweetpotato had the least fat content (0.6%) (Fig 3). Sweetpotato and millet flours were very high in carbohydrate content.

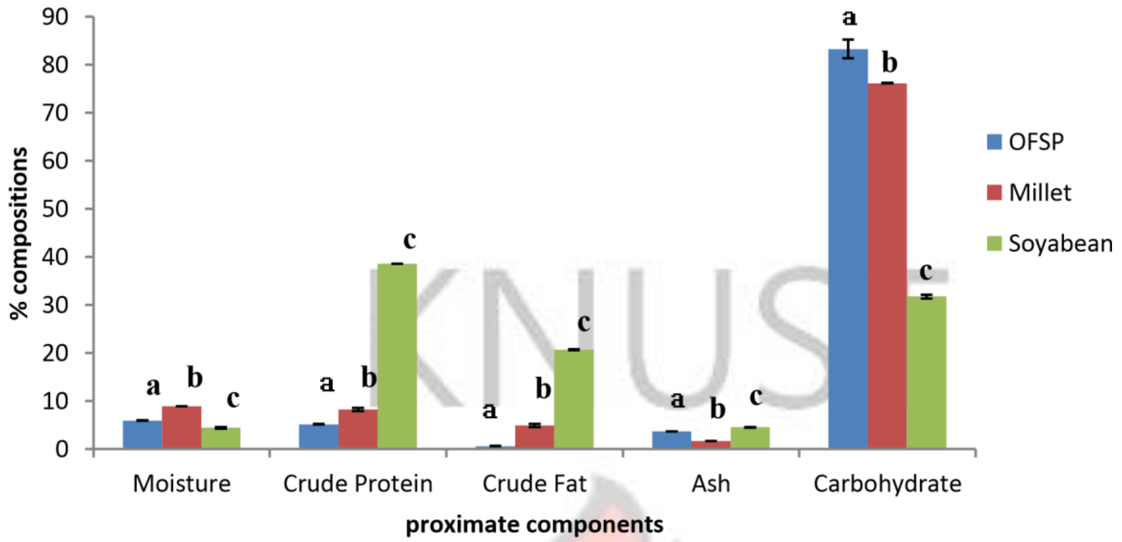

Figure 3: Proximate composition of sweetpotato, millet and soyabean flours
OFSP – Orange-fleshed sweetpotato flour Error bars represent standard deviation Bars with different superscript are significantly different at 95% confidence level

The variety of sweetpotato used in this study, *Bohye*, had higher protein content (5.17%) than that reported by Dansby and Bovell-Benjamin (2003); they reported a protein content of 1% for another orange-fleshed variety. Protein content of sweetpotato could also be as high as 9.21 to 9.80% depending on the variety (Kamal *et al*., 2013).

Carbohydrate content of sweetpotato reported by Dansby and Bovell-Benjamin (2003) was however higher (90.6%) than that reported in this study (83.29%). More similar to this study, Kamal *et al*. (2013) reported approximately 80% of carbohydrate content in their sweetpotato flour. The difference may be due to the variety and mode of cultivation (Gichuhi *et al*., 2014). The sweetpotato flour reported by Dansby and Bovell-Benjamin (2003) was hydroponic sweetpotato flour but the exact variety was not specified. Again the protein, fat and ash content of the orange-fleshed sweetpotato were higher than reported by Jangchud *et al*. (2003) who also used an orange-fleshed variety. The difference in these components could be due to difference in climate and soil conditions under which the roots were cultivated (Gichuhi *et al*., 2014). Being a high energy food due to the high starch content, sweetpotato flour, complemented with soyabean will help make up for its low protein and fat content, in order to help make the complementary food whole in terms of nutrients.

4.3.0 Functional, pasting properties and colour of formulation blends before drumdrying

4.3.1 Functional properties of the formulation before drum-drying

Water absorption capacity of samples ranged from 152.5 to 216.7 %. The first formulation with 60% OFSP (Orange fleshed sweetpotato), 10% MF (millet flour) and 30% SBF (soyabean flour) had the least water absorption capacity, while the formulation with 55% OFSP, 10% MF and 35% SBF had the highest water absorption capacity (Table 3). A significant difference was observed between the first and fourth formulation but not between the first and third, second and fourth formulations, as well as between the second and third formulations (Table 3). The water absorption capacity of formulated blends was found to be higher than 150-180% reported by Olapade *et al*. (2015), 124.67-165.33 reported by Adepeju *et al*. (2014) and 95-133% reported by Ayo-Omogie and Ogunsakin (2013) in their complementary blends. The variations and differences could be as a result of the various components of the complementary food blend.

Drum drying the product may further improve upon this characteristic of the complementary food although not as much as an extruder would (Colonna *et al*., 1983; Majzoobi *et al*., 2011).

Swelling index was observed to be significantly higher ($p<0.05$) in samples with lower percentages of soyabean compared with those with higher percentages. It ranged from 6.652 in formulation 3 to 7.734 in formulation 2 (Table 3). This implies that samples could swell up to about 7 times their original weight. The lower swelling power could be attributed to the soyabean present. Soyabean contains fats and this may interfere with water absorption by the starch granules by forming films around starch granules or competing with water that could have interacted readily with starch granules (Akingbala *et al*., 1995). Although the percentage of fat in soyabean flour is a little over 20% and amount of soyabean flour used is small, there could have been significant interference. Moreover, the relatively higher sweetpotato flour contents in formulations 1 and 2 could also be a contributing factor to the significantly higher swelling index. Considering complementary foods, the lower swelling index obtained seems to be an advantage, since lower swelling power is desirable. Complementary foods with lower swelling power are easily digestible by infants (Okorie *et al*., 2011).

Table 3: Functional properties of sample formulations before drum-drying

	Functional properties			
Samples	**WAC (%)**	**Swelling Index (g/g)**	**Bulk Density (g/ml)**	**Solubility Index (%)**
1(60:10:30)	152.5 ± 5.00^{a}	7.297 ± 0.22^{a}	0.827 ± 0.05^{a}	17.78 ± 0.81^{a}
2(60:15:25)	193.3 ± 11.55^{bc}	7.734 ± 0.04^{a}	0.815 ± 0.02^{a}	18.74 ± 0.76^{a}
3(50:15:35)	185.0 ± 12.91^{ab}	6.652 ± 0.10^{b}	0.807 ± 0.00^{a}	18.78 ± 1.15^{a}
4(55:10:35)	216.7 ± 5.77^{b}	6.655 ± 0.35	0.787 ± 0.02^{a}	20.32 ± 1.46^{a}

-Values are averages of triplicate determinations -Data is represented as mean ± standard deviation
-Sample ratios are represented as (Orange-fleshed sweetpotato:millet:soyabean)
-Values in same column with different superscripts are significantly different at 95% confidence level

The swelling index was found to be higher than that reported by Ijarotimi and Oluwalana (2013). Their highest swelling index was reported in the control sample, Cerelac® to be

2.43%. Ayo-Omogie and Ogunsakin (2013) reported a much higher swelling index (10.310.8 g/ml) in a fermented maize-cardaba banana complementary food. The difference between the swelling index of this study and that reported in literature may be attributed to the various food materials used in formulating the complementary food. The drum drying process is reported to improve upon this parameter by causing the gelatinization of starches in the sample (Doublier *et al*., 1986; Majzoobi *et al*., 2011; Jittanit *et al*., 2011).

The bulk densities of sample formulations ranged from 0.787 to 0.827 (Table 3). Although formulation 1 had the highest bulk density, there was no significant difference observed amongst samples. Bulk density is the mass of particles of the flours per total volume it occupies. It is influenced by the porosity of samples; thus, the spaces in-between flour particles and size of particles (Kinsella, 1987). For complementary foods, lower bulk densities are desired (Akubor *et al*., 2013), because products prepared are less bulky and easily digestible by infants while retaining the nutrients as compared with flours with high bulk densities which will require the addition of more water to make them less bulky and thereby reducing the nutrients; since infants only consume smaller amounts of food at a given time. Lower bulk densities were reported by Ikujenlola (2014) (0.50–0.75 g/cm^3), Ijarotimi and Oluwalana (2013) (0.66–0.73 g/cm^3) and Ayo-Omogie and Ogunsakin (2013) (0.40–0.44 g/cm^3). Since their complementary foods were also unprocessed the difference in bulk density could be attributed to the different food ingredients used in the formulation of the complementary foods. Processing the formulated blends using the drum drying process is expected to reduce the bulk density of the Sweetpotato-based complementary foods being developed (Pua *et al*., 2010; Majzoobi *et al*., 2011; Jittanit *et al*., 2011).

Solubility index (soluble solids) of samples were low, ranging from 17.78% in formulation 1 to 20.32% in formulation 4 (Table 3). It was observed that the higher the soyabean content in the formulation the higher the solubility. This could be attributed to the proteins present in soyabean (deMan, 1999). Proteins in the tertiary structure have hydrophobic regions which associate with non-polar solvents and hydrophilic regions which in turn associate with polar solvents, thus water. Soyabean also contains oligosaccharides which are water soluble and may have contributed to the high solubility index in samples containing higher soyabean flour. However, no significant differences were observed amongst samples. Solubility is further improved with processing methods such as drum drying and extrusion (Doublier *et al*., 1986; Tang *et al*., 2003).

4.3.2 Pasting properties of formulations before drum-drying

The pasting temperatures observed amongst the sample blends were high, ranging from 77.80 ºC in formulation 1 to 78.40 ºC in formulation 3 (Table 4). The highest pasting temperatures were observed in samples with reduced orange-fleshed sweetpotato flour (OFSPF) but increased levels of soyabean. A significant difference was observed between formulations 2 and 3 (Table 4). Considering the pasting temperatures in the individual ingredients, it can be observed that the ingredients complemented one another to result in the pasting temperatures observed. Therefore formulating complementary food is an important part as it may affect the resulting characteristics of the product. The pasting temperature of OFSP in this study was found to be lower than that reported by Jangchud *et al*. (2003).

The pasting temperatures of all four samples reported in this study were however lower than that reported by Olapade *et al*. (2015) and within range reported by Adebayo-Oyetoro *et al*. (2012) but higher than that reported by Adepeju *et al*. (2014). Adebayo-Oyetoro *et al*. (2012) developed a complementary food from fermented sorghum, walnut and ginger, while Adepeju *et al*. (2014) produced theirs from breadfruit. Although all products are complementary foods the various components used are different, hence the difference in pasting temperature. Since pasting temperature corresponds to the amount of energy required to cook the food, lower pasting temperatures are more desirable.

Table 4: Pasting properties of sample formulations before drum-drying

Samples	Sample properties				
	Pasting temperature (°C)	**Peak viscosity (BU)**	**Breakdown viscosity (BU)**	**Setback viscosity (BU)**	**Peak time (min)**
1(60:10:30)	77.80±0.00^{ab}	128.0±2.83^{a}	14.00±1.41^{ab}	26.00±1.41^{a}	16.10±0.14^{ab}
2(60:15:25)	77.75±0.07^{a}	142.0±2.83^{a}	18.00±0.00^{b}	31.50±0.71^{b}	15.20±0.00^{a}
3(50:15:35)	78.40±0.28^{b}	90.50±4.95^{c}	8.00±1.41^{c}	23.00±0.00^{a}	15.75±0.42^{ab}
4(55:10:35)	78.15±0.07^{ab}	109.0±2.83^{b}	12.50±0.71^{b}	22.00±1.41^{a}	16.20±0.07^{b}
OFSPF	77.4	495	115	25	12.55
Millet flour	78.5	300	67	402	14.15
Soyabean flour	50.2	8	3	3	0.00

-Values are averages of triplicate determinations -Data is represented as mean ± standard deviation
-Sample ratios are represented as (Orange-fleshed sweetpotato:millet:soyabean)
-Values in same column with different superscripts are significantly different at 95% confidence level

Peak viscosity was observed to be highest in formulation 1 (128.0 BU) and least in formulation 3 (90.50 BU) (Table 4). Again, just like the swelling power in Table 3, the peak viscosity was observed to be highest for formulations with lower soyabean flour levels. Individually, the peak viscosities of millet and OFSP flours were higher compared to soyabean which had a peak viscosity of 8 BU (Table 4). Given the wide difference in peak viscosities between soyabean and millet or OFSP, soyabean flour is therefore the main reason for the decreased peak viscosities. This is because soyabean has negligible amount of starch (Akingbala *et al.*, 1995). Therefore products with more soyabean content are more likely to be less viscous.

Breakdown viscosities of sample formulations were observed to be as low as 8 BU in formulation 3 to 18 BU for formulation 2 (Table 4). It was observed that reducing OFSPF resulted in lower breakdown viscosities (Table 4). OFSPF had a relatively higher breakdown viscosity compared with millet and soyabean (Table 4). Therefore formulations with lower OFSPF may have reduced breakdown viscosities. There was however no significant differences observed between formulations 1, 2 and 4 (Table 4). Breakdown viscosities reported in this study is much lower than that reported by Ayo-Omogie and Ogunsakin (2013), who reported 11-326 BU in complementary food from fermented maize-cardaba banana formulation. A lower breakdown viscosity indicates the product's ability to withstand higher cooking temperatures, which is also an indication of lower viscosities (Okorie *et al.*, 2011). This will be a good characteristic for baby foods, because the product produced will be thin enough for easy digestion.

With respect to setback viscosity, formulation 4 had the least setback viscosity (22.00 BU) while formulation 2 had the highest (31.50 BU) (Table 4). There was however no significant differences between formulations 1, 3 and 4 but between formulation 2 and the other 3 formulations (Table 4). Millet flour has a relatively high setback viscosity compared with the other flours. The flour blends had lower setbacks as expected because the proportion of millet (which as high setback) is low (10-15%) in the products. Therefore its reduced levels in the formulations compared with the other flours resulted in the low setback viscosities obtained.
Ayo-Omogie and Ogunsakin (2013) reported much higher setback viscosities (38.5-174.58 BU) for their fermented maize-cardaba banana complementary food blend. This could be attributed to the difference in individual components of the complementary foods. Flours or starches with lower setback values have a lower tendency to retrograde (Okorie *et al.*, 2011); thus the separation of paste formed from the water component of the mixture after a gel has been formed upon cooling.

Peak time is the amount of time needed to reach the peak viscosity. Thus, the amount of time required to completely gelatinize the starches in the flour samples, thus, the cooking time. It was found to range between 15.20 to 16.20 min (Table 4). Formulation 4 had the highest time while formulation 2 had the least (Table 4). A significant differences ($p<0.05$) was observed between formulation 2 and 4. But none was observed between 1 and 3 (Table 4).

The peak times were found to be higher in the blends than the individual flours with soyabean recording 0 min. The presence of high fat, protein and other food components in the soyabean could have caused this effect. Chinma *et al*. (2012) reported a peak time of 5.61 min for a full fat soybean sample. However, they extracted the starch from the soyabean sample before conducting the analysis and the Rapid Viscoamylograph (RVU) was used in the analysis.

4.4.0 Colour of sample formulations before drum-drying

Colour is an important parameter when it comes to food products as it has an influence on the purchasing and preference of the product. The colour of the formulated blends was observed to be very light or whiter, given the very high L-values. L-values beyond 50 indicates relatively lighter or brighter colour while values below 50 represents darker colour (Falade and Olugbuyi, 2010). The L-values ranged from 83.88 in formulation 3 to 84.33 in formulation 1 (Table 5). No significant differences ($p>0.05$) were observed between the flour formulations. However, a significant difference ($p<0.05$) was observed between the four formulations and Orange-fleshed sweetpotato (OFSP) flour; and this may be due to the difference in flour compositions. The L-value for OFSP reported in this study (85.09) was observed to be lower than 87.70 reported by Jangchud *et al*. (2003). This could be attributed to the processing conditions involved in producing the sweetpotato flour.

The a-values of the formulated blends were found to be in the range of -2.82 to -3.03 (Table 5). That of sweetpotato flour was -3.66. Given the interpretation of the a-value, the values can be found slightly in the green region of the a-scale (Falade and Olugbuyi, 2010). The sweetpotato flour was found to be relatively more in the green region than the formulations (Table 5) and this could be attributed to the flour compositions. The a-value reported in this study was however different from that reported by Jangchud *et al*. (2003). Their orangefleshed sweetpotato was slightly in the red colour region (thus the positive, +a, region) compared to that reported in this study.

Table 5: Colour of formulated blends before drum-drying

Formulations	L	a	b	ΔC	ΔE
Sweetpotato flour	85.09±0.24^{a}	-3.66±0.01^{a}	17.36±0.09^{a}		
1(60:10:30)	84.33±0.10^{b}	-3.02±0.03^{b}	17.23±0.06^{ab}	0.66±0.02^{a}	1.01±0.21^{a}
2(60:15:25)	83.99±0.08^{b}	-2.90±0.03^{c}	16.54±0.03^{c}	1.12±0.08^{b}	1.57±0.19^{bc}
3(50:15:35)	83.88±0.19^{b}	-2.82±0.04^{c}	16.19±0.14^{d}	1.44±0.20^{c}	1.88±0.19^{c}
4(55:10:35)	84.27±0.24^{b}	-2.90±0.02^{c}	17.03±0.15^{b}	0.86±0.10^{ab}	1.19±0.07^{ab}

-Values are averages of triplicate determinations -Data is represented as mean ± standard deviation
-Sample ratios are represented as (Orange-fleshed sweetpotato:millet:soyabean)
-Values in same column with different superscripts are significantly different at 95% confidence level

The b-value indicates the yellowness or blueness of the product (Falade and Olugbuyi, 2010). Positive values indicate that the product is in the yellow region while negative values indicate vice versa. The formulations were therefore in the yellow colour region. The b-value of the formulations ranged from 16.19 to 17.23. That of the sweetpotato flour was found to be 17.36 (Table 5). Jangchud *et al*. (2003) however reported a relatively higher b-value (25.8-30) for sweetpotato flour. There were significant differences between formulation 1, 2 and 3, but not between 1 and 4 (Table 5).

Delta chrome (ΔC) represents the change in level of saturation of samples with respect to a standard sample while delta E (ΔE) represents the change in level of intensity of colour of a sample with reference to a standard sample (Falade and Olugbuyi, 2010). Delta chrome (ΔC) of formulated samples with reference to the sweetpotato flour was found to be in the range of 0.66 to 1.44. That of the colour intensity (ΔE) was also in the range of 1.01 to 1.88. Significant differences were observed between samples 1, 2 and 3 but not 4, in terms of the delta chrome (ΔC). In the colour intensity (ΔE) a significant difference was only observed between formulation 1 and 3 (Table 5). Smaller positive values obtained indicate that the difference in colour intensity and level of saturation of formulated blends and sweetpotato flour is very small. Therefore it could be inferred that the impact on the colour of sweetpotato flour by the other individual components (millet and soyabean) was very small. The colour of sweetpotato flour hence dominated.

The relatively higher level of saturation and colour intensity values were obtained in formulation 3 (Table 5). This sample formulation also had the lowest values of L, a and b (Table 5). As a result, the difference between the colour of sweetpotato flour and that of the formulation will be relatively wider. The formula for calculating delta chrome (ΔC) and colour intensity (ΔE) (Falade and Olugbuyi, 2010; Falade and Oyeyinka, 2014) confirms this explanation. Moreover, this formulation, had the highest amounts of millet and soyabean flours amongst all the flour formulations, hence the reason for the result. Therefore the millet and soyabean flours impacted on the flour colour although very small. An increase in millet and soyabean flour could result in higher values hence change in colour.

4.5.0 Functional properties of drum-dried complementary food

The Water Absorption Capacity (WAC) of a food product is its ability to absorb moisture. It is defined as the amount of moisture taken up by the flour to achieve a desired consistency or optimal result.

The WAC of the drum dried formulated products were in the range of 40 to 43.67% (Table 6). It was highest in formulation 1 and least in formulation 3 (Table 6). Also, formulations with higher soyabean content had lower WAC (Table 6). There was however no significant differences (p>0.05) among the samples.

Compared to results in Table 3, it can be observed that the drum drying process may have caused a decrease in the WAC. A flour or starch sample with higher water absorption capacity at low temperature is a suitable ingredient for quick preparations or instant food (Pacheco-Delahaye *et al*., 2008). This may happen when there is a full or complete gelatinization of the starch granules. Compared to a local and common complementary food, weanimix, and a well-known commercial complementary food in Ghana, the OFSP-based complementary food had more soluble solids. The drum drying process was used in order to make the product instant, therefore based on what was reported by Pacheco-Delahaye *et al*. (2008), the formulated complementary foods would be more readily soluble in water than the control samples. The interference of the various components, milk powder and sugar, can also not be ignored. Milk contains proteins and sugars which could dissolve in polar solvents.

Olapade *et al*. (2015) reported a much higher water absorption capacity (150-180%) in plantain and cowpea complementary blends. Brou *et al*. (2013), using maize, millet, beans and soyabeans in the development of complementary foods also reported a range of 95 to 133%. In both cases the complementary food blends were not gelatinized. This implies that the higher WAC of the complementary food blends before drum-drying (Table 3) is within range, although the various components of the complementary flours are different.

Considering weanimix, the initial roasting process of the ingredients may have resulted in incomplete gelatinization of starches hence the low WAC. No significant differences (p>0.05) were observed amongst samples but between samples and the control samples (Table 6).

Table 6: Functional properties of drum-dried complementary food blend

Sample	Functional properties			
	WAC (%)	Swelling power (g/g)	Solubility (%)	Bulk density (g/ml)
1(60:10:30)	43.33 ± 3.51^{a}	5.10 ± 0.06^{a}	15.10 ± 1.84^{a}	0.81 ± 0.04^{ab}
2(60:15:25)	43.67 ± 4.51^{a}	5.22 ± 0.09^{a}	13.75 ± 3.04^{ab}	0.76 ± 0.02^{ab}
3(50:15:35)	40.00 ± 5.29^{a}	5.10 ± 0.09^{a}	18.20 ± 0.14^{a}	0.77 ± 0.03^{ab}
4(55:10:35)	41.00 ± 4.24^{a}	5.17 ± 0.63^{a}	15.80 ± 1.27^{a}	0.75 ± 0.04^{ab}
Weanimix	19.00 ± 2.65^{b}	5.55 ± 0.30^{a}	6.75 ± 1.34^{b}	0.93 ± 0.01^{c}
CCF	28.00 ± 0.50^{c}	2.86 ± 0.05^{b}	31.8 ± 1.13^{c}	0.69 ± 0.00^{a}

-Values are averages of triplicate determinations -Data is represented as mean ± standard deviation
-Sample ratios are represented as (Orange-fleshed sweetpotato:millet:soyabean)
-CCF – Commercial Complementary Food
-Values in same column with different superscripts are significantly different at 95% confidence level

The swelling power of the drum-dried complementary foods was in the range of 5.1 to 5.22 g/g (Table 6). There was no significant difference ($p>0.05$) amongst test samples and weanimix but with the commercial complementary food. The commercial complementary food had the least swelling power (Table 6). This difference could be attributed to the different processing methods and ingredients used in the production of the various complementary foods.

Weanimix had a comparable swelling power to the orange-fleshed sweetpotato complementary foods due to the initial processing methods of roasting. This processing step may have reduced the swelling power of the starch granules. Okoli (1998) reported that a moderate to high swelling power would enhance functionality of flours in foods such as baby foods and breakfast cereals.

The swelling power obtained by Ikujenlola (2014) and Adepeju *et al*. (2014) were relatively lower (1.10 – 1.50 g/g; 0.15 – 0.21 g/g, respectively) than all the complementary foods reported in this study. Ikujenlola (2014) developed complementary food from a blend of malted and unmalted acha, soybean and defatted sesame while Adepeju *et al*. (2014) developed a complementary food from a blend of bread fruit, groundnut and soyabean. Ijarotimi and Oluwalana (2013) also had a relatively lower swelling power (2.43 g/g) than that reported in this study (5.1 – 5.5 g/g). These variations could be attributed to the individual components used in the formulation of the complementary food. According to Majzoobi *et al*. (2011), drum drying is able to increase the cold water viscosity of flours while the native flours are unable to do the same. Therefore the OFSP-based complementary food is able to form partial viscous solutions in cold water due to the process of drum drying; thereby making it a partial instant food. This was due to the chosen processing conditions (from trials conducted) of drum drying.

The solubility of formulated samples ranged from 13.75 to 18.20% (Table 6). It was observed to be higher than weanimix but significantly ($p<0.05$) lower than the commercial complementary food. No significant differences ($p>0.05$) were observed amongst the OFSPbased complementary food (Table 6). Compared to the water solubility index of the formulated samples before drum drying (Table 3), solubility of the drum dried complementary food is relatively low. This may be due to the incomplete gelatinization of the starch granules in the samples by the drum drying process.

A study to optimize the conditions in the drum drying process could result in the full gelatinization of starch granules thereby increasing the solubility of the complementary food. Another processing method, such as extrusion cooking could also be used, because it has been reported by Doublier *et al*. (1986) to result in higher solubility than drum drying.

Solubility of sweetpotato flour could range from 1.5 to 9.6% (Aina *et al*., 2012). This is often due to the sugars present in the sweetpoato. Therefore the water solubility index of the formulated blends could be influenced by the other flour components and ingredients. Addis *et al*. (2013) reported a solubility index of 1.1-3 g/g, while Adepeju *et al*. (2014) reported 3.27 to 4.9 g/g. Brou *et al*. (2013) also reported a solubility index between 0.02 and 0.20 g/g. The differences may be due to the various components used in the formulation.

Bulk density is the mass of particles of the flours per total volume it occupies. It is influenced by the porosity of samples, thus, the spaces in-between flour particles and size of particles. The packaging material and design for a product is dependent on its bulk density (Kinsella, 1987). The bulk density of the OFSP-based complementary foods ranged from 0.75 to 0.81 g/ml (Table 6). No significant differences ($p<0.05$) were observed amongst formulations. Compared to the local complementary food (weanimix) the OFSP-based complementary food had relatively lower bulk densities (Table 6). The commercial complementary food had the least. The product developed is therefore an improvement on the local complementary food but could be improved to compete with the commercial complementary food.

Lower bulk density is best for a complementary food (Akpata and Akubor, 1999; Akubor *et al*., 2013). Higher bulk density implies lesser spaces between particles of flours. This will end up increasing the viscosity of the flour. For complementary foods, high viscosities are not desired because consumption and digestion becomes difficult for babies.

This will result in the addition of more water by most mothers, hence reducing the nutrients of the food per serving to a baby. The bulk densities of OFSP-based complementary food were found to be higher than that reported by Ikujenlola (2014), Ijarotimi and Oluwalana (2013), Adepeju *et al*. (2014) but comparable to complementary food developed by AyoOmogie and Ogunsakin (2013). The various components used in the formulation of the complementary foods were different.

4.6.0 Pasting properties of drum-dried complementary food

Pasting temperature represents the temperature required to gelatinize starches in a sample. It is an indication of the amount of energy required to cook the starch sample (Adeyemi and Idowu, 1990). The pasting temperatures of the drum dried formulations ranged from 75.75 ºC to 86.95 ºC. There was a significant difference ($p<0.05$) observed between formulations 1, 2 and 3, 4. However between formulations 1 and 2, and 3 and 4 there were no significant differences ($p>0.05$) observed (Table 7). Formulations 1 and 2 had the same sweetpotato flour content which differed in formulations 3 and 4 and that may have resulted in the significant differences observed. Compared to the pasting temperatures before drum drying (Table 4), values were similar, however, the peak time (which is the time required to fully gelatinize the starches and also an indication of cooking time) reduced. Therefore, the drum drying process reduced the cooking time of the complementary food.

Table 7: Pasting properties of drum-dried formulation blend

	Pasting properties				
Samples	**Pasting temperature (ºC)**	**Peak viscosity (BU)**	**Breakdown viscosity (BU)**	**Setback viscosity (BU)**	**Peak time (min)**
1(60:10:30)	75.75±0.64^{a}	42.00±1.41^{a}	5.00±0.00^{ab}	12.50±0.71^{a}	14.78±0.53a
2(60:15:25)	77.70±0.56^{a}	44.00±1.41^{a}	5.50±0.71^{b}	17.50±0.71^{b}	14.45±0.07a
3(50:15:35)	86.95±1.63^{b}	26.00±2.83^{b}	2.00±0.00^{ac}	12.00±1.41^{a}	15.40±0.14a
4(55:10:35)	86.50±0.57^{b}	24.50±0.71^{b}	1.50±0.71^{c}	9.50±0.71^{a}	15.20±0.21a
Weanimix	92.50±1.98^{c}	27.00±4.24^{b}	1.00±0.05^{c}	12.50±0.71^{a}	25.88±1.87b
CCF	50.20±0.00^{d}	11.00±1.41^{c}	3.00±0.04^{abc}	2.50±0.71^{c}	0.00±0.00c

-Values are averages of triplicate determinations -Data is represented as mean ± standard deviation
-Sample ratios are represented as (Orange-fleshed sweetpotato:millet:soyabean)
-CCF – Commercial Complementary Food
-Values in same column with different superscripts are significantly different at 95% confidence level

Compared to weanimix, the drum dried products had significantly ($p<0.05$) lower pasting temperatures and peak time. The commercial complementary food had the least pasting temperature (50.20 ºC) and required no time at all to reach maximum viscosity (Table 7). This implies that the starches in the commercial complementary food are probably fully gelatinized and therefore fully cooked making it an instant product (Majzoobi *et al*., 2011) than the formulated products and weanimix. The drum drying process could be improved upon (by optimizing the temperature, time and moisture content of dough) to reduce pasting temperatures and peak times to a point where the starches in the product are fully gelatinized or the product is fully cooked.

Peak viscosity gives an indication of the viscous load or amount of energy required during mixing. It has been linked with the quality of products (Ragaee and Abdel-Aal, 2006). The peak viscosity ranged between 24.5 to 44 BU, which is significantly lower ($p<0.05$) than what was reported for the formulation before drum drying (Table 4). There was no significant differences ($p>0.05$) between 1 and 2, and 3 and 4. Formulation 4 had the least peak viscosity but was not significantly ($p>0.05$) different from formulation 3. Differences could be attributed to the flour compositions in the formulations (Abioye *et al*., 2011).

Peak viscosities were comparable with weanimix (Table 7) but higher than the commercial complementary food. The product developed is therefore very viscous in comparison with the commercial product. A significant difference ($p<0.05$) was observed between the commercial complementary food and the other complementary foods. With respect to complementary foods, lower viscosities are suitable (Amagloh *et al*., 2013).

Breakdown and Setback viscosities were also reduced after drum drying the formulations. Breakdown viscosities were in the range of 1.50 to 5.50 BU while that of setback ranged from 9.50 to 17.50 BU (Table 7). Setback and Breakdown viscosities are an indication of the extent of retrogradation; that is, the separation of amylose from water in the gel formed upon cooling of a starch or flour paste. Low breakdown viscosities are an indication that the starches are stable and could withstand high temperatures (Okorie *et al.*, 2011). This has an influence on peak viscosity, such that lower peak viscosities will be obtained (Okorie *et al.*, 2011), hence making the complementary food thin enough for easy digestion by infants and young children. Low setback viscosities of starches indicate that the products have a lower tendency to retrograde (Babajide and Olowe, 2013). Therefore the complementary foods developed have the potential to form a stable paste hence the less likely the paste formed will separate upon cooling. As a result, when the complementary food is cooked and cooled, there will not be water formed at the surface of the paste; which is a desirable property for foods that needs to cool before consumption. The commercial complementary food had the least of both Breakdown and Setback viscosities (Table 7). Breakdown and setback viscosities are lower than that reported by Ayo-Omogie and Ogunsakin (2013) but higher than that reported by Adepeju *et al*. (2014).

4.7.0 Colour of drum-dried formulations for complementary food

L-values indicate the lightness/whiteness or darkness of the product. It is on a scale of 1 to 100; where 1-50 indicates the darker region and 50-100 indicates the lighter or whiter region (Falade and Olugbuyi, 2010).

Therefore given the L-values of the drum dried formulations, the colour of the product is light or in the whiter region. It ranged from 75.50 to 76.69. No significant differences ($p>0.05$) were observed amongst formulations 1, 2 and 3.

Table 8: Colour of drum-dried complementary food

Formulations	L	a	b	ΔC	ΔE
Sweetpotato flour	85.09±0.24^{a}	-3.66±0.01^{a}	17.36±0.09^{a}		
1(60:10:30)	76.02±0.08^{bc}	-1.26±0.05^{b}	22.00±0.19^{b}	5.59±0.60^{a}	10.66±0.32^{a}
2(60:15:25)	76.69±0.05^{c}	-1.15±0.01^{b}	22.07±0.03^{b}	5.77±0.69^{a}	10.33±0.71^{a}
3(50:15:35)	76.11±0.03^{c}	-0.94±0.03^{b}	21.72±0.01^{b}	5.53±0.63^{a}	10.40±0.22^{a}
4(55:10:35)	75.50±0.03^{b}	-0.81±0.01^{b}	22.19±0.01^{b}	6.02±0.66^{a}	11.24±0.31^{a}

-Values are averages of triplicate determinations -Data is represented as mean ± standard deviation
-Sample ratios are represented as (Orange-fleshed sweetpotato:millet:soyabean)
-Values in same column with different superscripts are significantly different at 95% confidence level

Drum drying relatively reduced the L-values from the initial formulation (Table 5). This may have been as a result of Maillard reaction taking place between proteins and sugars present in the samples (Chin-Lin *et al*., 2003).

The a-values, just like L-values were reduced due to the drum drying, however the colour compared to that before drum drying remains in the green region of the a-b-colour-chart; based on the negative values obtained. The a-values ranged from -0.81 to -1.26 (Table 8). No significant differences (p>0.05) were observed amongst the formulations. The b-value which represents the yellowness (positive values) or blueness (negative values) of a product, also increased compared with the formulations before drum drying (Table 5). The b-values ranged from 21.72 to 22.19 and no significant differences were observed amongst formulations.

In general, the drum drying process increased the redness (indicated by the reduction in avalues after drum drying) and yellowness (indicated by the increase in positive b-values) of the product (Table 8). The level of saturation (delta chrome, ΔC) and colour intensity (ΔE) increased compared to the formulations before drum drying. ΔC ranged from 5.53 to 6.02 while

ΔE ranged from 10.33 to 11.24. This increase in colour saturation and intensity could be as a result of browning which caused a decrease in the lightness or whiteness of the product (Chin-Lin *et al*., 2003).

4.8.0 Panellists' preference of the products developed

The preference of the drum dried complementary food formulated, with reference to all parameters given, was between "neither like nor dislike (3)" and "Like moderately (4)" on the 5-point hedonic scale. Preference for colour of samples was highest in weanimix (the maize-based complementary food) and formulation 4, followed by formulation 3 (Fig 4). The first two formulations, formulation 1 and 2, were relatively the least preferred (Fig 4). The thickness and consistency of the OFSP-based complementary foods were most preferred compared to weanimix (Fig 4).

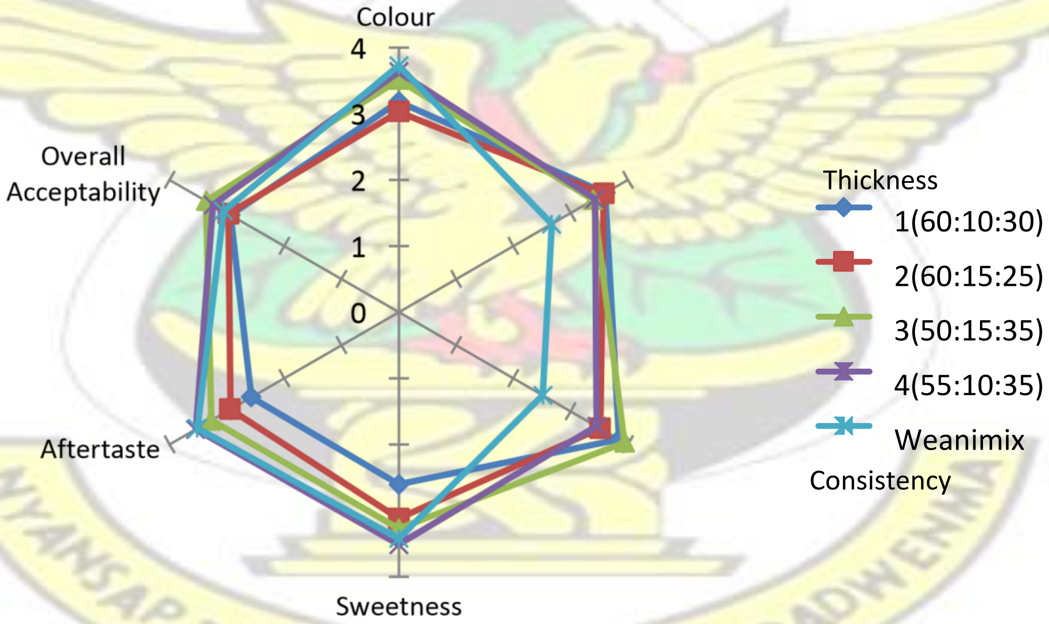

Figure 4: Preference of OFSP-based complementary food compared with weanimix

-Sample ratios are represented as (Orange-fleshed sweetpotato:millet:soyabean)

-Scale: 1-dislike very much, 2-dislike moderately, 3-neither like nor dislike, 4-like moderately and 5-like very much

The OFSP-based complementary food was smoother with suitable thickness for babies compared with weanimix according to panellists. Bonazzi and Dumoulin (2011) have reported that the drum drying process is suitable for the development of complementary foods and baby cereals. Also, according to Mustafa *et al*. (2014) the drum dryer could also be used to develop food products of good sensorial attributes.

The preference for sweetness of the product was highest in formulation 4, weanimix and formulation 3. These were followed by formulation 2, while formulation 1 was the least preferred. A bitter aftertaste was observed by panellists in formulation 1 which may have affected its score for the sweetness. This is confirmed by a positive strong correlation observed between sweetness and aftertaste ($r = 0.795$, $p<0.01$); which implies that even if the sweetness was high enough for the product to be preferred more, the bitter aftertaste becomes stronger and leads to the low rating of the product. The bitterness could have resulted from the heat application to the dough (mixture of flour ingredients for the complementary food and water) and/or interaction between the various flours and ingredients during processing. Also, a bitter compound identified in sweetpotato known as ipomeamarone, which may be induced by dry heat application (Uritani *et al*., 1980) could have been a factor. This compound may have been more distinct in formulations with relatively high sweetpotato content and may have resulted in the relatively least preference for formulations 1 and 2.

In terms of overall acceptability, sample 3 was the most preferred followed by formulation 4, weanimix and then formulations 1 and 2. The bitter aftertaste again resulted in the least preference for formulations 1 and 2. The most important attributes determining the overall acceptability of the products are sweetness ($r = 0.649$, $p<0.01$) and aftertaste ($r = 0.602$, $p<0.01$), from the correlation conducted amongst attributes. The sweetness of the product seems to be the most determining factor, just as was reported by Chin-Feng *et al*. (2014) in his sensory analysis of baked sweetpotato.

4.9.0 Nutrient composition of complementary foods

4.9.1 Proximate and β-carotene composition of complementary foods

The most preferred formulation compared with the control samples (weanimix and the commercial complementary food) had significantly higher amounts of ash, fibre and protein contents. It had a significantly ($p<0.05$) higher ash content (2.71%) compared with weanimix (1.99%) (Table 9). No significant differences were observed between the ash content of the most preferred formulation and the commercial complementary food.

Table 9: Nutrient composition of complementary foods Complementary foods Proximate components

	(50:15:35)	Weanimix	CCF	Sweetpotato flour
Moisture (%)	6.47 ± 0.12^{a}	3.80 ± 0.40^{b}	1.37 ± 0.25^{c}	-
Ash (%)	2.71 ± 0.03^{a}	1.99 ± 0.12^{b}	2.82 ± 0.05^{a}	-
Fat (%)	6.20 ± 0.44^{a}	10.46 ± 2.15^{b}	3.93 ± 0.07^{a}	-
Fibre (%)	1.70 ± 0.07^{a}	1.65 ± 0.19^{a}	1.20 ± 0.08^{b}	-
Protein (%)	16.96 ± 0.60^{a}	15.56 ± 0.24^{b}	14.78 ± 0.20^{b}	-
Carbohydrate (%)	65.95 ± 0.87^{a}	66.55 ± 2.54^{a}	75.91 ± 0.35^{b}	-
β-carotene (mg/100g)	0.53 ± 0.02^{a}	0.15 ± 0.01^{b}	0.33 ± 0.02^{c}	1.11±0.09

-Values are averages of triplicate determinations -Data is represented as mean ± standard deviation
-CCF – Commercial Complementary Food
-Most preferred sample ratio is represented as (Orange-fleshed sweetpotato:millet:soyabean)
-Values in same row with different superscripts are significantly different at 95% confidence level

The presence of ash is an indication of minerals present in the sample (Owiredu *et al*., 2013). The ash is relatively higher than what was reported by Bonsi *et al*. (2014) (1.39–1.98%) and Haque *et al*. (2013) (1.90–2.14%) in their orange-fleshed sweetpotato complementary foods. However, Adenuga (2010) and Amagloh *et al*. (2012b) had relatively higher ash content, 2.80–11.25%, in their sweetpotato-based complementary foods developed. FAO (1990) and FAO/WHO/UNICEF (1972) reported that the ash content of a complementary food should be less than 5%. The most preferred sample therefore meets this standard.

The fat content of the most preferred sample was significantly higher (6.02%) than the commercial complementary food (3.93%) but lower than weanimix (10.46%) (Table 9). A significant difference ($p<0.05$) was observed between weanimix and the other samples. The higher fat content in weanimix could be attributed to the composition of the product; locally the product is often made with maize, soyabean and peanut. The fat content obtained was therefore contributed to by the peanut and soyabeans. The FAO (1990) reports that the fat content of complementary foods should be greater or equal to 12% while FAO/WHO/UNICEF (1972) reports that it should be less or equal to 10%. CAC/GL 08 (1999) also reports that the fat content should be at least 20%. Although the most preferred product was unable to meet these standards, it was higher than sweetpotato-based complementary food reported by Adenuga (2010) (2.40–2.80%) and Bonsi *et al*. (2014) (4.30%).

Protein content of the most preferred sample was significantly higher than weanimix and the commercial complementary food (Table 9). It was able to meet the protein standard of FAO (1990) and FAO/WHO/UNICEF (1972), as well as the CAC/GL 08 (1999) and CAC (2011) standards. Adenuga (2010) however reported relatively higher protein content (31.50– 38.5%). This may have been due to the level of soyabean in his formulation of complementary food. According to Arrage *et al*. (1992) protein quality of food substances are improved upon through the process of drum drying. Although drum drying process reduces some amino acids such as isoleucine and methionine, lysine content is significantly increased. Moreover protein digestibility is improved upon through the process of drum drying (Arrage *et al*. 1992).

Carbohydrate contributes a lot towards energy in complementary foods. Its content could be high but must be digestible enough for infants and young children to obtain the energy required or needed (CAC/GL 08, 1999; CAC, 2011). The carbohydrate content obtained (65.95%) compared with the commercial complementary food (75.91%) was significantly ($p<0.05$) lower but was comparable with that of weanimix (66.55%) (Table 9). Carbohydrate content of the complementary foods were able to meet FAO (1990), CAC/GL 08 (1999) and CAC (2011) standards for carbohydrate. The carbohydrate content was also comparable with what was reported by Bonsi *et al*. (2014) and Haque *et al*. (2013) (42.30–54.5%). However, unlike the most preferred complementary food in this study, the complementary foods by Bonsi *et al*. (2014) and Haque *et al*. (2013) were not pregelatinized, hence might have higher peak times; thus cooking times or time required for the complete gelatinization of the product.

The fibre content of the most preferred complementary foods was low (1.70%) and meets the criteria set by CAC/GL 08 (1999) and CAC (2011); which reports that fibre content should be less than 5%. This is because the presence of high quantities of fibre makes the food bulky and induces flatulence (CAC/GL 08, 1999; CAC, 2011) which is an uncomfortable feeling in infants.

Moreover, digestion of high fibre foods is a difficult task for infants, since their digestive system is not well developed at that stage. The fibre content was lower than what was reported by Amagloh *et al*. (2012) and Adenuga (2010).

β-carotene is essential for the development of infants and young children. In sub-Sahara Africa where vitamin A deficiency continues to be a problem, development of a complementary food with high content of β-carotene is essential. Prevalence of vitamin A deficiency has been reported to be around 35.6% in Ghana (Egbi, 2012).

Dietary sources of vitamin A are key to eradicating vitamin A deficiency in Ghana and Africa as a whole (Amagloh *et al*., 2012a). The β-carotene content of the most preferred sweetpotato-based complementary food was 0.53 mg/100g which was significantly ($p<0.05$) higher than weanimix (0.15 mg/100g) and the commercial complementary food (0.33 mg/100g). The high β-carotene content of the Orange fleshed sweetpotato flour (1.11 mg/100g) contributed to this significant increase (Table 9).

The β-carotene content obtained was higher than what was reported by Haque *et al*. (2013) and Bonsi *et al*. (2014). In both studies, the orange-fleshed sweetpotato was used such that in the studies by Bonsi *et al*. (2014), the formulation with the highest β-carotene content (0.11 mg/100g) had 50% of orange fleshed sweetpotato flour. Difference in variety of the orange fleshed sweetpotato may have resulted in this variation. The *Bohye* variety used in this study is therefore a very good source of β-carotene.

According to Koletzko *et al*. (2008) the recommended daily allowance of vitamin A for infants within the age of 6 months to 3 years is between 350 and 400 µg in a day. Booth *et al*. (2001) also reported 350 µg (0.35 mg) for infants and 400 µg (0.40 mg) for young children in a day. Using the conversion factor of 12 employed by Jaarsveld *et al*. (2005) in their study, the vitamin A content in the complementary food developed is 44.17 µg/100g, which is 11-12.6% of the RDA needed by infants and young children.

Being a complementary food, it will contribute to the nutrients obtained by infants and children in other foods they consumed. The processing methods used, such as the oven drying of the sweetpotato, drum drying and storage may have affected the β-carotene levels hence the low vitamin A content compared to what was reported by Christides *et al*. (2015) in their study of sweetpotato-based complementary food.

4.9.2 Mineral composition of complementary foods

The most preferred sweetpotato-based complementary food had a significantly ($p<0.05$) higher iron and potassium content. The iron content was 1.95 mg/100g which was significantly higher than the values obtained for the control samples (commercial complementary food, 1.75 mg/100g and weanimix, 0.69 mg/100g) (Table 10). Given the iron content of the individual flours, the orange fleshed sweetpotato (OFSP) flour had the highest iron content (2.41 mg/100g). It therefore contributed to the relatively high content of iron in the most preferred orange-fleshed sweetpotato complementary food.

Table 10: Mineral composition of complementary foods

Flour samples	Mineral compositions				
	Ca (mg/100g)	**Fe (mg/100g)**	**Mg (mg/100g**	**K (mg/100g)**	**Zn (mg/100g)**
CCF	86.87 ± 1.53^{d}	1.75 ± 0.05^{b}	233.97 ± 1.20^{c}	52.08 ± 0.50^{a}	3.68 ± 0.07^{d}
Weanimix	1.75 ± 0.73^{a}	0.69 ± 0.02^{a}	236.41 ± 2.10^{c}	48.33 ± 0.08^{b}	2.18 ± 0.05^{c}
Soyabean	25.07 ± 0.97^{c}	1.61 ± 0.11^{b}	380.41 ± 3.30^{d}	96.11 ± 0.77^{c}	6.40 ± 0.03^{e}
OFSP	14.87 ± 0.06^{b}	2.41 ± 0.02^{d}	181.39 ± 8.49^{b}	62.35 ± 0.64^{d}	2.28 ± 0.04^{c}
Millet	2.14 ± 0.62^{a}	0.56 ± 0.02^{a}	58.30 ± 0.39^{a}	34.46 ± 0.04^{e}	1.04 ± 0.04^{b}
OFSPCF	23.91 ± 0.47^{c}	1.95 ± 0.06^{c}	234.81 ± 0.97^{c}	56.87 ± 1.11^{f}	0.89 ± 0.04^{a}
RDI (mg/day)	210 – 500	1.7 – 11	30 – 80	60 – 160	2 – 3

-Values are averages of triplicate determinations -Data is represented as mean ± standard deviation
-OFSP – Orange Fleshed Sweetpotato flour -RDI – Recommended Daily intake (Koletzko *et al*., 2008)
-OFSPCF – Orange Fleshed Sweetpotato complementary food 3(50:15:35) -CCF – Commercial Complementary Food
--Values in same column with different superscripts are significantly different at 95% confidence level

Iron deficiency among infants and young children is common; therefore the need to have enough iron in the diet of infants. It is required for mental and physical well-being of children, and is needed in the synthesis of haemoglobin in the body. The recommended nutrient intake value for iron in infants between ages of 6 months and 3 years is between 1.7 to 11 mg/day

(Koletzko *et al*., 2008). 100 g of the complementary food is therefore enough to meet the Recommended Daily Intake (RDI) of infants.

The potassium content was also 56.87 mg/100g, which was significantly ($p<0.05$) higher than the commercial complementary food and Weanimix (Table 10). This relatively high content of potassium seems to have been contributed by soyabean which had the highest of potassium content compared with sweetpotato flour and millet (Table 10). The range of potassium content recommended in baby formulas for infants is 60-160 mg/100g (Koletzko *et al*., 2008). This is slightly higher than the sweetpotato-based complementary food developed. The infant would therefore need to acquire the difference from other sources such as breast milk or other foods, that is, if he/she is able to consume 100g complementary meal in a day. Besides, the product is a complementary food and is meant to complement breast milk or baby formulas. Potassium is required in the body for regulation of fluid, muscle control and normal functioning of the nerves (Nieman *et al*., 1992).

Magnesium content of most preferred sample was comparable to that of the commercial complementary food and Weanimix. No significant difference ($p>0.05$) was observed amongst the magnesium content of the most preferred sample, the commercial complementary food and Weanimix (Table 10). Magnesium was highest in soyabean flour and may have significantly contributed to the magnesium content of the sweetpotato-based complementary food. Zinc content was however observed to be lower than that of the commercial complementary food and Weanimix. A significant difference ($p<0.05$) was observed amongst these three complementary foods. The zinc content in the sweetpotatobased complementary food was influenced by soyabean. Soyabean had the highest zinc content of 6.4 mg/100g (Table 10).

Calcium content was highest in the commercial complementary food, 86.87 mg/100g, followed by sweetpotato-based complementary food, 23.91 mg/100g and then weanimix, 1.75 mg/100g

(Table 10). Most of the commercial complementary foods are fortified, and that could be a reason for the relatively high calcium and zinc contents observed.

The test product could also be fortified if adopted and being processed at the commercial level. Again, soyabean contributed significantly to the calcium content of the complementary food. The milk powder added could have also contributed to it. The RDI of calcium for infants ranges from 210 to 500 mg/day (Koletzko *et al*., 2008). It can therefore be observed that, besides iron content that orange-fleshed sweetpotato flour contributed to, soybean contributed significantly to the mineral composition of the most preferred complementary food. It is therefore very important to complement root and tuber or cereal flours with legumes such as soyabean to improve upon the mineral content in developing complementary foods.

4.10.0 Microbial levels of most preferred complementary food

The microbial load or levels in the complementary food was low. The Total Plate Count (TPC) was found to be 2.18 $\log_{10}$ cfu/g (Table 10). This was found to be significantly lower ($p<0.05$) than the control sample (weanimix) (Table 11). It was also lower than 2.23 to 3.54 $\log_{10}$ cfu/g reported by Sanoussi *et al*. (2013) in the sweetpotato-based complementary food with a blend of sorghum and soyabean. The standard for TPC in complementary foods should be less than 2.70 $\log_{10}$ cfu/g (CAC, 2008).

Yeast and moulds count was also low. The most preferred sample had 1.99 $\log_{10}$ cfu/g which was significantly ($p<0.05$) lower than weanimix (2.03 $\log_{10}$ cfu/g) (Table 11). Again, it was lower than what was reported by Sanoussi *et al*. (2013) (2.10 to 2.60 $\log_{10}$ cfu/g).

The standard for yeast and mould in complementary foods has been reported to be less than 2.48 $\log_{10}$ cfu/g for ready to eat foods made for infants and 3 $\log_{10}$ cfu/g for foods that require cooking (CAC, 2008).

Table 11: Microbial levels in complementary food developed

Sample	Complementary foods	
	(50:15:35) Log_{10}	Weanimix Log_{10}
Total plate count (cfu/g)	2.18	2.30
Yeast and mould (cfu/g)	1.99	2.03
Coliforms (*E. coli*) (cfu/g)	ND	ND
Staphylococcus aureus (cfu/g)	ND	ND

-Values are averages of triplicate determinations -Data is represented as mean ± standard deviation
-Most preferred sample ratio is represented as (Orange-fleshed sweetpotato:millet:soyabean) -ND – Not Detected
-Values in same row with different superscripts are significantly different at 95% confidence level

E. coli count and that of *S. aureus* was not detected. This conformed to what was reported by Sanoussi *et al*. (2013). More so, the standard for *E. coli* in complementary foods should be 0 as reported by CAC (2008). The low microbial count indicates the most preferred sample is safe for consumption. Tang *et al*. (2003) has reported that the drum drying process can be a clean and hygienic process, thus if all Good Manufacturing Practices are put in place. Also, if there was any form of contamination during the processing, packaging and storage of the raw materials for the formulation of the complementary foods, the heat being applied by the drum drying could reduce the microbial load.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Soyabean had relatively higher protein and fat contents, while orange-fleshed sweetpotato (OFSP) had the highest carbohydrate content. Based on these results, four unprocessed complementary food samples were formulated. The colour of the product was observed to be very light with high L-values (>80) while level of saturation (ΔC) and intensity (ΔE) of the colour compared with OFSP flour was low. The drum drying process however increased the level of saturation and intensity of the colour, with reference to OFSP. Water absorption capacity (WAC) of formulations ranged from 152.5 to 216.7%, swelling index (SP) from 6.65 to 7.73, bulk density (BD) from 0.79 to 0.83 g/ml and solubility from 17.78 to 20.32%. Drum drying reduced the WAC, SP, BD and solubility. Pasting temperatures before and after drum drying were comparable but peak time, peak viscosity, breakdown and setback viscosities were reduced. The most preferred formulation was the blend with 50% OFSP, 15% Millet and 35% Soyabean flours. It had significantly ($p<0.05$) higher protein (16.96%) and β-carotene (0.53 mg/100g) contents than the control complementary foods. Ash and fat were comparable to that of the commercial complementary food. In addition, the preferred test product had a significantly higher iron and potassium content compared with the commercial complementary food and weanimix (another commercially available complementary food). Most of the minerals except iron were contributed to by the soyabean. The product was safe to consume because it was able to meet the microbial standards set by Codex Alimentarius Commission. OFSP flour could be used to develop a complementary food with improved functional, pasting and nutrient properties, when complemented with millet and soyabean flours. This when adopted will help with vitamin A deficiency in Ghana and also increase the utilization of OFSP to help achieve food and nutrient security.

5.2 Recommendations

1. Optimization of the drum drying process conditions (moisture content of dough, temperature and time for drum revolution) in the development of the OFSP-based complementary food.
2. The shelf life study of the most preferred OFSP-based complementary food could be studied.
3. Studies on the use of other orange-fleshed sweetpotato varieties and the use of sweetpotato puree in the development of complementary food through the process of drum drying in comparison to extrusion cooking could be studied.

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APPENDIX A: FORMULAS

Formulas for calculating the proximate and mineral contents Calculation for moisture content

The moisture content was calculated as

$$\% \text{ moisture content} = \frac{Wa - Wb}{Wa - Wc} \times 100$$

Wa = Weight of can + sample
Wb = Weight of can + dried sample
Wc = Weight of can

Calculation for ash content

The ash content of sample was calculated as

$$\% \text{ ash content} = \frac{c - a}{b - a} \times 100$$

a = weight of empty crucible b
= weight of crucible + sample c
= weight of crucible + ash

Calculation for fat content

The fat content of the sample was calculated as

$(A + B) – A = B$ $\quad$ % ether extract = $B/C \times 100$

where A = flask weight, B = ether extract weight, C = sample weight

Calculation for fibre content

It was calculated as

$$\% \text{ crude fibre} = \frac{A – B}{C} \times 100$$

where A = wt. of dry crucible and sample
B = wt. of incinerated crucible and ash C = sample weight.

Calculation for protein content

The nitrogen and protein content was then calculated as

$$\% \text{ Nitrogen} = \frac{(\text{titre - B}) \times N \times 1.401}{\text{Mass of sample}}$$

B= blank, N= normality of acid

% Protein = % nitrogen x factor (6.25)

Mineral content using AAS

The formula for calculating is:

$$\text{Mineral element} = \frac{\text{conc. of element (mg/L)} \times \text{Total volume used (L)}}{\text{Weight of sample (kg)}}$$

Where; total volume used = 250 ml

= 0.25 L

Weight of sample = 1.0 g

= 0.001 kg

Results were expressed in mg/kg.

Phosphorus content was calculated using the formula;

$$P\ (mg/kg) = \frac{\dfrac{\text{Absorbance (nm)}}{\text{Graph factor}} \times \text{Dilution factor} \times \text{Total volume used (ml)}}{\text{Weight of sample (g)}}$$

Where; Absorbance = readings on the spectrophotometer measured in nanometres (nm)

$$\text{Graph factor} = \frac{\text{Sum of Absorbance readings of P standards}}{\text{Sum of concentrations of P standards}}$$

$$\text{Dilution factor} = \frac{\text{volumetric flask used for aliquot (25 ml)}}{\text{Volume of aliquot used (1 ml)}}$$

Total volume used after digestion = 250 ml

Weight of sample = 1.0 g

Formula for calculating β-carotene

$$\beta\text{-carotene (mg/100g)} = \frac{A\ x\ volume\ of\ extract\ x\ 10000}{A^{1\%}_{1cm}\ x\ samle\ weight\ (g)}$$

where A = absorbance
volume of extract = total volume of extract
$A^{1\%}_{1cm}$ = Absorption coefficient of β-carotene in Petroleum Spirit (2592)

Swelling Power and Solubility Index Determinations

$$\textbf{Swelling Power} = \frac{\text{Wt. of sedimented flour paste}}{\text{Wt. of dry flour sample taken}}$$

$$\textbf{Solubility Index} = \frac{\text{Wt. of dried supernatant}}{\text{Wt. of flour sample taken}} \text{ X 100}$$

Water Absorption Capacity

$$WAC(\%) = \frac{y - z}{x} \times 100$$

Where x = Initial weight of (dried) sample taken y = Initial volume of water added z = Volume of supernatant collected y – z = Volume of water retained by the sample after centrifugation **OR**

$$WAC\ (\%) = \frac{y - x}{x} \times 100$$

Where x = Initial weight of (dried) sample y = Weight of wet sample (without supernatant) after centrifugation y – x = Weight of water retained by the sample after centrifugation

NB: In this case, the initial weight (g) of the centrifuge tube needs to be taken prior to the addition of the sample.

Assumption:

✓ Density of distilled water = 1g/cm^3 ✓ This implies that the weight of 1cm^3 1g of distilled water.

Appendix B: Statistical Tables

Statistical tables for the functional and pasting properties

Oneway

ANOVA

bulkdensity

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.003	3	.001	1.127	.377
Within Groups	.012	12	.001		
Total	.015	15			

bulkdensity

Tukey HSD

Sample3	N	Subset for alpha = 0.05
		1
4.00	4	.7874
3.00	4	.8070
2.00	4	.8146
1.00	4	.8271

Sig.		.324

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 4.000.

Oneway

ANOVA SP

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.904	3	.968	19.037	.000
Within Groups	.559	11	.051		
Total	3.463	14			

SP Tukey HSD

Sample4	N	Subset for alpha = 0.05	
		1	2
3.00	4	6.6521	
4.00	4	6.6545	
1.00	4		7.2969
2.00	3		7.7336
Sig.		1.000	.093

Means for groups in homogeneous subsets are displayed. a. Uses Harmonic Mean Sample Size = 3.692.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Oneway

ANOVA

Solubility

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	9.933	3	3.311	2.798	.101
Within Groups	10.652	9	1.184		

Total	20.584	12			

Solubility

Tukey HSD

Sample5	N	Subset for alpha = 0.05
		1
1.00	3	17.7778
2.00	3	18.7421
3.00	4	18.7857
4.00	3	20.3175
Sig.		.064

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.200.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Oneway

ANOVA

WAC

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	13625.000	3	4541.667	9.820	.001
Within Groups	5550.000	12	462.500		
Total	19175.000	15			

WAC Tukey

HSD

Sample6	N	Subset for alpha = 0.05		
		1	2	3
1.00	4	152.5000		
3.00	4	185.0000	185.0000	
2.00	4		205.0000	205.0000
4.00	4			232.5000

Sig.		.196	.571	.316

Means for groups in homogeneous subsets are displayed. a.

Uses Harmonic Mean Sample Size = 4.000.

Oneway

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
PastingT	Between Groups	.565	3	.188	8.370	.034
	Within Groups	.090	4	.022		
	Total	.655	7			
PeakV	Between Groups	3023.375	3	1007.792	83.117	.000
	Within Groups	48.500	4	12.125		
	Total	3071.875	7			
Breakdown	Between Groups	102.375	3	34.125	30.333	.003
	Within Groups	4.500	4	1.125		
	Total	106.875	7			
SetbackV	Between Groups	109.375	3	36.458	32.407	.003
	Within Groups	4.500	4	1.125		
	Total	113.875	7			

PastingT Tukey HSD

Sample7	N	Subset for alpha = 0.05	
		1	2
2.00	2	77.7500	
1.00	2	77.8000	77.8000
4.00	2	78.1500	78.1500
3.00	2		78.4000
Sig.		.170	.053

Means for groups in homogeneous subsets are displayed. a.

Uses Harmonic Mean Sample Size = 2.000.

PeakV Tukey

HSD

Sample7	N	Subset for alpha = 0.05		
		1	2	3
3.00	2	90.5000		
4.00	2		109.0000	
1.00	2			128.0000
2.00	2			142.0000
Sig.		1.000	1.000	.052

Means for groups in homogeneous subsets are displayed. a.

Uses Harmonic Mean Sample Size = 2.000.

Breakdown Tukey

HSD

Sample7	N	Subset for alpha = 0.05		
		1	2	3
3.00	2	8.0000		
4.00	2		12.5000	
1.00	2		14.0000	14.0000
2.00	2			18.0000
Sig.		1.000	.553	.064

Means for groups in homogeneous subsets are displayed. a.

Uses Harmonic Mean Sample Size = 2.000.

SetbackV Tukey

HSD

Sample7	N	Subset for alpha = 0.05	
		1	2
4.00	2	22.0000	
3.00	2	23.0000	
1.00	2	26.0000	

2.00	2		31.5000
Sig.		.064	1.000

Means for groups in homogeneous subsets are displayed. a. Uses Harmonic Mean Sample Size = 2.000.

Statistical Tables for colour determinations

Oneway

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
L	Between Groups	2.664	4	.666	19.340	.000
	Within Groups	.344	10	.034		
	Total	3.008	14			
a	Between Groups	1.415	4	.354	393.122	.000
	Within Groups	.009	10	.001		
	Total	1.424	14			
b	Between Groups	2.918	4	.729	66.147	.000
	Within Groups	.110	10	.011		
	Total	3.028	14			

L

Tukey HSD

Sample	N	Subset for alpha = 0.05

		1	2
C	3	83.8833	
B	3	83.9933	
D	3	84.2667	
A	3	84.3333	
Control	3		85.0867
Sig.		.082	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

a T

ukey HSD

Sample	N	Subset for alpha = 0.05		
		1	2	3
Control	3	-3.6633		
A	3		-3.0200	
D	3			-2.9033
B	3			-2.9000
C	3			-2.8233
Sig.		1.000	1.000	.052

Means for groups in homogeneous subsets are displayed. a.

Uses Harmonic Mean Sample Size = 3.000.

b T

ukey HSD

Sample	N	Subset for alpha = 0.05			
		1	2	3	4
C	3	16.1867			
B	3		16.5367		
D	3			17.0300	
A	3			17.2333	17.2333
Control	3				17.3567
Sig.		1.000	1.000	.200	.619

Means for groups in homogeneous subsets are displayed. a.

Uses Harmonic Mean Sample Size = 3.000.

Oneway

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
AA	Between Groups	1.058	3	.353	23.954	.000
	Within Groups	.118	8	.015		
	Total	1.176	11			
AC	Between Groups	1.368	3	.456	14.809	.001
	Within Groups	.246	8	.031		
	Total	1.615	11			

AA Tukey

HSD

sample2	N	Subset for alpha = 0.05		
		1	2	3
1.00	3	.6561		
4.00	3	.8442	.8442	
2.00	3		1.1230	
3.00	3			1.4428
Sig.		.301	.086	1.000

Means for groups in homogeneous subsets are displayed. a.

Uses Harmonic Mean Sample Size = 3.000.

AC Tukey

HSD

sample2	N	Subset for alpha = 0.05		
		1	2	3
1.00	3	1.0148		
4.00	3	1.1783	1.1783	
2.00	3		1.5685	1.5685
3.00	3			1.8802
Sig.		.676	.098	.210

Means for groups in homogeneous subsets are displayed. a.
Uses Harmonic Mean Sample Size = 3.000.

Statistical Tables for sensory and nutrient determinations

Oneway

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
colour	Between Groups	11.842	4	2.961	1.740	.144
	Within Groups	272.303	160	1.702		
	Total	284.145	164			
thickness	Between Groups	19.455	4	4.864	2.767	.029
	Within Groups	281.212	160	1.758		
	Total	300.667	164			
consistency	Between Groups	42.121	4	10.530	6.718	.000
	Within Groups	250.788	160	1.567		
	Total	292.909	164			
sweetness	Between Groups	16.933	4	4.233	2.366	.055
	Within Groups	286.242	160	1.789		
	Total	303.176	164			
aftertaste	Between Groups	22.339	4	5.585	3.136	.016
	Within Groups	284.909	160	1.781		
	Total	307.248	164			
OA	Between Groups	4.388	4	1.097	.544	.703
	Within Groups	322.424	160	2.015		
	Total	326.812	164			

Correlations

Correlations

		colour	thickness	consistency	sweetness	aftertaste	OA
colour	Pearson Correlation	1	.072	-.084	.072	.130	.079
	Sig. (2-tailed)		.359	.281	.360	.097	.314
	N	165	165	165	165	165	165
thickness	Pearson Correlation	.072	1	.303**	.214**	.183*	.241**
	Sig. (2-tailed)	.359		.000	.006	.019	.002
	N	165	165	165	165	165	165
consistency	Pearson Correlation	-.084	.303**	1	.275**	.261**	.418**
	Sig. (2-tailed)	.281	.000		.000	.001	.000
	N	165	165	165	165	165	165
sweetness	Pearson Correlation	.072	.214**	.275**	1	.795**	.649**
	Sig. (2-tailed)	.360	.006	.000		.000	.000
	N	165	165	165	165	165	165
aftertaste	Pearson Correlation	.130	.183*	.261**	.795**	1	.602**
	Sig. (2-tailed)	.097	.019	.001	.000		.000
	N	165	165	165	165	165	165
OA	Pearson Correlation	.079	.241**	.418**	.649**	.602**	1
	Sig. (2-tailed)	.314	.002	.000	.000	.000	
	N	165	165	165	165	165	165

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Oneway

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
	Between Groups	14975.005	5	2995.001	4067.529	.000
	Within Groups	8.836	12	.736		
Ca	Total	14983.841	17			
	Between Groups	7.957	5	1.591	496.963	.000
Fe	Within Groups	.038	12	.003		
	Total	7.995	17			
	Between Groups	162148.715	5	32429.743	2164.774	.000
Mg	Within Groups	179.768	12	14.981		
	Total	162328.483	17			
	Between Groups	6464.035	5	1292.807	3146.424	.000
	Within Groups	4.931	12	.411		
K	Total	6468.966	17			
	Between Groups	63.380	5	12.676	5632.346	.000
	Within Groups	.027	12	.002		
Z	Total	63.407	17			

Ca Tukey

HSD

f	N	Subset for alpha = 0.05			
		1	2	3	4
2.00	3	1.7523			

5.00	3	2.1397			
4.00	3		14.8697		
6.00	3			23.9090	
3.00	3			25.0710	
1.00	3				86.8737
Sig.		.992	1.000	.580	1.000

Means for groups in homogeneous subsets are displayed. a.

Uses Harmonic Mean Sample Size = 3.000.

Fe Tukey

HSD

f	N	Subset for alpha = 0.05			
		1	2	3	4
5.00	3	.5573			
	3	.6907			
2.00	3		1.6117		
3.00	3		1.7520		
1.00	3			1.9497	
6.00	3				2.4113
4.00					1.000
Sig.		.109	.085	1.000	

Means for groups in homogeneous subsets are displayed. a.

Uses Harmonic Mean Sample Size = 3.000.

Mg Tukey

HSD

f	N	Subset for alpha = 0.05			
		1	2	3	4
5.00	3	58.2973			
4.00	3		181.3940		
1.00	3			233.9730	

6.00	3			234.8187	
2.00	3			236.4050	
3.00	3				380.4123
Sig.		1.000	1.000	.968	1.000

Means for groups in homogeneous subsets are displayed. a.

Uses Harmonic Mean Sample Size = 3.000.

K

Tukey HSD

f	N	Subset for alpha = 0.05					
		1	2	3	4	5	6
5.00	3	34.4580					
2.00	3		48.3320				
1.00	3			52.0763			
6.00	3				56.8747		
4.00	3					62.3453	
3.00	3						96.1123
Sig.		1.000	1.000	1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed. a.

Uses Harmonic Mean Sample Size = 3.000.

Z Tukey

HSD

f	N	Subset for alpha = 0.05				
		1	2	3	4	5
6.00	3	.8857				
5.00	3		1.0387			
2.00	3			2.1847		
4.00	3			2.2790		
1.00	3				3.6830	
3.00	3					6.3983
Sig.		1.000	1.000	.218	1.000	1.000

Means for groups in homogeneous subsets are displayed. a.

Uses Harmonic Mean Sample Size = 3.000.