KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI

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DEPARTMENT OF FOOD SCIENCE AND TECHNOLOGY

DEVELOPMENT OF TWO IMPROVED *AGBOZUME* BISCUITS USING ORANGE-FLESHED SWEETPOTATO PUREE AND COWPEA FLOUR

BY

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Masters of Science in Food Science and Technology

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DECLARATION

I hereby declare that this submission is my own work towards the award of MSc. Food Science and Technology degree 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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DEDICATION

For their loving kindness and unflinching support, I dedicate this thesis report to my parents Mr. and Mrs. Paa Kofi Grant and my lovely siblings.

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With a grateful heart my utmost thanks goes to the Lord Jesus Christ for bringing me this far and being the source of my wisdom and understanding.

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ABSTRACT

Agbozume biscuit is a gluten-free local delicacy made from cassava starch and coconut milk. In spite of its potential to meet the dietary needs of gluten-intolerant individuals, it is produced at the cottage industry level leading to variability in its production processes and quality. The study aimed to understudy the existing process for producing the biscuit and develop two improved forms of the biscuit. The nutrient content of the biscuit was improved by substituting cassava starch (C) up to 50% with orange-fleshed sweetpotato puree (OFSPP) and cowpea flour (CP). Different recipes were developed for the two improved biscuits. Separate consumer preference tests were conducted using a 5-point Hedonic scale to assess the acceptance of the two improved biscuits. Proximate, mineral and beta-carotene was determined for the most preferred improved biscuits. The most preferred formulations were: (80%C: 15%CP: 5% OFSPP) and (50% C: 30% OFSPP: 20% CP). Likeness for the improved biscuits was comparable to the traditional *Agbozume* biscuit. Biscuit with 50%C: 30%OFSPP: 20%CP had the highest amount of crude protein (7.78%), fibre (0.55%), moisture (6.45%), ash (0.89%), iron (22.5mg/100g), potassium (318mg/100g) and magnesium (74.5 mg/100g). Biscuit with 80%C: 5%OFSPP: 15%CP had the highest calcium value (61.5 mg/100g) and the traditional *Agbozume* biscuit (100%C) had the highest fat (17.69%) and zinc content (33.5 mg/100g). The biscuit with 50%C: 30%OFSPP:

20%CP had a beta-carotene content of 13.00µg/g and biscuit with 80%C: 5%OFSPP: 15%CP was 9.44µg/g. The biscuits being gluten-free, if promoted will serve as a good and healthy snack option for gluten-intolerant individuals, young and aged people. It will also enhance the use of orange-fleshed sweetpotato to help achieve food and nutrient security.

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CHAPTER ONE

INTRODUCTION

1.0 BACKGROUND OF STUDY

In recent times, consumers' have an increased interest in snacking options which are healthier, resulting in numerous innovations in relation to nutritious snack production (Hartman Eating Occasions, 2013).

Snacks, may be grouped into various categories including drinks, pastries (cakes), turnovers, fruits, salads and biscuits (Hartman Eating Occasions, 2013). Biscuits, which form the commonest both in Ghana and abroad, have been defined in Hiberno-English and Commonwealth English as a small baked product that would be called either a "cookie" or a "cracker" in the United States and sometimes a "cookie" in English-speaking Canada (Oxford English Dictionary, 2009).

Snacks become more important as a child grows because he/she is unable to wait many hours between the regular schedules of meals (Bobroff, 2004). Parents and guardians must therefore provide snacks appropriate for the child's age and nutritional health. Sweetpotato ranks highly with wheat, rice, maize, barley and cassava as the world's most important food crops and is highly nutritious amongst the other roots and tubers (Kays, 2005). It is high in potassium , with the orange-fleshed variety noted for beta-carotene, a potent source of Vitamin A (Low and van Jaarsveld, 2008). Consumption of these roots is therefore to be encouraged since they are highly nutritious and will therefore serve as a good source of nutrients.

Children, including infants and adults are encouraged to eat more of orange- fleshed sweetpotato in order to be protected against blindness (Kapinga *et al.*, 2011). Besides its β-carotene content, it is also rich in other minor components such as iron, phenolic acid and vitamins B, C, E (Aina *et al*, 2009; Martí, 2000; Picha and Padda, 2009). It has also been considered as a food which is highly functional, low in calories, with anti-diabetic effects (Kusano and Abe, 2000); making it a possible health food.

Cassava (*manihot esculenta*) is a root crop, widely cultivated in tropical countries. Africa produces half of the world's cassava. Since 1960, cassava production has tripled to 87 million metric tonnes per year and the yield has doubled to around 13 tonnes per ha (Nweke, 2005). It serves as one of the major source of dietary food energy for the majority of people living in the sub humid tropics of West and Central Africa, and in the lowland tropics (Echebiri and Edaba, 2008).

Ghana is the sixth largest producer of cassava in the world with more than 14 million metric tonnes produced per year (FAO STAT, 2011), making it one of the most important agricultural commodities in Ghana. According to the Ministry of Food and Agriculture (MoFA) (2005), it stands for 22 % of the Agricultural Gross Domestic Product (GDP) and is considered as a crop that can drive rural and industrial development to generate income for producers, processors, and traders. The crop has been viewed as a means of attaining food security for households and increasing availability of food in Africa (Lebot, 2009).

Cassava is rich in starch, and its flour has been widely examined as a local alternative to wheat flour (Taylor *et al.*, 2006). It is reportedly, consumed by those with celiac disease because it does not contain gluten (Alvarenga *et al.*, 2011). High value and shelf stable cassava products that may offer export opportunities and possibility to earn foreign exchange include cassava starch and High Quality Cassava Flour (HQCF)(Eriksson, 2013).

Starch extracted from cassava roots is used as an important raw material in the food industry and also in the non-food industries for textile, paint, cement, detergents, plywood, and paper (Eriksson, 2013). It has been reportedly used for pharmaceutical purposes as well (Balagopalan, 2002). Some characteristics of cassava starch include high freeze-thaw stability, high paste viscosity and high paste clarity, which are valuable for many industries (Odedina and Adebayo, 2012).

In Ghana, cassava starch is used in the production of a type of biscuit called *Agbozume* biscuit commonly found in the Volta region. This biscuit is mainly associated with the *Ewes* (an ethnic group in Ghana) specifically, the people of Agbozume hence the name *Agbozume* biscuit.

1.1 PROBLEM STATEMENT

Agbozume biscuit is a crispy snack with enormous economic potential but it is common at only select locations in Ghana. It is also being produced at the cottage industry level and the production process is at the discretion of the producers. This has led to variability in its production process and product quality, which needs to be studied and defined. Also, there are limited diversified products from sweetpotato, cowpea and cassava which makes encouraging their consumption challenging.

1.2 JUSTIFICATION

Production methods of the *Agbozume* biscuit under laboratory conditions (a controlled temperature and accurate measurements), and development of improved forms of the biscuit with orange-fleshed sweetpotato puree, and cowpea flour will impact the nutritional quality, and the consistency of the biscuits by providing an alternate, and nutritious biscuit which can also be consumed by gluten-intolerant individuals.

The use of sweetpotato, cowpea and cassava will also help in diversifying their use through value addition by improving the food security and livelihood of farmers and the vast majority of citizens in Ghana and Africa at large.

1.3 MAIN OBJECTIVE

- To understudy the traditional cassava starch (*Agbozume*) biscuit production methods and to develop two improved forms of the cassava starch biscuit

1.3.1 SPECIFIC OBJECTIVES

- To produce the traditional *Agbozume* biscuit under laboratory conditions and develop two improved types using orange-fleshed sweetpotato puree and cowpea flour
- To determine the sensory acceptance and nutrient (proximate, mineral and beta-carotene) composition of the improved biscuits

CHAPTER TWO

LITERATURE REVIEW

2.0 General Overview of Snacks

Snacks are generally eaten by people from various backgrounds and various age groups (Hartman Eating Occasions, 2013). Children, and even adults are usually found nibbling on snacks in between meals at various times of the day. Principal ingredients of snack preparation include wheat flour, fat, sugar and water; while other ingredients include milk, salt, flouring agent and aerating agent (Afework *et al.*, 2016). These ingredients are comparatively expensive because most of them are processed and others imported. Biscuits however could be made from many other ingredients that can serve as cheaper alternatives. Flours produced from various roots and tubers and other food crops could be used in the production of these products. In the today's baking industries, study has shown that biscuits are usually developed from composite flours (Hooda and Jood, 2005).

2.1 Traditional *Agbozume* Biscuit

Traditionally, cassava starch is used in the production of *Agbozume* biscuit in the Volta Region of Ghana (ghanaweb, 2012). The use of cassava starch as a raw material in the production of the biscuit is a very unique method that could be explored for improved biscuit productions. The biscuit is brown in color (Plate 2.1), and noted for its very hard, crunchy nature and unique coconut flavor which may be ascribed to the presence of cassava starch and coconut milk, respectively in its production. Its use thus, encourages the use of cassava, a very common crop in Ghana.

Plate 2.1 Traditional *Agbozume* biscuit packaged for sale

2.2 Cassava as a Crop

Cassava is a dicotyledonous perennial plant that grows in areas with tropical climate and ranges from 1 to 5 m in height (Eriksson, 2013). Although the leaves are edible and often consumed as vegetables, cassava is mainly grown for its starchy tubers, producing 5 to 10 tubers per plant (Nweke, 2005). The crop is traditionally produced in small-scale family farms and mostly processed and consumed at household levels. Cassava is a cheap, readily available and reliable source of carbohydrates, especially in times of famine.

This drought-tolerant crop has historically played an important role for famine prevention in Eastern and Southern Africa (Nweke, 2005). Compared to cereals such as rice, wheat and maize, cassava requires less labour, as well as little water, fertilizer and pesticide input and provides more dietary energy per land unit, as it is one of the most efficient convertors of solar energy (Eriksson, 2013). It is a hardy crop able to grow in dry and nutrient-depleted soils where other crops have failed. It can be grown all year round and can be harvested anytime from 7 up to 18 months after planting (Balagopalan *et al*., 1988).

Research on cassava earlier focused on improved yields, better cultivation practices and crop protection but since 1985, it has encouraged mechanized processing, quality control and new products development (Adebowale *et al.*, 2008). This development has transformed cassava into a commercial cash crop aimed for urban consumers (Nweke, 2005).

2.2.1 Nutritional Profile of Cassava

Cassava roots have been reported to contain about 60-65% moisture, 30-35 % carbohydrates on fresh weight basis and 80-90 % carbohydrates on dry matter basis (Balagopalan *et al*., 1988).

The starch content, representing 80 % of the carbohydrates produced, reaches a peak during the 10th to 11th month after planting although peak starch yield, differs between cassava varieties as observed by Apea-Bah *et al.* (2011). Study has shown that as the crop ages the starch content reduces and the fibrous level increase.

Cassava is a poor source of protein as it contains only 1-3% protein on dry matter basis (Montagnac *et al.*, 2009) and contains very low amount of essential amino acids such as methionine, lysine, tryptophan, phenylalanine and tyrosine (Falade and Akingbala, 2010). A cassava-based diet therefore requires a good amount of protein to prevent nutritional deficiency symptoms (Balagopalan *et al.*, 1988).

2.2.2 Toxic Components in the Cassava Roots

It is well established that cassava is not entirely eaten raw due to the presence of toxic compounds. It contains linamarin and lotaustralin, two cyanogenic compounds which occur in every part of the plant with the highest concentration in the root peel. Although cyanogenic glucosides content of cassava, varies considerably depending on variety, climate and environmental conditions, normal levels may range from 31 to 630 ppm and calculated as mg HCN/kg of fresh cassava root (Eriksson, 2013). Sweet cassava varieties however, often have lower levels of cyanide than bitter varieties although there is no established correlation between the taste and the toxicity (Falade and Akingbala, 2010).

Hydrolyzing enzymes present in the plant, such as linamarase, degrade the cyanoglucosides to hydrogen cyanide (HCN) as soon as the plant tissue is wounded. If the root is ingested without previous processing, acute poisoning may occur due to the release of HCN in the body (Eriksson, 2013). Cyanide affects tissue respiration in mitochondria, as it is a potent inhibitor of oxidase and other important enzymes in the respiratory chain (Balagopalan *et al.*, 1988). Chronic exposure of inadequately processed cassava can lead to diseases such as tropical ataxic neuropathy, goiter and cretinism. However, the toxicity can be reduced to safer levels during traditional processing (Falade and Akingbala, 2010).

2.2.3 Utilization of Cassava in Food Preparation

It is estimated that cassava accounts for 30 % of the daily calorie intake in Ghana and is grown by nearly every farming family (Odedina and Adebayo, 2012). About 30 % of the cassava produced is consumed by the producers themselves. The rest is sold at the market or processed into various types of fermented products, such as *gari* and *agbelima*: the most widely used cassava products in Ghana (MoFA, 2005).

Cassava is also consumed boiled or roasted, along with spices and vegetables. *Fufu* is prepared by pounding the fresh, peeled and boiled cassava roots into a thick and smooth paste (Apea-Bah *et al.*, 2011). The Food Research Institute (FRI) of the Council for Scientific and Industrial Research (CSIR) and other private entrepreneurs have started to produce new convenient foods made from cassava such as *fufu* flours to promote consumption of cassava and add value to the root. The products are popular among Ghanaian consumers although their price is not yet competitive (MoFA**,** 2005)**.**

High value and shelf stable cassava products that may offer export opportunities and possibility to earn foreign exchange include cassava starch and High Quality Cassava Flour (HQCF), which may be processed within 24 hours after the crop is harvested. It is white in colour and is not sour like the traditionally processed cassava flour. The flour does not introduce a bad taste or smell to food and can be combined with wheat flour for use in baked products like cake or bread (IITA, 2005). Cassava starch contains high paste viscosity, high paste clarity and high freeze-thaw stability, which are of industrial benefit (Odedina and Adebayo, 2012).

2.2.4 Alcoholic Cassava Based Beverages

Cassava acts as a substrate for most fermented foods and drinks produced across the globe. In Uganda and some part of South America, fermented drinks like *beiju, banu* and *kasili* are produced from cassava (Lancaster *et al.*, 1982).

In Ghana, Guiness Ghana Limited has a beer named "Ruut", of which, cassava is used as an adjunct. *Mingao* is also a drink consumed in the Amazon Region, it is produced by dissolving fermented starch in boiling water and simmering for some time but flavoured with palm fruits, pineapple or bananas in order to mask the undesirable taste (Balagopalan, 1988)

2.2.4.1 Production Techniques of Some African Cassava Based Foods

A) ***Tiwul:*** in Indonesia, it is produced from *gaplek* (dried cassava), via pulverizing and sieving. The meal is kneaded along with a little water into paste, mixed with sugar and steamed. The gritty material is served as a substitute for rice (Setyona *et al.*, 1991).

B) ***Farina:*** According to Balagopalan (1988), farina is a flour meal produced from cereal or grain but in South America and West Indies it is made from fresh tubers. The pulp is forced through a sieve by pressing in wooden screws and finally, roasted at low temperature. After several months of storage it is consumed in combination with other foods. In Brazil, some cassava varieties (yellow bitter) are usually soaked for about three days before peeling and finally grated. The mash obtained is then mixed with fresh roots and allowed several days to undergo fermentation before it is toasted.

C) ***Attieke****:* in Cameroon, is a meal prepared by peeling the cassava roots, placing them in water and grinding into a paste. After two days of fermenting the paste in a jute sack, it is pressed before removing from the sack, crumbled using the hand and steamed. This product is consumed with meat, vegetable or milk (Balagopalan, 2002).

D) ***Gari:*** it forms a very important part of the diet of many African countries especially Ghana and Nigeria. It is a product from cassava flour which has undergone fermentation and frying (Edem *et al.*, 2001; Kordylas *et al.*, 1990; Oduro *et al.*, 2000). In Zaire and Brazil it is also known as *Farinhade moniaca* (Lancaster *et al.*, 1982). In processing gari, about 83% of the cyanogenic glucosides are detoxified in the final product while 98% of the accumulated cyanide may be lost in the preparation of food like *eba* making it safe for consumption (Mahungwu *et al.*, 1987).

2.2.4.2 Recent Trends In Cassava Food Products

Organizations including FAO and International Institute for Tropical Agriculture (IITA) have recognized the need to introduce affordable local resource in producing common products such as cookies (Falola *et al.*, 2011). Studies have that local crops like sweetpotato, millet and many others can be used in making cookies (Falade and Akingbala, 2008; IITA, 1985).

Researchers at IITA reported that, cassava flour (100%), is an excellent choice in the preparation of baked products such as cookies and doughnuts (Onabalu and Bokanga, 1998). Wheat flour, which is used in the production of most bakery products have become expensive especially in Africa due to high cost of importation (Ukwuru and Egbonu, 2013). This has instigated the use of cassava flour as an alternative, and this has shown to be a good substitute for wheat (Adebayo *et al.*, 2010; Balagopalan *et al.*, 1988; Day *et al.*, 1996).

The Federal Institute of Industrial Research Oshodi (FIIRO), in Nigeria, has produced a new bread product with 20% high quality cassava flour (HQCF) and 80% wheat flour. This product is a suitable substitute for wheat flour in terms of both sensory and nutritional properties (Ukwuru and Egbonu, 2013). This technique has the advantage of eliminating the need for the drying stage in bread production, characterized by high energy consumption. It is therefore, of special interest to bakeries in rural communities in the developing countries where fresh cassava is readily available. In processing cassava flour for making bread, a temperature of about 50°C is required to obtain the desirable flour colour (Ogunsua, 1989). The introduction of composite flour will go a long way in assisting developing countries to save money.

The HQCF has been promoted by the International Institute for Tropical Agriculture (IITA) as a suitable replacement for wheat flour in making meat or fish pies (12.5%); bread (5-20%); as well as other food products from cassava (Abass and Onabolu, 1998). Sensory acceptance scores showed a general acceptability rate by the public when used in the manufacture of baked products (Akinlonu, 2011). Report by Oyewole (2002) and Akinlonu (2011), indicated that

HQCF could be a good source of safe consumable food products, however, suggested that it should be fortified to meet the nutritional demand of everyone so it could be used for nutrition related intervention programs.

2.2.5 Cassava Starch

Starch may be obtained from grain or root crops. It is usually used as food but may be readily converted to other useful products (James and West, 1997; Matsui *et al.*, 2004) like paper textile, adhesives, pharmaceuticals and many others (Daramola and Osanyinlusi, 2005). It is mainly composed of two polysaccharides and plays an important role for the storage of energy in higher plants, especially tubers.

Amylose, the minor component, has a linear structure of α-D-glucopyranose units joined by α (14) D-glucosidic linkages, while amylopectin, with a higher molecular weight, has a branched structure due to the presence of α (1-6) linkages (Balagopalan, 2002). The structural differences of the two polymers give them different properties in aqueous solutions. Amylopectin is more stable due to its branched nature while amylose molecules have a tendency to precipitate spontaneously due to the formation of hydrogen bonds between aligned molecules (Balagopalan *et al.*, 1988).

Cassava starch is of great importance to many industries due to its high paste viscosity, paste clarity, and freeze – thaw stability (Gomes *et al.*, 2005; Nzigamasabo and Ming, 2006; Zaidul *et al.*, 2007). Cassava starch is in two forms; native and modified starch.

Native starches are produced from starch extracted from crops such as cassava, maize and sweet potato. Native starch may be used in the production of noodles (Wang *et al.*, 1993). The native starch obtained retains the original properties of the extracted starch (Ene, 1992). This starch is sold under different grades for food, pharmaceuticals, human and industrial purposes.

For those characteristics, which are maintainable with native starch, modified starch can be used for other industrial applications through a series of techniques, chemical, physical and enzymatic modification (Feuer, 1998). Thus, modified starch is native starch that has been changed in its physical and/or chemical properties. With modified starches, the amylose and amylopectin molecules of the granules have been altered to suit specific industrial purpose such as textile, petroleum, paper pulp and many others (Curvelo *et al.*, 2001; Fringant *et al.*, 1996).

2.3 Sweetpotato as a Crop

Sweetpotato, one of the major roots and tubers, is reportedly the 7th most important food crop in the world (Kays, 2005) but according to the International Potato Centre (CIP), it has become the 6th most important food crop after rice, wheat, potatoes, maize and cassava (CIP, 2013). In developing countries, however, it is the 5th most important crop.

About 105 million metre tonnes of sweetpotato is produced globally each year with developing countries contributing about 95% (CIP, 2013). Asia is currently the largest sweetpotatoproducing region in the world; producing about 90 million metre tonnes annually (CIP, 2013; Peters, 2004).

Sweetpotato is grown across all regions in Ghana except the Western regions (MoFA and SRID, 2012). The major growing region is the Upper East region, with 34.9% of the 131,990 metre tonnes of sweetpotato produced in Ghana. Bawku Municipal was the District with the major production and largest production area. This region also has the largest area of cultivation of sweetpotato (57.7% of the 9,622 Ha production areas).

Other major producing regions are the 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 (MoFA and SRID, 2012).

The entire village of Fiaso in the Brong Ahafo region of Ghana reportedly, 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 incorporate it into newly developed products. This will contribute to value addition of the crop and provide more income for the farmers who would in turn, increase their yield. This could go a long way to help with the attainment of food and nutrient security in Ghana.

2.3.1 Sweetpotato Varieties

Sweetpotato roots are generally classified or differentiated by the colour of their flesh which could be pale yellow, yellow, white, cream, pale orange and purple-fleshed (Kapinga *et al.*, 2011). The indicator as to the amount of β- carotene contained in a particular sweetpotato root is its colour (Dugje, Omoigui, Ekeleme, Kamara, & Ajeigbe, 2009).

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 (Philpott *et al.*, 2004; Steed and Truong, 2008; Teow *et al.*, 2007). The orange-fleshed sweetpotato roots have received a lot of attention due to its high β-carotene content.–This has promoted the release of more varieties to help curb vitamin A deficiency in sub-Saharan Africa.

The International Potato Centre, after researching into the nutritious and economic importance of sweetpotato instituted a project to improve human health and income generation through the development and adoption of new sweetpotato varieties (CIP, 2013). These varieties had enhanced postharvest characteristics and the application of virus cleanup techniques for the production of healthy planting material in low-input subsistence farming systems (CIP, 2013).

In Ghana, the Crops Research Institute of the Council for Scientific and Industrial Research (CSIR-CRI) has developed several varieties of sweetpotato. 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).

Hi-Starch varieties, locally known as *Ogyefo*, *Otoo* and *Apomuden* were also released. These are high yielding, resistant to pests and diseases and good for food and industrial products. *Apomuden* recorded the highest mean fresh tuber yields followed by *Otoo*, *Ogyefo* and HighStarch (CSIR-CRI, 2005). The *Apomuden* variety is an orange-fleshed variety of sweetpotato with more β-carotene compared to the other varieties but high in moisture content (CSIR-CRI, 2005). This implies it may not be economically feasible for the development of flour but ideal for puree or even non-alcoholic beverages.

As a result, 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 (CSIRCRI, 2005). This will enable the processing of an orange fleshed variety of sweetpotato into flour while retaining enough of the β-carotene.

2.3.2 Nutritional Profile of Sweetpotato

Sweetpotato like the other roots and tubers mainly consists of carbohydrates. Total carbohydrates, which are mainly starch (FAO, 2002; Mazzei *et al.*, 1995), make up about 19%- 28% of the root. On dry basis, 86% of the total soluble sugars are glucose, the remainder are fructose and sucrose (Zhang *et al.*, 2002), besides having a significant fiber content.

Sweetpotato root is therefore a major source of energy due to its high carbohydrate content and is also 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 (Aina *et al.*, 2009; MARTÍ, 2000; Picha and Padda, 2009).

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. These anthocyanins act as antioxidants in situ and in vitro within the purple fleshed sweetpoato roots (Philpott *et al.*, 2004).

Vitamin A deficiency is a major problem for children under five and for pregnant and lactating women. Vitamin A deficiency in a serious form can lead to blindness whereas chronic deficiency reduces a child's capacity to fight other diseases. All these may lead to a negative long-term effect on the health of the child (Odebode *et al.*, 2008). It is therefore important to know the potentials of sweetpotato so as to promote its utilization in Ghana.

Beta-carotene is produced in plants and Vitamin A is produced only in animals (including humans). The conversion of beta-carotene to vitamin A after its absorption is controlled naturally. Vitamin

A however, does not exist in plants so there is little danger that over-ingestion of beta-carotene from sources such as sweetpotato could lead to vitamin A toxicity (Booth *et al.*, 2001). In view of this, if excessive amounts of beta-carotene are ingested (which is very unlikely) simply reducing this intake will correct the situation with no lasting toxic effects (Odebode *et al.*, 2008).

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

Sweetpotato is ranked highest in nutritional value amongst other roots and tubers. The consumption of the roots relieves the symptoms of stomach ulcer, inflammed conditions of the colon, haemorrhoids and cancer prevention in glands and organs with epithelial tissue (Teye, 2010). Sweetpotato roots and leaves are also used in folk remedies to treat illnesses such as diarrhea, night blindness and asthma. 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; cardiovascular, 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 lead to food sustainability. The highly acclaimed β-carotene content in the roots could help curb the problem of vitamin A deficiency in Ghana and Africa as a whole. This objectively, strengthens its value as an ingredient for improving *Agbozume* biscuit.

2.3.3 Utilization of Sweetpotato in Food

Sweetpotato is being utilized in various forms in different parts of the world. In the United States of America, the yellow-fleshed variety tubers are commonly cut into large chunks and sealed in cans (Bonsi *et al*., 2014). Sweetpotato may also be dried or fermented into silage to feed livestock. This is a common practice in China, India, the United States, and Taiwan (Scott, 1992; Woolfe, 1992).

In Japan, sweetpotato starch may be used in the production of starch syrup, glucose and isomerized glucose syrup, lactic acid beverages, bread and other confectionaries, as well as distilled spirits called *shochu* (Odebode et al., 2008). Noodles and isomerized saccharides which is used as a sweetener for soft drinks are also made from sweetpotato starch in Japan as well as China and Vietnam (Prain *et al*., 1997).

It can also be used in making *sparri* (coined from 'sweetpotato gari'); grated sweetpotato that is roasted after 1-2 days of fermentation in the same way as *gari* (produced from cassava). The product is as tasty as *gari* and keeps well (Egeonu, 2004).

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 (Tewe *et al*., 2003). Lastly, it is sometimes sliced into chips, dried and fried in vegetable oil. In Ghana, it is usually sliced, fried and eaten with pepper and fish or boiled and eaten with stew.

Confectionaries such as buns, cakes, rolls and puff-puff can be made from parboiled and grated sweet potato dough. Several studies in this area have been conducted in Ghana in the Department of Food Science and Technology of the Kwame Nkrumah University of Science (KNUST). Other studies done in KNUST include investigating the nutritional qualities, physicochemical properties as well as the potential of product diversities from different varieties of sweetpotato. Some of the products include non-alcoholic drinks. Sweetpotato tubers were processed into nonalcoholic beverage flavoured with citrus lime and ginger. Two varieties namely *faara* and *sauti* were used. The beverage from the *faara* variety had a higher vitamin A equivalent (WirekoManu *et al.*, 2010).

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 and in frozen form in the U.S (Kays, 1985; Walter and Schwartz, 1993).

2.3.3.1 Sweetpotato Puree products

According to Sindi *et al.* (2013), consumers' perceptions of some products that were processed using a mix of wheat flour and either sweetpotato puree or sweetpotato flour, and others that were made purely (100%) from wheat flour were studied. They used the orange-fleshed sweetpotato (OFSP) to replace a percentage of wheat flour in various bakery products since it is rich in beta-carotene. They speculated that using orange-fleshed sweetpotato in bakery products and ensuring that they have enough beta-carotene could help minimize the incidences of vitamin

A deficiency especially in sub-Saharan Africa. The use of such products by urban consumers (instead of the less preferred fresh sweetpotato) could help alleviate vitamin A deficiency in children, pregnant women and lactating mothers (Low *et al.*, 2001).

Study conducted in South Africa showed that consumption of 125g of OFSP enhances the vitamin A status of children, and hence can serve as a viable long-term food-based strategy for managing vitamin A deficiency in developing countries (Van Jaarsveld *et al.*, 2005). However, for sweetpotato to be incorporated in the bakery products, processors had to be sure that consumers will either prefer the new products or be indifferent between them and the regular ones made purely from wheat flour. It was also important to ensure that sweetpotato-wheat based products had appropriate characteristics of appearance, aroma, taste and texture, which are key determinants of consumers' sensory acceptability of bakery products (Sindi *et al*., 2013).

Other sensory tests of baked products have found that replacing some basic components changes structure and volume of the crumb (Gujral and Rosell, 2004), its structure and texture (Mezaize *et al.*, 2009). Gujral and Rosell (2004), conducted sensory testing of industrial wheat-sweetpotato processed products that had been formulated for markets in Rwanda. This was critical in ensuring that sufficient demand existed to help pull sweetpotato along the value chain and into the market place. Evaluating and confirming the quality and consumer acceptability of the wheat-sweetpotato processed products, informed the improvement and promotion of the best practices along the value chain, enhancement of capacity of farmers and dissemination of technology for commercial production and supply of quality sweetpotato (Sindi *et al.*, 2013).

In a separate study, Bonsi *et al.* (2014) accessed the acceptability of orange sweetpotato bread. A previous study utilizing orange sweetpotato flour to make the typical Ghana bread found it not to be as moist as the traditionally baked breads in Ghana bread (Aniedu and Agugo, 2010). Hence, there was the need to process such bread and evaluate its acceptability when processed with sweetpotato puree. This was to encourage the promotion of the orange sweetpotato cultivars by farmers, as well as provide food-based fortification (Bonsi *et al.*, 2014).

Results from the study by Sindi *et al.* **(**2013) following sensory analysis, consumer showed high preference for bread made with 30% orange-fleshed sweetpotato puree to that made from 100% wheat. No preference difference was observed between doughnuts and queen cakes made from 100% wheat-flour and those with mix of 60% wheat-flour and 40% OFSP-puree. Biscuits made from a formulation of 40% orange-fleshed sweetpotato puree and 60% wheat-flour was preferred to those made with 100% wheat-flour. Therefore, the orange-fleshed sweetpotato based products were acceptable to Rwandan consumers (Sindi *et al.*, 2013).

A pilot study by Bonsi *et al.* (2014) found the most acceptable bread to be that with the highest percentage (30%) of puree. The bread made with 30% puree was therefore replicated and its acceptability tested among 192 volunteers in three regions of Ghana namely, the Greater Accra, Northern and Volta Regions, which constituted a 33% representation of the ten regions of the country.

The overall acceptability rating of the bread ranged from, 5.77-6.77 (82-97%). The highest (6.77, 97%) was from the Greater Accra region and the lowest (5.77, 82%) from the Northern region. Gender, age, texture and overall acceptability were indicated to be significant ($P<0.05$) after a correlation analysis. Texture was rated to be the lowest (3.87), and this is indicative of a need for locally processed sweet potato puree. The attribute with the highest correlation (0.0314, $P<-0.01$) with overall acceptability was sweetness. From all regions, the mean rating of the bread (6.25, 89%) seemed to indicate that the bread made with 30% orange-fleshed sweetpotato puree is indicative of likeness, and could increase the intake of vitamin A when such bread is consumed in Ghana (Bonsi *et al.*, 2014).

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2.4 Cowpea

Cowpea (*Vigna unguiculata L. Walp.),* is an annual legume also referred to as southern pea, black eye pea and Crowder pea. Cowpea originated from Africa and is widely grown in Africa, Latin America, and South East Asia and in the Southern United States (Davis *et al.*,1991). Like other grain legumes, cowpea is an important foodstuff in tropical and subtropical countries (Chinma *et al.*, 2008) because it is mainly used as a grain crop, a vegetable or fodder for animals.

In Ghana, cowpea covers 156,000 ha but the yields of the crop, however, are among the lowest in the world, averaging 310 kg/ha (Ofosu-Budu *et al.*, 2008). Meanwhile, the crop is one of the widely cultivated legumes, mainly in the savannah and transition zones of Ghana (CRI, 2006).

Cowpea is the second most valued legume in Ghana after groundnut. Ghana has been selfsufficient in cowpea production over the last decade with production outstripping consumption (MoFA, 2009). Cowpea is highly acknowledged for its ability to tolerate drought and its high protein content of about 25% (IITA, 2007), makes it a valuable crop and a good choice crop for satisfying the food security needs of societies.

In Ghana, especially in the rural communities, if cowpeas are demanded in higher quantities, many poor households will benefit immensely in economic terms (Agboka *et al.,* 2015). This will aid in the alleviation of poverty in Ghana and other developing countries.

Some cowpea varieties include *Bengpla,* which is a white seed variety with black eye, *Vallenga* which is red seeded, *Apagbaala* which has a white seed coat with small brown eye and *Marfo-*

Tuya which has a white seed coat with brown eye (SARI, 2012).

Plate 2.2: Different varieties of cowpea marketed in Ghana

Other varieties include: *Asontem*,*Adom, Soronko*, *Asetenapa*, *Nhyira*,*Tona* and *Hewale*.These are varieties released by Crops Research Institute.

2.4.1 Nutritional Benefits of Cowpea

There is reported information on the presence of anti-nutritional factors in cowpea (Olapade and Aworh, 2012), although their concentrations have been shown to be reduced by normal household preparation methods. Cowpea contributes a significant amount of protein and watersoluble vitamins to the African diet.

The cowpea seed is a nutritious component in the human diet as well as the feed of livestock. Cowpea is of major importance to the livelihoods of millions of people in developing countries of the tropics particularly in Asia and Africa (Agboka *et al*., 2015). It is consumed in many forms; its sprouting leaves, green pods and green seeds are used as vegetable and the dry seeds are used in various food preparations. Cowpea is a major source of protein, minerals and vitamins in daily diets and thus it positively impacts the health of consumers (Agboka *et al*., 2015). Nutrients provided by cowpea make it extremely valuable where many people cannot afford proteins from animal sources such as meat and fish (Akpapunam and Sefa-Dedeh, 1997).

2.4.2 Products Developed From Cowpea

There is a demand for less expensive protein-based foods with good nutritional and functional properties, particularly in developing and less developed countries where the supply of animal originated food is limited due to high cost and non-availability (Agboka *et al.*, 2015). Cerealbased foods fortified with protein from legumes have received considerable attention due to its additional nutritional benefit (Agboka *et al.*, 2015)**.** Combination of these cereal products with cheaper and more available plant proteins sources like cowpea can improve the nutritional quality of cereal based foods.

Cowpea is used in diverse ways around the globe for the preparation of salads, casseroles, fritters, bean cakes, curry dishes with ham and rice (Agboka *et al.*, 2015). In Ghana, cowpea is mainly prepared and eaten as a whole meal or part of a meal. It is used in foods such as *koose* (cowpea fritters), *gari* and beans (roasted grated fermented cassava and cooked beans) and *tugbani* (steamed bean cake). It is also used locally in Ghana, for various dishes such as beans stew, '*waakye*', soups, *jollof* rice, 'and some blend it with other legumes such as millet and sorghum for the making of porridge.

In a work by Agboka *et al.* (2015), there was the development of composite cowpea-wheat flour which followed a 3 x 2 factorial design with cowpea-wheat proportions (100%:0%, 75%:25% and

50%:50%) and heat treatments (150°C and 200 °C) as factors. The composite flour produced was then used to produce cake and a sensory evaluation based on ranking for preference was conducted. The composite flour with proportion 50%:50% cowpea: wheat baked at 200°C produced the most preferred cake which was significantly higher ($p < 0.05$) in terms of taste (7.22±2.01) and overall acceptability (7.03±1.82) when compared with the taste (6.67±1.84) and overall acceptability (6.80 ±1.81) of the control (100% wheat flour). The application of this at an industrial level will encourage the use of cowpea, which is a readily available legume for the production of cake.

In another study by Olapade and Adeyemo (2014) cassava and cowpea were processed into flours and used to substitute wheat flour for preparation of cookies. Significant ($p<0.05$) reductions were observed in anti-nutritional factors after baking. Cookies from composite flours showed no significant ($p>0.05$) difference from the control (100% wheat flour cookies) in overall acceptability. This indicates the feasibility of producing nutritious cookies with desirable organoleptic qualities from cassava, wheat and cowpea composite flour.

In a study by Stull and Taylor (1981), the authors developed new food product formulations from whole cowpeas, highly acceptable food products were developed from either mild alkali- treated or dry- roasted cowpea “flours”. These foods included chocolate- flavored puddings, cowpea "butter ", cookies, frozen desserts and bread from wheat /cowpea blends. The use of comparatively simple, inexpensive processing and formulation procedures was a major consideration in the work.

2.5 Coconut, Its Uses and Health Benefits

Coconut (*Cocos nucifera*) is one of the most important fruit trees especially in the tropical and subtropical regions where it is a food source for millions of people hence the name ‘tree of life’ (Chan and Elevitch, 2006). Its palm may have 12 different crops of nuts on it, from opening flower to ripe nut. The world leading producers of coconut are Indonesia, the Philippines and India

(DebMandal and Mandal, 2011). Annual production in India is about 7562 million nuts with an average of 5295 nuts/hectare (NMCE, 2007).

Coconut belongs to the family of the *Arecaceae* (Palmae), the subfamily *Cocoideae*. There are two main varieties of coconut, mainly, tall and dwarf. The tall varieties grow slow and bear fruits 6 to 10 years after planting. Its copra, oil and fibre are of good quality. This type is comparatively hardy, and lives up to a ripe age of 80 to 120 years. As male flowers mature earlier than the female flowers, this type is highly cross-pollinated. Nuts mature within a period of 12 months after pollination (Debmandal and Mandal, 2011).

The dwarf varieties are fast growing and bear early: 4 to 5 years. They are self-pollinated and bear yellow, red, green and orange colored nut. These type require good climatic condition for better yield (NMCE, 2007).

Plate 2.3: Coconut meat

Less matured coconuts are known for their sweet, refreshing juice. The meat of the less matured coconut is thin, soft, and sweet. The mature coconut (Plate 2.3) however has thick, firm meat and is usually used in shredded or grated form, often for baked goods in Ghana and in some parts of the world. In its mature stage, coconut has a chewy texture, a rich nutty flavor and a higher oil content than young coconut (Yong *et al*., 2009). Coconut milk, coconut cream, and coconut oil all extracted from mature coconuts (Vegparadise, 2004).

Coconuts, whose water is to be used for drinking purposes are harvested from green colored coconut palms (Ganguly, 2013a). Coconut water is a product which is highly demanded in the tropics, especially in Africa, Pacific Islands, Southeast Asia, and the Caribbean. In these regions , consumers obtain it in fresh, canned, or bottled forms (Conis, 2011). It is also widely consumed in Ghana, usually in its fresh form. Coconut water serves as a good source of natural mineral especially potassium (Ganguly, 2013b). Also, its low content of carbohydrates, calories, sodium and non-fat content make it in highly demanded by consumers. Its promising health utilities also make it a potential healthy drink for adults and the aged (Yong *et al.*, 2009) .

Coconut cream is another product derived from coconut, but with lower water content comparatively. It is a thick substance which is paste-like and its milk has a consistency that is fluid in nature (Ganguly, 2013a). For the reason that they have a mild sweet taste ,coconut milk and cream are used as ingredients for cooking (Ganguly, 2013b)**.** They are used in the preparation of various dishes and various confectionaries. In desserts and beverage preparation coconut cream is employed as a major ingredient (Ganguly, 2013a)

Creamed coconut is a dehydrated and solid waxy lump of coconut flesh. It is crushed to a white paste which is semi-solid, has a creamy dehydrated consistency and is non-sweet in nature (Ganguly, 2013b). It is sold in a hard white block form which can be stored at room temperature.

It is highly in demand by its consumers because of its very prominent coconut aroma and flavor. In cookery, it is grated or chopped into pieces before it is added to dishes. It can be made into coconut milk or coconut cream by adding warm water to it.

Coconut milk has great importance, especially in Ayurvedic traditional medicinal purposes which is a system of medicine with historical roots in the Indian subcontinent (Meulenbeld, 1999). It is generally used to rule out dehydration losses and to maintain the electrolyte balance. Also, it is known for its therapeutic property especially in the treatment of mouth ulcers (Nneli and Woyike, 2008).

Studies have shown that coconut milk has anti-microbial properties in the gastrointestinal tract, qualities for balancing hyperlipidemia and is useful for topical applications (Campbell-Falck *et al.*, 2000; Paniappan, 2002). In addition, the coconut milk contains auric acid as saturated fat which has medicinal utilities in the cardiovascular system (Mensink *et al.*, 2003). Coconut is a highly valued ingredient, owing to its enormous health benefits. Due to its high lipid and saturated fat content, it is however not encouraged in the diet of patients suffering from hypertension and cardiovascular ailments (Ganguly, 2013a). The great medicinal properties of coconut water and the flesh of the fruit make the fruit of major importance. In Indian and Asian homemade food, the meat of mature coconut is used as a flavoring and texture improving ingredient (Ganguly, 2013b). Traditionally, in the preparation of *Agbozume* biscuit coconut milk is used as a major ingredient.

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CHAPTER THREE

MATERIALS AND METHODS 3.0 Source of Raw Materials

The *Ampong* variety of Cassava and *Hewale* variety of Cowpea were obtained from the farms of the Crops Research Institute (CSIR-CRI), Fumesua-Ghana. The *Apomuden* variety of Sweetpotato was obtained from a farmer in the Volta Region and the matured Coconut and Sugar were obtained from the Kumasi Central Market in Ghana.

3.1 Understudying Of Traditional *Agbozume* Biscuit Production Process

Production steps of the traditional method for *Agbozume* biscuit, was observed and also investigated through oral interviews with 3 major producers (one in Kumasi and two in Agbozume) in the Ashanti and Volta Regions of Ghana respectively.

From observation, to produce 1kg of biscuit, 1.2kg of cassava starch was first decanted and dried. Coconut meat (200g) was cut into rectangular pieces using a sharp knife and grated using a metallic grater. Water (20 ml) was added to it, and a pint of salt (0.36g) was put in a clean pan. Using a clean cheese cloth, 1kg of the grated coconut was squeezed and the milk (870ml) poured into the pan (Plate 3.1). Sugar (350 g) and 1kg of cassava starch were added and mixed by hand until thick dough was formed. The dough was sun-dried for 3 hours.

Biscuits were then moulded by rubbing the dough in the palms into flat round shapes and arranged in seven sets of twelve on a 52cm × 26 cm baking tray and their surfaces were designed with either a fork or an object with a pattern. The biscuit was baked for 1 hour using a gas oven at a temperature of 204°C.

Plate 3.1 Extracted Coconut milk

3.1.1 Preparation of Starch from Cassava

Fresh cassava tubers were weighed, peeled and washed under running water. Peeled cassava was then weighed, grated and blended with a Kenwood blender. Blended cassava was washed through a cheese cloth into buckets. The starch was left to settle. The water was then decanted (Plate 3.2) and starch sun dried until cracks appeared on the surface. Starch was then milled.

Plate 3.2: Decanted starch ready to be dried

3.1.2 Preparation of Cowpea Flour

Cowpea was sorted and soaked in water (Plate 3.3) for 18 hours. It was then de-hulled by palm rubbing and then oven dried at 60°C for 24 hours. The dried cowpea was then milled and sieved using a sieve of 280 microns' particle size.

Plate 3.3: Sorted cowpea soaked in water

3.1.3 Preparation of Sweetpotato Puree

Sweetpotatoes were cleaned and washed. Each tuber was divided into two and wrapped in aluminum foil and baked for 1 hour at 204°C. Sweetpotatoes were then peeled and mashed into a puree using a Kenwood hand mixer at speed 3 for 5 minutes (Plate 3.4).

Plate 3.4: Preparation of sweetpotato puree

3.1.4 *Agbozume* Biscuit Production Method under Laboratory Conditions

Based on the observation, *Agbozume* biscuit was produced under laboratory conditions as shown in Figure 3.1. Cassava starch was extracted in the lab and coconut milk was extracted by cutting coconut into chunks and milled using a Kenwood blender mill. Water (20 ml) was added to the milled coconut. Using a clean cheese cloth, the coconut milk was extracted by squeezing milled coconut.

To prepare biscuit with 100% cassava starch, 100g of cassava starch was weighed into a bowl. A pint of salt (0.36g), sugar (35g) and coconut milk (87 ml) were then added. All ingredients were mixed by hand until dough was formed. The dough was left under the sun for 1 hour 30 minutes to set.

Biscuits were then moulded by rubbing the dough in the palms into flat round shapes and arranged in seven sets of twelve on a 52cm × 26 cm baking tray and a design made on the top with a fork (Plate 3.5). The biscuit was baked for 1 hour 45 minutes at 137.7°C based on simulations, using a gas oven. The baked products were brown in colour (Plate 3.6; see page 42)

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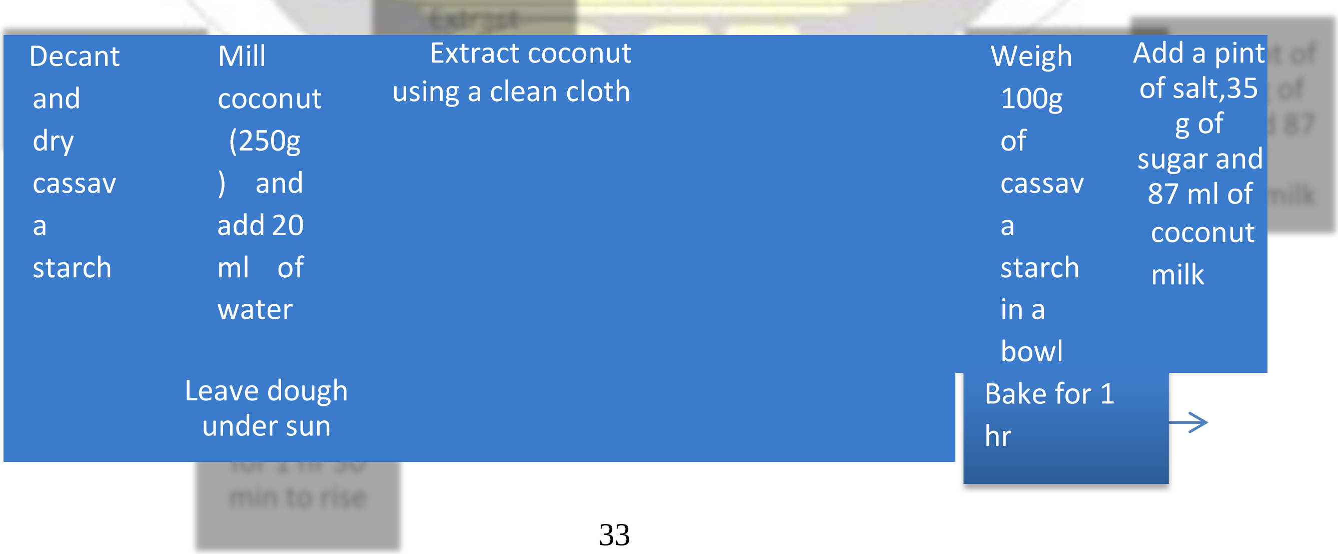
Plate 3.5 Moulded *Agbozume* biscuit ready to be baked



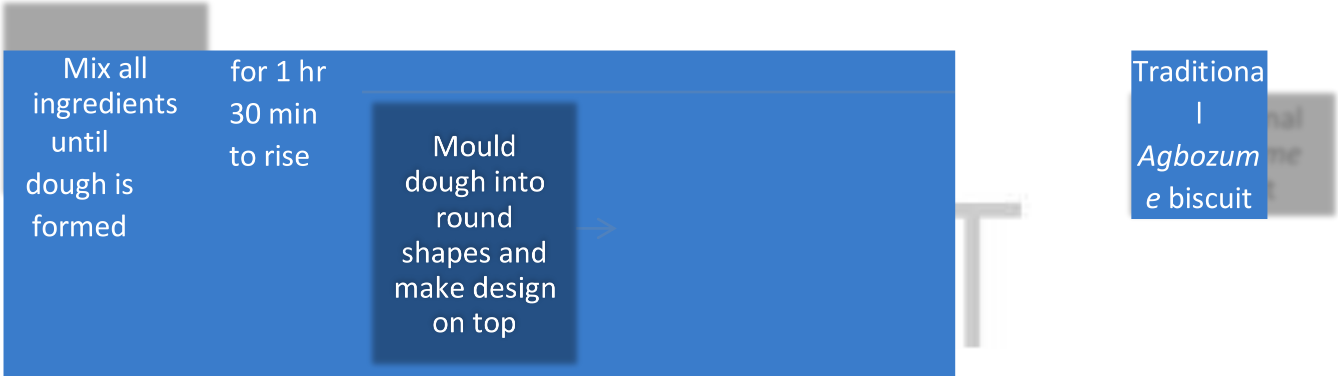


Figure 3.1 Flow diagram showing *Agbozume* biscuit production process under laboratory conditions

Plate 3.6: *Agbozume* biscuit

3.1.5 Formulation of the improved *Agbozume* Biscuits

Various trials were conducted with different formulations (40:35:25, 40:40:20, 50:40:10 and 40:30:30; Cassava starch: Orange-fleshed sweetpotato puree: cowpea flour). Based on these trials, in order to produce an improved biscuit with a high nutrient level, the percentage of substitution with cowpea flour for the first form of improved *Agbozume* biscuit was between 15% and 20%.

That of orange-fleshed sweetpotato puree was between 5% and 10%. Coconut milk was used just like in the traditional recipe of *Agbozume* biscuit.

For the second form of improved *Agbozume* biscuit, the percentage of substitution with cowpea flour was between 10% and 20%. For the orange-fleshed sweetpotato puree, it was between 30% and 35%. In addition, coconut meat which contained milk was used instead of coconut milk only.

The ranges were then subjected to the Mixture Design of Statgraphics Centurion XV.I to obtain a total of four biscuit products from each of the improved forms (Table 3.1; Table 3.2).

Table 3.1: Formulation for the first form of improved *Agbozume* biscuit

Sample code	Cassava starch (g)	Orangefleshed Sweetpotato puree (g)	Cowpea flour (g)	Sugar(g)	Coconut milk(ml)
154	80	5	15	35	50
935	75	10	15	35	50
378	70	10	20	35	50
287	75	5	20	35	50
608	100	0	0	35	50

Table 3.2: Formulation for the second form of improved *Agbozume* biscuit product

Sample code	Cassava starch(g)	Orange-fleshed Sweetpotato puree(g)	Cowpea(g)	Sugar(g)	Coconut meat(g)
463	55	35	10	20	30
189	55	30	15	20	30
727	45	35	20	20	30

535	50	30	20	20	30

3.1.6 Development of Recipe for the first form of improved *Agbozume* Biscuit Production

To prepare biscuit with the formulation of 80% cassava starch: 5% OFSP puree mixture: 15%cowpea flour (Figure 3.2), cassava starch (80g) was weighed into a bowl. Cowpea flour (15g), sugar (35g), sweetpotato puree (5g) and coconut milk (50ml) were added. All the ingredients were then mixed by hand until dough was formed. The dough was sun-dried for 1 hour 30 minutes to set.

The biscuit was then moulded by rubbing the dough in the palms into flat round shapes and a fork used to make designs at the top. They were arranged in four sets of twelve on a 52cm × 26 cm baking tray into round shapes and baked at 137.7°C for 1 hour 30 minutes.

Plate 3.7: First form of improved *Agbozume* biscuit

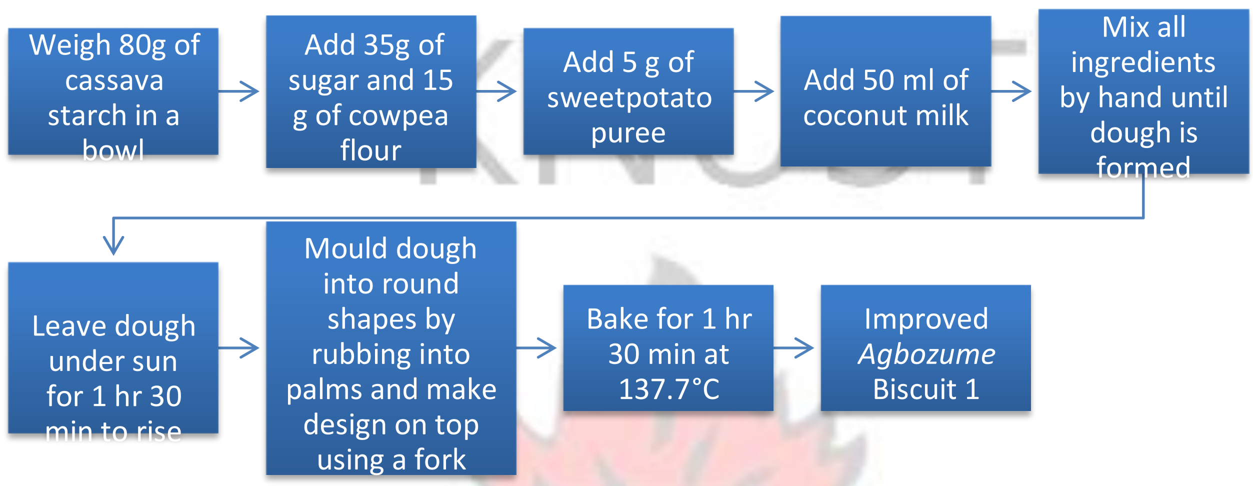


Figure 3.2 Flow diagram showing the first form of improved *Agbozume* biscuit production process

3.1.7 Recipe For the second form of improved *Agbozume* Biscuit Product

To prepare biscuit with the formulation of 50% cassava starch: 30% OFSP puree mixture: 20%cowpea flour (Figure 3.3), 50g of cassava starch was weighed into a bowl. Afterwards, cowpea flour (20g) and sugar (20g) were added. Sweetpotato puree (30g) and milled coconut meat (30g) were also added. All the ingredients were mixed by hand until dough was formed. The dough was left under the sun for 1 hour to set.

Dough was rolled to a thickness of 5mm using a rolling pin with a diameter of 6cm and cut with a round biscuit cutter with a diameter of 4.6cm and arranged individually in a 52cm×26 cm baking tray. Eight biscuits filled the tray .Biscuit was then baked for 45 minutes at 137.7°C.

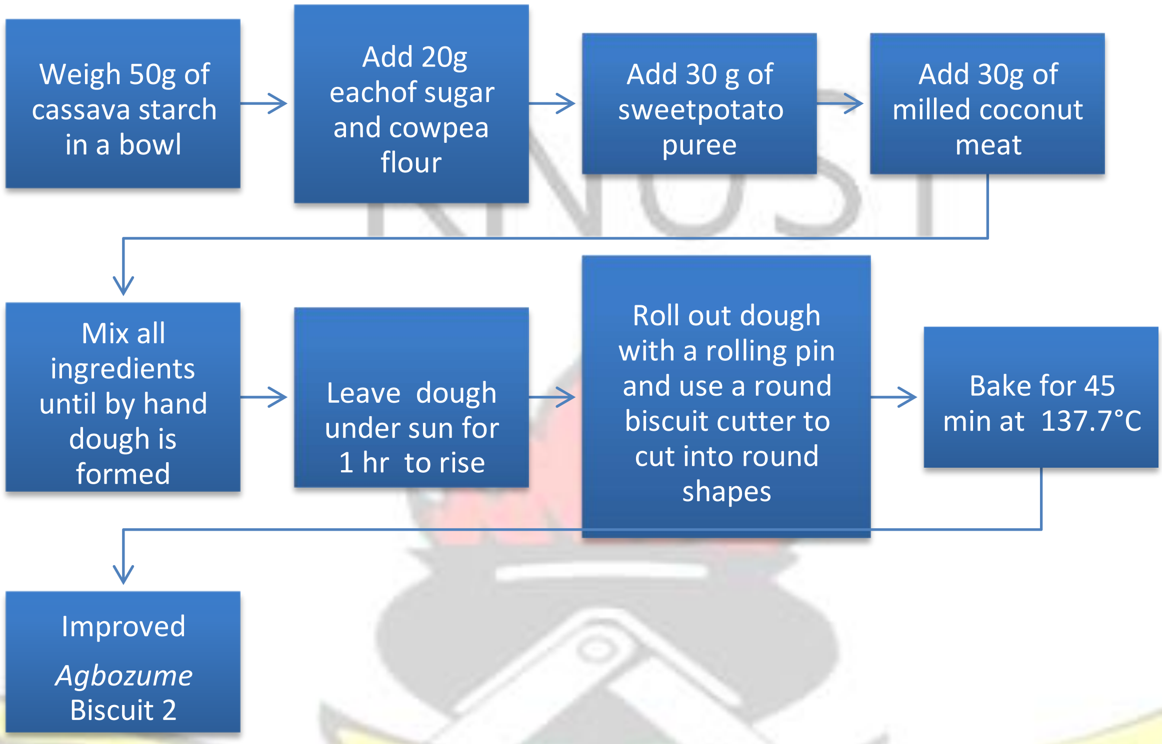


Figure 3.3 Flow diagram showing second form of improved *Agbozume* biscuit production process

Plate 3.8: Cut out shapes of second form of improved *Agbozume* biscuit

3.2.0 Preparation of samples and sensory evaluation

3.2.1. Sensory Evaluation 1

The traditional *Agbozume* biscuit was prepared and used as the control sample for this sensory evaluation. This was a consumer preference sensory evaluation. The formulations of the biscuits used for this evaluation have been given in Table 3.1. This sensory evaluation was conducted amongst people from the Ewe ethnic group of Ghana, who were familiar with the traditional *Agbozume* biscuit. The biscuit samples were served in disposable plates in a random order for panelists to assess. The sensory evaluation was carried out in a classroom (a closed room) at the Evangelical Presbyterian Church School, Afful Nkwanta-Kumasi.

The classroom had adequate lighting from the sun and panelists were seated on individual seats (Plate 3.9). The evaluation was carried out for a day between 8:00am - 12:00pm. The untrained panelists were 52 in number and were asked to assess the coded biscuit samples in terms of colour, hardness, crunchiness, sweetness, aftertaste and overall acceptability using a 5-point Hedonic scale (1-dislike very much and 5-like very much). Water was provided as a palate cleanser.

Plate 3.9: Panelists for the sensory evaluation 1

3.2.2 Sensory Evaluation 2

The formulations of the biscuits used for this evaluation have been given in Table 3.2. This was also a consumer preference sensory evaluation. The biscuit samples were served in disposable plates in a random order for panelists to assess. The sensory evaluation was carried out in a sensory laboratory at the Department of Food Science and Technology, KNUST. The laboratory had adequate lighting from daylight and panelists were seated in individual booths. The evaluation was carried out for a day between 10:00am - 4:00pm. The untrained panelists (people between age 19-33) were 53 in number were asked to assess the coded complementary biscuit samples in terms of likeness for colour, hardness, crunchiness, sweetness, aftertaste and overall acceptability using a 5-point Hedonic scale (1-dislike very much and 5-like very much). Water was also provided as a palate cleanser.

3.3.0 Proximate analysis of Samples

The most accepted sample from sensory analysis 1 and sensory analysis 2 were biscuits made from 80% cassava starch: 5% orange-fleshed sweetpotato puree: 15% cowpea flour and 50% cassava starch: 30% orange-fleshed sweetpotato puree: 20% cowpea flour respectively. These and the traditional *Agbozume* biscuit were packaged in Ziploc bags and processed into powder for analysis.

The proximate analysis was conducted in the Biochemistry laboratory of the Crops Research Institute (CSIR-CRI), Kumasi and was done in triplicate.

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 labeled and weighed, and then 3 g of sample was weighed into the moisture cans. Weighed moisture cans and samples were put in a desiccator 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 desiccator 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 desiccator before use. They were labeled, 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 8 - 25 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 till fat was left in the round bottom flask. It was further dried in a hot air oven, cooled in a desiccator and then weighed (AOAC, 1990).

3.3.4 Crude Fibre Determination

The sample (2.5 g), was weighed into a beaker and washed with petroleum ether 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. Two hundred millimeters (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 a large volume of boiling water until the residue washing was no longer acidic. The filtrate 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 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

The sample (2 g) was weighed and transferred into a digestion tube. A blank was prepared alongside; that is, an empty digestion tube without sample. Concentrated Sulphuric acid (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 (AOAC, 1990).

3.3.5.2 Distillation

After digestion, the tubes were allowed to cool and the content was diluted with a small quantity of distilled water and made up to 100 mL. From the 100 mL digest, 10 mL was pipetted into distillation flasks with the addition of 90 mL distilled water. To the solution, 20 mL of 40% Sodium Hydroxide (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 (AOAC, 1990).

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 Hydrochloric Acid (HCL). A colour change (from green to light blue) was observed and titre values noted (AOAC, 1990).

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 with slight modifications. 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. After, 10 ml of concentrated perchloric acid (70 % $HClO_4$) was added and the digestion continued at 200 °C until the solution was colourless or nearly so. 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. The experiment was done in triplicate.

3.4.1 Determination of minerals (Calcium, Magnesium, Potassium, Zinc and Iron)

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 (AOAC, 2005).

3.5.0 β-carotene determination of improved biscuits and orange-fleshed sweetpotato puree

The β-carotene content of the most preferred improved biscuits and the orange-fleshed sweetpotato puree was determined using the method described by Imungi and Wabule (1990). Two grams of flour sample was weighed into a beaker and then transferred into a mortar. It was then grinded with 50 mL cold acetone.

It was then filtered with suction through a Buchner funnel. The mortar, pestle, funnel and residue were washed 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. Petroleum ether (40 mL) was put into a 500 mL separation funnel with teflon stop-cock after which acetone was added.

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 ml of the reconstituted solution was injected into Shimadzu HPLC equipment. Before sample solution is injected a standard βcarotene 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.

3.6.0 Statistical Analysis of Data

The data obtained from the various tests were analyzed by means of the one-way ANOVA using SPSS at a confidence level of 95%.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 Results from Interviews and Observation of Traditional *Agbozume* Biscuit Producers

There were two oral interviews and one practical session with the traditional *Agbozume* biscuit producers who volunteered to help. The interactions revealed that the production process between the three producers were similar although, all the three producers did not weigh their ingredients but used them at their own discretion. This implies that there were likely to be differences in the quantities of their ingredients since they were not weighed. This could therefore result in differences in the formulation of their biscuits.

4.1 Production of traditional *Agbozume* biscuit under laboratory conditions and two forms of improved *Agbozume* biscuit

The traditional *Agbozume* biscuit was produced under laboratory conditions. Two improved *Agbozume* biscuits were developed. The first form of improved biscuit (improved Biscuit 1) had cassava starch substituted with cowpea flour and orange-fleshed sweetpotato puree up to 30%. The second form of improved biscuit (improved Biscuit 2) also had cassava starch substituted with cowpea flour and orange-fleshed sweetpotato puree up to 55% and it was complimented with milled coconut meat which contained milk instead of coconut milk only.

4.2 Sensory evaluation of First form of improved *Agbozume* biscuit (Sensory evaluation 1)

Figure 4.1 summarizes the results for the sensory evaluation and overall acceptability of the biscuit samples. The traditional *Agbozume* biscuit (100% cassava starch biscuit) served as the control for the sensory evaluation.

Biscuit A, B and E (control) had the highest score (4) for sweetness. Biscuits A and B both contained 15% of cowpea flour but 5% and 10% of orange-fleshed sweetpotato puree, respectively. These combinations may have attributed to the sweetness level of the biscuits. The sweetness of the control was liked probably because panelists were already used to that level of sweetness of the biscuit. The least liked biscuit was biscuit C which contained 20% cowpea flour and 10% orange-fleshed sweetpotato puree.

The crunchiness of all five biscuits had a similar score on the Hedonic scale which corresponded to neither like nor dislike. But the highest ranked was the control (biscuit A) and the least was biscuit C. Its crunchiness level was the least because it had 10% of orange-fleshed sweetpotato puree and 20% of cowpea flour which may have affected the crunchiness level.

colour

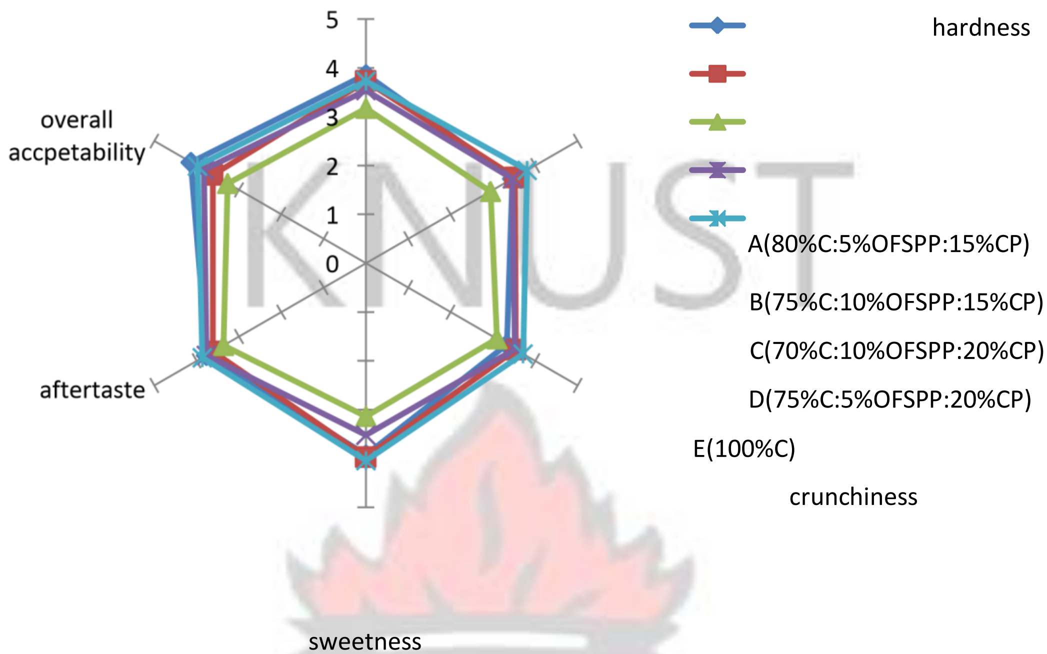


Figure 4.1 Preference of Consumers on First forms of improved *Agbozume* biscuit

Key: 1-dislike very much, 2-dislike moderately, 3-neither like nor dislike,4-like moderately, 5-like very much, C: Cassava, OFSP: Orange-fleshed sweetpotato puree, CP: Cowpea flour

The colour of all the biscuits were in a similar range on the Hedonic scale which was between 'neither like nor dislike' and 'like moderately'. This suggests that the colour of the biscuits were generally acceptable by the panelists. The highest ranked biscuit was biscuit A and the least was biscuit C. The high percentage of orange-fleshed sweetpotato puree (10%) and cowpea flour (20%) in biscuit C resulted in a very brown colour. Panelists did not like this colour as much as the others (Figure 4.1) above.

The hardness of four of the biscuits with the exception of biscuit C were similar as judged by the panelists. The trend observed was that the higher the percentage of cassava starch, the higher the score for hardness. Biscuit C had the least percentage of cassava starch (70%) and had the least score for hardness.

The aftertaste of all 5 biscuits rated between neither like nor dislike and like moderately. The biscuit with the highest score was the control (biscuit E) and the least was biscuit C. It was observed that biscuits with lower substitution of cowpea flour were more preferred.

From Figure 4.1, it was observed that the improved biscuits were generally acceptable to the panelists. Biscuit A had the highest score which corresponded to 'like moderately and like very much' on the scale and the least was biscuit C. Biscuit A was more preferred by panelists to the control .This suggests that this improved biscuit will be accepted by consumers. It had the least substitution of cassava starch (20%) and was therefore the most similar to the control.

There was no significant difference at $p>0.05$ between the most preferred biscuit (biscuit A) and the control (biscuit E) in all the sensory attributes assessed. The proximate, mineral and betacarotene content of the most preferred of this form of improved *Agbozume* biscuit (biscuit with 80% Cassava starch: 5% OFSP puree: 15% Cowpea flour) was then determined.

4.3 Sensory evaluation of Second form of improved *Agbozume* Biscuit (Sensory Evaluation 2)

Figure 4.2 summarizes the results for the sensory evaluation and overall acceptability of the biscuit samples.

Biscuit M had the highest score (4) for sweetness which corresponds to 'like moderately' whereas the other 3 rated between 'neither like nor dislike' and 'like moderately'. Generally, all the biscuits had a high score for sweetness which could be attributed to the high percentage of orange-fleshed sweetpotato puree (30-35%) which is known to be sweet.

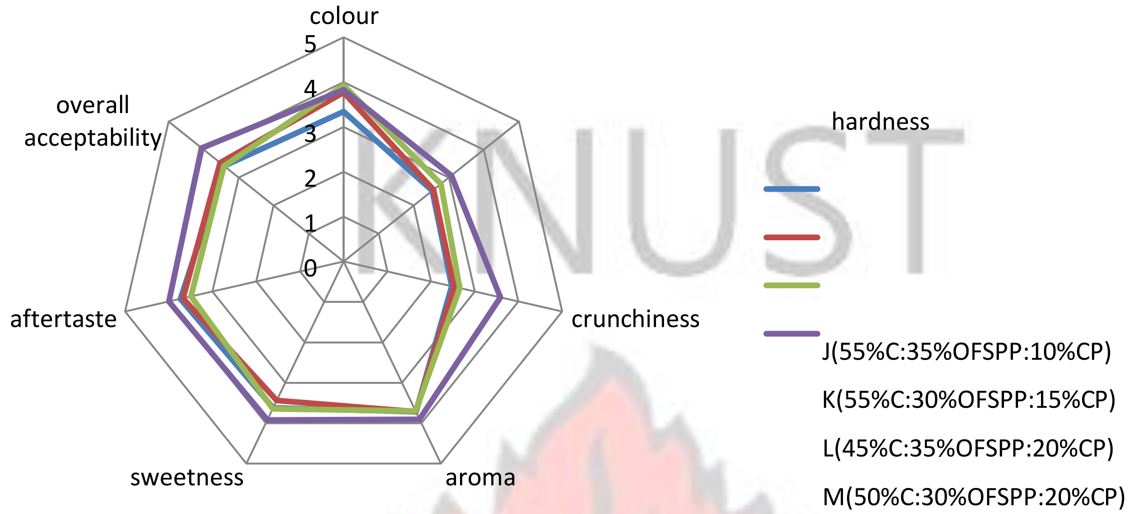


Figure 4.2 Preference of consumers on second form of improved *Agbozume* biscuits

Key: 1-dislike very much, 2-dislike moderately, 3-neither like nor dislike, 4-like moderately, 5-like very much, C: Cassava, OFSP: Orange-fleshed sweetpotato, CP: Cowpea flour

Biscuit M was also the most preferred for the attribute of aroma and crunchiness. The other three biscuits had a similar preference for aroma which was between 'neither like nor dislike' and 'like moderately'. The aroma of the biscuits could be attributed to the high percentage of orangefleshed sweetpotato puree and cowpea flour present in the biscuits. The crunchiness of the three biscuits had low scores on the scale which corresponded to 'dislike moderately' and 'neither like nor dislike'. The crunchiness of the biscuits may have been affected by the high percentage of orange-fleshed sweetpotato puree and also the presence of the milled coconut meat which was fibrous in nature.

Generally, from Figure 4.2 it is observed that all the biscuits had a low score for hardness. Panelists did not seem to like the level of hardness of the biscuits. The observation made was that biscuits with a higher percentage of cassava starch (55%) had the least scores. Therefore the hardness of the biscuit could be attributed to the high percentage of cassava starch present in the biscuits. All the biscuits with the exception of biscuit J had a similar likeness for colour by the panellists. The bright orange colour of the orange-fleshed sweetpotato puree and the light brown colour of the cowpea flour contributed to the colour of the biscuits.

The aftertaste of biscuit M had the highest score 4 which corresponds to 'like moderately'. The other biscuits rated between 'neither like nor dislike' and 'like moderately'. The aftertaste could be attributed to the blend of orange-fleshed sweetpotato puree, cowpea flour and the milled coconut meat.

For overall acceptability, biscuit M scored 4 on the scale which corresponds to 'like moderately' whereas the other biscuits rated between 'neither like nor dislike' and 'like moderately'. The most preferred biscuit was biscuit M. Panelists however recommended a crunchier form of the biscuit M.

The proximate, mineral and beta-carotene content of the most preferred of the second form of the improved *Agbozume* biscuit was then determined.

4.4.0 Proximate Composition of Cassava Starch Biscuit (*Agbozume*) and improved *Agbozume* Biscuits

The proximate composition of the traditional *Agbozume* biscuit (100% cassava starch biscuit), the two improved *Agbozume* biscuits selected, which are improved biscuit 1(80% cassava starch: 5%

orange-fleshed sweetpotato puree: 15% cowpea flour) and improved biscuit 2(50% cassava starch: 30% orange-fleshed sweetpotato puree: 20% cowpea flour) baked in the lab were determined.

It was observed that the improved biscuit 2 had the highest moisture content (6.45%), crude fibre content (0.55%), crude protein content (7.78%) and ash content (0.89 %) (Table 4.1; see page 55). The traditional *Agbozume* biscuit had the highest fat content (17.69 %) and the improved biscuit 1 had the highest carbohydrate content (76.39%). This indicates that increased substitution of cassava starch with orange-fleshed sweetpotato puree and cowpea flour increased the nutritional value of the traditional *Agbozume* biscuit.

The moisture content of the improved biscuit 2 (6.45) was higher than that of biscuit produced by Abayomi *et al.* (2013) from 70% sweetpotato flour and 30% soya bean flour which was 2.13%. The moisture content of the improved biscuit 2 was however lower than that of biscuits produced by Ndife *et al.*(2014) from whole wheat flour and full fat soya bean flour (ranged from 7.24-9.85%). The moisture content reported ranged from 7.24%-9.85%. The moisture content of the improved biscuit 1(4.48%) is similar to that reported by Owiredu *et al.* (2013) for biscuits prepared with soft wheat flour replaced with 30% cashew nut flour (4.4%). The moisture content of the improved biscuit 1 was also lower than that reported by Ndife *et al.* (2014) which ranged from 7.24%-9.85%. These differences observed can be attributed to the different ingredients (sweetpotato flour, soya bean flour, soft wheat flour and cashew nut flour) used for the various biscuits.

The traditional *Agbozume* biscuit had the lowest moisture content (1.30%) and this suggests it will have a long shelf-life since lower moisture content of baked products is critical for prolonging the shelf life (Galić *et al.*, 2009). The two improved biscuits may however have a shorter shelf-life as compared to the *Agbozume* biscuit since high moisture content has been associated with short shelf life of baked products, as they encourage microbial proliferation that lead to spoilage (Akhtar *et al.*, 2008; Elleuch *et al.*, 2011; Ezeama., 2007).

The biscuit with the highest substitution of cassava starch had the highest moisture content (6.45%) and the traditional *Agbozume* biscuit which had 100% cassava starch had the least moisture content (1.30%). Therefore the differences could be attributed to the different percentages of orange-fleshed sweetpotato puree and cowpea flour present in the improved
biscuits.

The traditional *Agbozume* biscuit had the least amount of protein (5.14%), crude fibre (0.13%) and ash (0.33%). There was however no significant difference between the crude fibre and fat contents of the traditional *Agbozume* biscuit and the improved biscuit 1. There was also no significant difference between the crude protein and carbohydrate contents of all three biscuits.

The protein content of the improved biscuit (7.21%) and the improved biscuit 2 (7.78%) were similar to that of a biscuit (7.53%) produced by Ndife *et al*. (2014) which had wheat flour replaced with 20% soybean flour but that of the traditional *Agbozume* biscuit was however lower (5.14%). Contrary to this study however, Abayomi *et al.* (2013) reported a much higher protein content (17.65-21.65%) for their biscuits produced from sweetpotato flour and soybean flour. Their biscuits had sweetpotato flour substituted up to 30% with soybean flour. The protein content of the biscuits increased as the percentage of soybean flour increased. The higher protein content of the biscuits produced by Abayomi *et al.* (2013) may be attributed to the high percentage of soybean flour present in the biscuit.

Proteins are important food components, especially for children since they are needed as building blocks for the body, necessary for growth and for the repair of damaged tissues (Wardlaw, 2004). Children consuming these products will therefore benefit immensely.

The fat content of the traditional *Agbozume* biscuit (17.69%), the improved biscuit 1 (11.13%) and the improved biscuit 2 (9.69%) were higher than that of a biscuit (5.25%) with 70% sweetpotato flour and 30% soybean flour produced by Abayomi *et al.* (2013). These differences could be attributed to the different ingredients (cassava starch, coconut milk, coconut meat, cowpea flour, orange-fleshed sweetpotato puree) used for the biscuits in this study.

Table 4.1: Proximate Composition of the traditional *Agbozume* Biscuit and the two improved *Agbozume* Biscuits

Proximate components	Biscuit samples		
	Tradtional *Agbozume* biscuit	Improved biscuit 2 (50%C:30%OFSPP:20%CP)	Improved biscuit 1 (80%C:5%OFSPP:15%CP)
%Moisture	1.30 (0.08)^{a}	6.45 (0.10)^{c}	4.48 (0.08)^{d}
%Crude fat	17.69 (0.08)^{d}	9.69 (0.40)^{cd}	11.13 (1.34)^{d}
%Crude fibre	0.13 (0.03)^{a}	0.55 (0.06)^{b}	0.21 (0.03)^{ab}
%Crude protein	5.14 (0.13)^{a}	7.78 (1.45)^{a}	7.21 (0.02)^{a}
%Ash	0.33 (0.01)^{a}	0.89 (0.03)^{c}	0.58 (0.00)^{b}
%Carbohydrate	75.42 (0.16)^{c}	74.65 (1.11)^{c}	76.39 (1.25)^{c}

Values are represented as mean (standard deviation).
Values with different superscripts along columns are significantly different at 95% confidence level.
Key: C-cassava starch, OFSPP-orange-fleshed sweetpotato puree, CP-cowpea flour

The crude fibre content of the traditional *Agbozume* biscuit (0.13%), the improved biscuit 1 (0.21%) and the improved biscuit 2 (0.55%) were however lower than biscuits (2.71-8.50%) produced by Srivastava *et al*. (2012) and Ndife *et al*. (2014) which ranged from and 3.29-5.73% . Fibre in food facilitates easy digestion in the colon and reduces constipation (Elleuch *et al.*, 2011; Slavin, 2005).

The improved biscuit 1 had an ash content (0.58%) , the improved biscuit 2 had an ash content (0.89%) and the traditional *Agbozume* biscuit had an ash content (0.33%) which is lower than 2.20-2.57%, reported by Abayomi *et al.*(2013)**.** The presence of ash is an indication of minerals present in the sample (Owiredu *et al.*, 2013). The ash content of the biscuits increased as substitution of cassava starch increased. So the improved biscuit 2 had the highest ash content (0.89%) and the traditional *Agbozume* biscuit was the least. This trend shows an improvement in the ash content of the traditional *Agbozume* biscuit with increased substitution of cassava starch.

The carbohydrate content of the improved biscuit 1 (76.39%) and the improved biscuit 2 (74.65%) were lower than that reported (ranges 64.52-70.32%) by Abayomi *et al.*(2013) but higher than that reported (49.3-59.5%) by Owiredu *et al.* (2013). The high carbohydrate content of the traditional *Agbozume* biscuit (75.42%) and the improved *Agbozume* biscuits suggests a high energy content of the biscuits and high-energy foods tend to have a protective effect in the optimal utilization of other nutrients (Wardlaw, 2004). This means the biscuit will serve as a good source of energy for children and all its consumers.

4.4.1 Mineral Composition of Major Ingredients of the traditional *Agbozume* and improved *Agbozume* Biscuits

The results of the mineral content of the major ingredients of the traditional *Agbozume* and improved *Agbozume* biscuits are presented in Table 4.2 (see page 57). Coconut milk had the highest potassium content (4113 mg/100g), followed by the orange-fleshed sweetpotato puree (3123 mg/100g). The ingredient with the least potassium content was the coconut meat (639 mg/100g). The coconut milk also had the highest amount of calcium (88 mg/100g) and zinc (43mg/100g) whereas the coconut meat had the least calcium content (56 mg/100g) and cowpea flour had the least amount of zinc (20.5 mg/100g). There was no significant difference between the calcium content of the orange-fleshed sweetpotato puree and the cowpea flour at $p<0.05$.

Calcium is needed for development of strong bones (Institute of Medicine Food and Nutrition Board., 2001). There was no significant difference ($p<0.05$) between the zinc content of the orange-fleshed sweetpotato puree(30mg/100g) and coconut meat (31.5mg/100g), which both play important roles in the bowel system (Institute of Medicine Food and Nutrition Board., 2001). The cowpea flour had the highest iron content (75mg/100g) and the orange-fleshed sweetpotato puree had the least (8.3mg/100g). The coconut meat had the highest magnesium content (173.5mg/100g) and cowpea flour had the least (21.5mg/100g).The mineral content of the major ingredients signifies the biscuits' potential as a good mineral source for its consumers.

Table 4.2 Mineral content of major ingredients of the biscuits

Minerals	Samples			
	COC	COC MILK	COP	OFSPP
Iron (mg/100g)	22.25 (0.00)^{a}	55 (0.00)^{d}	75 (0.00)^{c}	8.3 (0.00)^{b}
Zinc(mg/100g)	31.5 (0.00)^{b}	43 (0.00)^{c}	20.5 (0.00)^{a}	30 (0.00)^{b}
Calcium(mg/100g)	56 (0.00)^{a}	88 (0.00)^{b}	65 (0.00)^{c}	64.5 (0.00)^{c}
Magnesium(mg/100g)	173.5 (0.00)^{a}	52 (0.00)^{b}	21.5 (0.00)^{c}	52 (0.00)^{b}
Potassium(mg/100g)	639 (0.00)^{a}	4113 (0.00)^{b}	1418.5 (0.00)^{c}	3123 (0.00)^{d}

Values with different superscripts across columns are significantly different at 95% confidence level.
Key: COC-coconut meat¸ COC milk-coconut milk, COP-cowpea flour, OFSPP-orange-fleshed sweetpotato puree

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4.4.2 Mineral Composition of Cassava Starch Biscuit (*Agbozume*) and improved *Agbozume* Biscuits

The mineral content of the traditional *Agbozume* biscuit and the two improved *Agbozume* biscuits are presented in Table 4.3 (see page 59). The improved biscuit 2 had the highest amount of iron (22.5mg/100g), magnesium (33.5mg/100g) and potassium (318.5 mg/100g). The improved biscuit 1 had the highest calcium content (61.5mg/100g) and the traditional *Agbozume* biscuit had the highest zinc content (33.5mg/100g). The traditional *Agbozume* biscuit had the least potassium content (115mg/100g), calcium content (50.5mg/100g) and magnesium content (12.5 mg/100g).

The iron content of the traditional *Agbozume* biscuit (21.7mg/100g), the improved biscuit 2 (22.5mg/100g) and the improved biscuit 1(18.75mg/100g) is similar to that reported by Laelago *et al.* (2015) in which wheat flour was replaced up to 40% with orange-fleshed sweetpotato flour.

The iron content of biscuit ranged from 10.77 mg/100g to 22.14 mg/100g with biscuit with 40% orange-fleshed sweetpotato flour having the highest iron content (22.14 mg/100g). The high iron content of the traditional *Agbozume* and the improved *Agbozume* biscuits could be attributed to the high iron content of the coconut meat (22.25mg/100g), cowpea (75mg/100g) and coconut milk (55mg/100g). The differences in iron values of the biscuits from that produced by Laelago *et al.* (2015) could be as a result of wheat flour and orange-fleshed sweetpotato flour used for their biscuits.

The World Health Organization (WHO) estimates that approximately half of the 1.62 billion cases of anemia worldwide are due to iron deficiency (WHO, 2008). This deficiency is more common among children and adolescents in food-insecure households than in food-secure households (Brotanek *et al.*, 2007; Eicher-Miller *et al.*, 2009). The traditional *Agbozume* biscuit and the improved *Agbozume* biscuits can therefore serve as a good source of iron complement in gluten-intolerant individuals, children, teenagers and the aged.

Table 4.3 Mineral composition of the traditional *Agbozume* biscuit and the two improved *Agbozume* biscuits

Minerals	Samples		
	Traditional *Agbozume* biscuit	Improved Biscuit 1(80% C:5% OFSPP:15% CP)	Improved Biscuit 2 (50% C:30% OFSPP:20% CP)
Iron (mg/100g)	21.7 (0.00)a	18.75 (0.00)a	22.5 (0.01)a
Zinc(mg/100g)	33.5 (0.00)b	29.05 (0.00)b	13.5 (0.00)a
Calcium(mg/100g)	50.5 (0.00)ab	61.5 (0.00)c	54.5 (0.00)bc
Magnesium(mg/100g)	12.5 (0.00)a	33.15 (0.00)b	74.5 (0.00)c
Potassium(mg/100g)	115 (0.00)c	251 (0.00)a	318.5 (0.00)b

Values with different superscripts across columns are significantly different at 95% confidence level
Key: C-cassava starch, OFSPP-orange-fleshed sweetpotato puree, CP-cowpea flour

The Zinc content of the traditional *Agbozume* biscuit (33.5mg/100g), the improved biscuit 2 (13.5mg/100g) and the improved biscuit 1 (29.05mg/100g) were higher than biscuits made from wheat flour and soya bean flour reported by Ndife *et al.*(2014) which ranged from 2.74mg/100g4.4mg/100g. In the work by Laelago *et al.* (2015), biscuit which was made with 100% orangefleshed sweetpotato flour had a zinc content of 10.54mg/100g which was highest as compared to biscuits from wheat flour substituted with up to 40% with orange-fleshed sweetpotato flour. The high zinc values of the traditional *Agbozume* biscuit and the improved biscuit 1 could be attributed to the high amount (87mL and 50mL respectively) of coconut milk added which had a zinc content of 43mg/100g.

Zinc supports normal growth and development during pregnancy, childhood, and adolescence(Fabris and Mocchegiani, 1995; Sandstead and Maret, 2006) and is required for proper sense of taste and smell (Prasad *et al*., 1997). A daily intake of zinc is required to maintain a steady state because the body has no specialized zinc storage system (Rink and Gabriel, 2000). When zinc deficiency does occur, it is usually due to inadequate zinc intake or absorption, increased losses of zinc from the body, or increased requirements for zinc (Cousins and King, 2005; Hambidge, 1989; Prasad, 1996). People at risk of zinc deficiency or inadequacy need to include good sources of zinc in their daily diets. The traditional *Agbozume* biscuit and the improved *Agbozume* biscuits can serve as a good source of zinc for gluten-intolerant individuals, children and the aged.

The calcium content of the traditional *Agbozume* biscuit (50.5mg /100g), the improved biscuit 2 (54.5mg/100g) and the improved biscuit 1 (61.5mg/100g) were lower than values obtained by Mosha *et al.*(2010) for cassava-wheat crackers(623 mg/100g) and cassava-bean-soybean-wheat cracker 2 (415.22mg/100g). The calcium content of the improved biscuit 2 was similar to biscuits with 70% wheat flour and 30% soybean flour produced by Ndife *et al.*(2014) which was 55.85mg/100g. The low calcium content of the biscuits in this study could be attributed to the low calcium content of its ingredients used (56-88mg/100g) (Table 4.2).

The magnesium content of the improved biscuit 2 (74.5mg/100g) was slightly lower than that reported by Owiredu *et al.*(2013) for biscuit with wheat flour replaced with cashew nut flour up to 30%. The value reported was 79.3 mg/100g. The magnesium content of the improved biscuit 2 was however higher than values reported by Ndife *et al.*(2014).The values ranged from 31.21mg/100g-42.65mg/100g. These biscuits had wheat flour replaced up to 50%. The differences in their values can be attributed to their different compositions. The magnesium value of the improved biscuit 1 (33.5mg/100g) was similar to the report of Ndife *et al.*(2014) whereas that of the traditional *Agbozume* biscuit (12.5mg/100g) was lower.

The high magnesium content of the improved biscuit 2 can be attributed to the high magnesium content of the coconut meat (173.5 mg/100g) and orange-fleshed sweetpotato puree (52mg/100g) since they were major constituents of the biscuit. The biscuit will therefore serve as a good source of magnesium.

The potassium content of the improved biscuit 2 was higher than all the other minerals. The potassium content of the traditional *Agbozume* biscuit (115mg/100g), the improved biscuit 2 (318.5mg/100g) and the improved biscuit 1 (251mg/100g) were lower than reported by Ndife *et al*.(2014) which ranged from 412.47 mg/100g-460.82 mg/100g and Owiredu *et al.*(2013) which ranged from 617mg/100g-990mg/100g. These differences could be attributed to the different ingredients used which were whole wheat flour and soya flour and soft wheat flour and cashew nut flour respectively.

It was observed that the potassium content of the all the biscuit products was higher than the other minerals (Table 4.3). This could be attributed to the high potassium content of coconut milk, orange-fleshed sweetpotato puree and cowpea flour (Table 4.2). The traditional *Agbozume* biscuit had the least potassium content possibly because it was made from cassava starch and coconut milk only whereas the other biscuits were made from cowpea flour and orange-fleshed sweetpotato puree as well which were also high in potassium. Potassium is required in the body for regulation of fluid, muscle control and normal functioning of the nerves (Nieman *et al*., 1992). The biscuits will therefore serve as a good source of potassium.

4.4.3 β-carotene content of the improved *Agbozume* Biscuits and OFSP puree

The β-carotene content of the orange-fleshed sweetpotato puree was 39.9µg/g, the improved biscuit 2 was 13.00µg/g and the improved biscuit 1 was 9.44µg/g as shown in Figure 4.3.

β-carotene is highly reduced when products are dried and baked at higher temperature and extended time (Anjum *et al.*, 2008). This could explain why the β-carotene content of the Improved biscuit 1 had the least amount of β-carotene because it was baked at an extended time(1 hour 30 minutes) than the improved biscuit 2 (45 minutes) though baked at the same temperature (137.7°C). The improved biscuit 2 also had a higher percentage of orange-fleshed sweetpotato puree (30%).

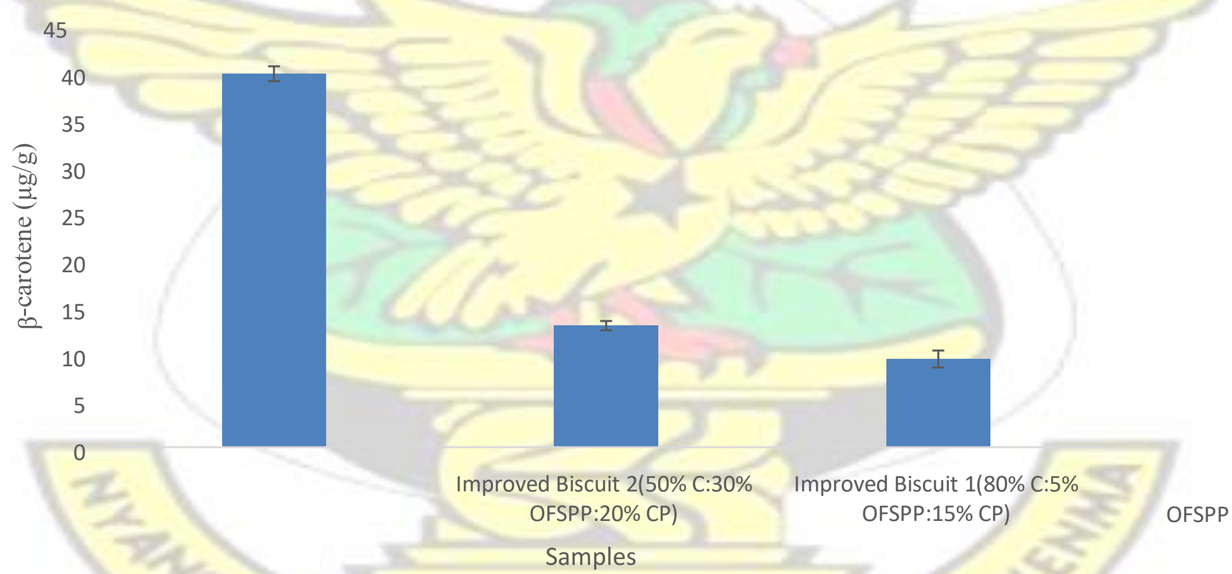

Figure 4.3 β- Carotene content of the improved *Agbozume* biscuits and OFSP puree

Key: C-Cassava starch, OFSPP-Orange-Fleshed sweetpotato puree, CP-Cowpea flour

The β-carotene content of the improved biscuit 2 was similar to the β-carotene content of the biscuit (13.11 μg/g) in which wheat flour was substituted with 40% orange –fleshed sweetpotato flour (Laelago *et al.*, 2015), and but higher than biscuits made by Afework *et al.*(2016) which had wheat flour replaced with 30% orange-fleshed sweetpotato flour baked at different temperatures and times (200 °C for 12 and 15 minutes and at 220°C for 9 and 12 minutes). The β-carotene content of the biscuits was 6.01 μg/g, 3.96 μg/g, 5.55 μg/g and 2.86 μg/g respectively for the different temperatures and times. The β-carotene content of the improved biscuit 1 was also higher than the biscuits produced by Afework *et al.*(2016).

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, the development of a biscuit with high contents of β-carotene is essential. Prevalence has also 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.*, 2012).

The consumption of the improved biscuit 2 and the improved biscuit 1 could reduce Vitamin A deficiency in children, pregnant/lactating women and other consumers in some amounts. βcarotene is a major source and precursor of dietary Vitamin A to human health. The β-carotene from plant sources converted to Vitamin A in the human body is to improve the diet of the population in food based approach (Kapinga *et al.*, 2011). Consumption of vitamin A rich OFSP can provide households with direct access to foods rich in β-carotene and the alleviation of Vitamin A deficiency.

Using the conversion factor of 12 employed by Jaarsveld *et al.* (2005), the vitamin A content in the improved biscuit 2 is 108.33μg/100g and the improved biscuit 1 is 78.70 μg/100g. The improved *Agbozume* biscuits can therefore serve as a good source of vitamin A for glutenintolerant individuals, children, adults and the aged.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.0 Conclusion

Two types of improved *Agbozume* biscuits were produced after understudying the traditional production methods. Starch in the traditional *Agbozume* biscuit was substituted with orangefleshed sweetpotato puree (*apomuden*) and cowpea flour (*hewale*) in both biscuits. However, the first improved form had coconut milk only whereas the second had milled coconut meat which contained milk.

The most preferred biscuit formulations (out of the improved biscuit forms) were biscuits made from 80% cassava starch, 5% orange-fleshed sweetpotato puree and 15% cowpea flour and 50% cassava starch: 30% orange-fleshed sweetpotato puree: 20% cowpea flour.

The improved *Agbozume* biscuits developed were higher in crude protein, crude fibre, potassium, calcium, magnesium and iron in comparison with the traditional *Agbozume* biscuit, with the added advantage of high beta-carotene content. The traditional *Agbozume* biscuit was however higher in fat and zinc in comparison to its improved forms. It also had a high carbohydrate content which will serve as a good source of energy and a low moisture content which could result in a longer shelf-life of the biscuit. The improved biscuit 2(50% cassava starch: 30% orange-fleshed sweetpotato puree: 20% cowpea flour) had the highest amount of potassium, magnesium, iron and beta-carotene. There was also no significant difference at $p>0.05$ between the improved biscuit 1 and the traditional *Agbozume* biscuit (control) in all the sensory attributes assessed

On the whole, the improved *Agbozume* biscuit products will also serve as a good and healthy snack option for gluten-intolerant individuals, children, adults and aged people. Its high content of beta-carotene will help reduce Vitamin A deficiency in Ghana and increase the utilization of the *Apomuden* variety of the orange-fleshed sweetpotato and cassava which will aid in achieving food and nutrient security. The biscuits will be ideal for people of different age groups and most importantly can be consumed by gluten-intolerant people.

5.1 Recommendations

From the study conducted the following recommendations are given.

1. Study the textural characteristics of the improved biscuit 2 (50% cassava starch: 30% orange-fleshed sweetpotato puree: 20% cowpea flour) using different formulations of coconut meat to improve on the crunchiness of the biscuit.
2. The shelf-life of the improved *Agbozume* biscuits could be studied.

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REFERENCES

Abass ,A.B., Onabolu, A.O. and Bokanga,M. (1998). Impact of the high quality cassava flour technology in Nigeria. In: root crops in the 21st century. *Compiled by Akoroda, M.O. & Ngeve, J.M. Proceedings of the 7th Triennial Symposium of the International Society for Tropical Root*.

Abayomi, H. T., Oresanya, T. O., Opeifa, A. O., and Rasheed,T. R. (2013). Quality Evaluation of Cookies Produced from Blends of Sweet Potato and Fermented Soybean Flour. *International Journal of Biological, Biomolecular, Agricultural, Food and Biotechnological Engineering*, *Vol:7*,(No:7,), 642–643.

Adebayo, K., Abayomi, L., Abass, A., Dziedzoave, N.T., Forsythe, L., Hillocks, R.J., Gensi ,R., Gibson, R.W., Graffham, A.J., Ilona, P., Kleih, U.K., Lamboll, R.I, Mahende, G., Martin, A.M., Onumah ,G.E., Orr, A.W., Posthumus, H., Sanni , L.O. and Sandifolo. V. and Westby, A. (2010). Sustainable Inclusion of Smallholders in the Emerging High Quality Cassava Flour Value Chains in Africa: Challenges for Agricultural Extension Services. *Journal of Agricultrual Extension*, *14*(1), 1–10.

Adebowale, A.A., Sanni, L. O. and Onitilo, M. O. (2008). Chemical composition and pasting properties of tapioca grits from different cassava varieties and roasting methods. *African Journal of Food Science.*, *2*, 77–82.

Afework Andualem, Abegaz, K. and Mezgebe, A. G. (2016). Development of pro-vitamin A and energy rich biscuits: Blending of orange-fleshed sweet potato (Ipomea batatas L.) with wheat (Triticum vulgare) flour and altering baking temperature and time. *African Journal of Food Science*, *Vol. 10)*((6), pp. 79–86.

Agboka, J.A., Kpodo, F.M.K., Dzah, C.S. and Mensah, C. (2015). Development and Assessment of Conformance of Cowpea Flour for Cake Production. *International Journal of Nutrition and Food Sciences*, *4*(3), 320–325. http://doi.org/10.11648/j.ijnfs.20150403.19

Aidoo, R., Wireko-Manu, F., Wangel, A., Lassen, A., Neilson, T. and Achampong, S. B. (2014). *Strengthening root and tuber value chains project in Ghana, Report on 1st joint field activities in Ghana(Draft report), DANIDA Roots and Tuber Value Chain Project.*

Aina, A.J., Falade ,K.O., Akingbala, J.O. and Titus, P. (2009). Physicochemical properties of twenty-one sweet potato cultivars. *International Journal of Food Science Technology*, *44,* : 1696–1704.

Akhtar S, Anjum F, Rehman S, S. M. and Farzena, K. (2008). Effect offortification on the physico-chemical and microbiological stability of whole wheat flour. *Food Chemistry*, *112:*, 156–163.

Akinlonu, E. O. (2011). *Nutritional and sensory qualities of novel dishes from cassava. A Dissertation submitted to the Department of Nutrition and Dietetics, College of Food Science and Human Ecology, University of Agriculture, Abeokuta.*

Akpapunam, M.A. and Sefa-Dedeh, S. (1997). Jack bean (Canavalia ensiformis) Nutrition related. Aspects and needed research. *Journal of Plant Food Human Nutrition*, *10*, 123– 127.

Alvarenga, N.B., Lidon, F.C., Belga, E., Motrena, P., & Guerreiro, S., Carvalho, M.J.,and Canada, J. (2011). Characterization of gluten-free bread prepared Maize Seaw, rice and tapioca flours using the hydrocolloid Agar-,. *Eed agar Recent Research Science and Technology.*, *6*, 64 – 68.

Amagloh, F.K. Weber, J.L., Brough, L., Hardacre, A., Mutukumira, A.N. and Coad, J. (2012). Sweetpotato-based complementary food for infants in low-income countries,. *Food and Nutrition Bulletin*, *33*((1):), 3–10.

Ames, B .N. , Shigenaga, M. K. and Hagen, T. M. (1993). Oxidants, Antioxidants, and the Degenerative Diseases of Aging. In *Proceedings of the National Academy of Sciences,Vol. 90,No. 17* (pp. 7915–7922). http://doi.org/doi:10.1073/pnas.90.17.7915

Aniedu, C and Agugo, U. A. (2010). Acceptability of Bread Produced from Hausa- Potato and Sweetpotato composite flours. *JASR*, *10*, 162–166.

Anjum F., Khan B.A., Noreen N., Masood ,T. and Faisal, S. (2008). Effect of boiling and storage on beta-carotene content of different vegetables. *Pakistan Journal of Life and Society of Science.*, *6*.((1):), 63–67.

AOAC. (1990). *Official methods of Analysis*. *Association of Official Analytical Chemists* (15th ed.). Arlington,VA.

AOAC. (2005). Official Methods of analysis. In *Association of Official Analytical Chemists* (18th Editi). Washington DC,USA.

Apea-Bah , F.B., Oduro, I., Ellis , W.O. andSafo-Kantanka, O. (2011). Factor Analysis and Age at Harvest Effect on the Quality of Flour from Four Cassava Varieties. *World Journal of Dairy & Food Sciences 43-54, 6,* 43–54.

Balagopalan , C., Padmaja, G., Nanda, S.K., and Moorthy, S. M. (1988). *Cassava in Food, Feed, and Industry*. CRC Press Inc: Boca Raton, Florida, USA.

Balagopalan, C. (2002). Cassava Utilization in Food, Feed and Industry. In *Cassava: biology, production and utilization* (pp. 301–318). Retrieved from http://www.cabi.org/CABeBooks/default.aspx?site=107&page=45&LoadModule=PDFHier&BookID=94.Kerala,India.

Bobroff, L. (2004). The Benefits of Healthful Snacking, *University of Florida*.

Bonsi, E., Chibuzo, E. and Zibawa, R. (2014). The Preliminary Study of the Acceptability of Ghana Bread Made with Orange Sweet Potato Puree. *Journal of Human Nutrition Food Sci*ence *2*(4), 1045.

Booth, S. L., Johns, T. and Kuhnlein,H.V. (2001). Natural food sources of Vitamin A and provitamin A. In: http://www.unu.edu/unupress/food/8F14le/8F141E05.htm.

Bovell-Benjamin. (2007). Sweetpotato: A review of its past, present and future role in human nutrition. *Advances in Food and Nutrition Research*, *52*, 1–59.

Brotanek ,J.M., Gosz, J., Weitzman ,M. and Flores,G. (2007). Iron deficiency in early childhood in the United States: risk factors and racial/ethnic disparities. *Pediatrics*, *120*, :568–75.

Campbell-Falck, D., Thomas, T., Falck, T. M., Tutuo, N. and Clem, K. (2000). The intravenous use of coconut water. *American Journal of Emergerncy Medicine*, *18*(1), 108–11.

Carey, E. E., V. Hagenimana, K'asambo, L., Oyunga,M.A., Benesi,I., Smit,N., Ocittip'Obwoya,C.,Turymureeba,G., Ndolo,P. J. and Low,J. (1999). Using orange-fleshed sweetpotato varieties to combat Vitamin a deficiency and enhance market opportunities for smallholder farmers in Sub- Saharan Africa. In *Proceedings of the Scientific Workshop of the Southern African Root Crops Research Network (SARRNET), held at Lusaka, Zambia* (p. 476).

Chan, C. and Elevitch, C. R. (2006). Species Profiles for Pacific Island Agroforestry. Retrieved from www.traditionaltree.org[Accessed on November 3,2010]

Chinma, C.E., A. I. C. and E. I. G. (2008). Physicochemical and Functional Properties of Some Nigerian Cowpea Varieties. *Pakistan Journal of Nutrition*, *7*(1), 186–190.

CIP. (2013). *Facts and Figures about sweetpotato.* Retrieved from http://nkxms1019hx1xmtstxk3k9sko.wpengine.netdna-cdn.com/wpcontent/uploads/publication files/fact-sheets-flyer-leaflet/005448.pdf,accessed 11/07/2015.

Conis, E. (2011). Coconut water: A health drink that's all it's cracked up to be? *Los Angeles Times.*

Crops Research Institute. (2006). *Cowpea production guide: Introduction to cowpea production*. Retrieved from http://www.cropsresearch.org/publications/pdf/cowpea_Introduction.pdf.

Curvelo , A.A., De Carvalho , A.J.F and Agnelli, J. A. M. (2001). Thermoplastic starchcellulosic fibers composites: preliminary results. *Carbohydrate Polymers Bark.*, *45*, 183– 188.

Daramola , B. and Osanyinlusi, S. A. (2005). Production, characterization and application of banana (Musa spp.) flour in whole maize. *African Journal of Biotechnology*, *5*(10), 992–995.

Davis , W., Oelke, E.A., Oplinger , E.S., Doll, J.D., Hanson , C.V. and Putman, D. H. (1991). Cowpea. Retrieved from Alternative Field Crop Manual on Cowpea Available at http://www.hort.purdue.edu/newcrop/afcm/cowpea.html

Day , G., Graffham,, J.A. and Amoako, M. (1996). Market potential for cassava based flours and starches in Ghana. Retrieved from NRI Report. Natural Resources Institute, Chatham United Kingdom

DebMandal, M. and Mandal, S. (2011). Coconut (Cocos nucifera L.: Arecaceae): In health promotion and disease prevention. *Asian Pacific Journal of Tropical Medicine*, *4*(3), 241–247. http://doi.org/10.1016/S1995-7645(11)60078-3

Dugje, I. Y., Omoigui, L. O., Ekeleme, F., Kamara, A. Y., and Ajeigbe, H. (2009). Farmers' Guide to Cowpea Production in West Africa.IITA,Ibadan,Nigeria

Echebiri,R.N. and Edaba, M. E. I. (2008). Production and Utilization of Cassava in Nigeria: Prospects for Food Security and Infant Nutrition. *PAT 2008*, *4*(1), 38–52. Retrieved from http://patnsukjournal.net/Vol4No1/p5.pdf

Edem, D.O., Ayatse, J.O.I. and Itam, E. H. (2001). Effect of soy protein supplementation on the nutritive value of "gari" (farina) from Manihot esculenta. *Food Chemistry*, *75*, 57–62.

Egbi, G. (2012). Prevalence of vitamin A, zinc, iodine deficiency and anaemia among 2-10 yearold Ghanaian children,. *African Journal of Food, Agriculture and Nutrition Development*, *12*((2)), : 5946–5958.

Egeonu, I. N. (2004). *Characterisation of 35 sweetpotato (Ipomoea batatas [L.] Lam) accessions in Southwestern Nigeria.* MSc. Project Report, University of Ibadan.

Eicher-Miller. H.A., Mason, A.C., Weaver ,C.M. and McCabe, G.P. and Boushey, C.J. (2009). Food insecurity is associated with iron deficiency anemia in US adolescents. *American Journal of Clinical Nutrition, 90:*, 1358–71.

Elleuch ,M., Bedigian, D., Roiseux ,O., Besbes, S., Blecker,C. and Attia, H. (2011). Dietary fibre and fibre-rich by-products of food processing: Characterisation, technological functionality and commercial applications: *Review on Food Chemistry 124:*, 411–421.

Ene, L. S. O. (1992). Prospects for processing and utilization of root and tuber crops in Africa. In *Proceedings 4th Triennial Symposium, International Society for Tropical Root Crops-Africa Branch Kinshasa, Zaire, December 5–8, 1989* (pp. 23–32).

Eriksson, E. (2013). *Flour from three local varieties of Cassava (Manihot Esculenta Crantz): Physico- chemical properties , bread making quality and sensory evaluation evaluation*. *Faculty of Natural Resources and Agricultural sciences Department of Food Science*

Ezeama, C.F . (2007). Food Microbiology: Fundamentals and Applications. *Natural Prints Ltd. Lagos.*

Fabris ,N.and Mocchegiani. E. (1995). Zinc, human diseases and aging. *Aging (Milano)*, *7*, :77–93.

Falade, K. O., Mnifst, P., Akingbala, J. O., Mift, P., Augustine, S., and Trinidad, T. (2008). Improved Nutrition and National Development Through the Utilization of Cassava in Baked Foods. In J. R. (Eds) Robertson, G.L. & Lupien (Ed.), *International Union of Food Science & Technology* (pp. 1–12).

Falola, A.O., Olatidoye, O.P., Balogun, I.O.and Opeifa, A. O. (2011). Quality characteristics of cookies produced from composite flours of cassava and cucurbita mixta seed. *Journal of Agricultural Veterinary Science*, *3*, 1–12.

FAO. (2002). *Tabla de composiciónquímica de alimentos de América Latina. Oficina Regional para América Latina y el Caribe. [on line]*. Retrieved from http://www.rlc.fao.org/ bases/alimento [22 Dec, 2006].

FAO STAT. (2011). Retrieved from available http://faostat.fao.org/site/339/default.aspx [201301-19]

Feuer, B. I. (1998). Methods of making starch acetate using an acid catalyst. USA Patent no. 5, 710, 269.

Fringant, C., Desvrieres, J.and Rinaudo, M. (1996). Physical properties of acetylated starchbased materials: relation with their molecular characteristics. *Polymer*, *37*(13), 2663–2673.

Galić, K., Ćurić, D. and Gabrić, D. (2009). Shelf Life of Packaged Bakery Goods - A Review. *Critical Reviews on Food Science Nutrition*, *49*((5)), :405–426.

Ganguly, S. (2013a). Coconut , its health benefits and its derivatives as an ingredient in common Asian food. *International Journal of Processing and Post Harvest Technology*, *4*(2), 132–134.

Ganguly, S. (2013b). S. Health Benefits of Coconut in the Asian Cuisines : A Review. *Journal of Biological Chemistry Research.*, *30*(2), 517–21.

GNA. (2002). Sweetpotato variety developed. *General News, Ghana News Agency*. Retrieved from http://www.modernghana.com/news/27112/1/sweet-potato-varietydeveloped.html,retrieved 19th July,2015

Gomes, A., Mendes da Silva, C. and Ricardo, N. (2005). Effects of annealing on the physicochemical properties of fermented cassava starch (polvilho azedo). *Carbohydrate Polymers*, *60*, 1–6.

Gujral, H., and Rosell, C. (2004). "Improvement of the breadmaking quality of rice flour by glucose oxidase. *Food Research Intitute*, *37*(1), 75–81.

Hartman Eating Occasions. (2013). "In what ways has your snacking changed in the past five years?. Hartman group, modern eating studies.USA

Hooda, S.and Jood, S. (2005). Organoleptic and nutritional evaluation of wheat biscuits supplemented with untreated and treated fenugreek flour. *Journal of Food Chemistry*, *90:*, 427–435.

http://www.ghanaweb.com/article2012-06-11).

http://www.vegparadise.com.8/30/2004

International Institute of Tropical Agriculture (1985). *IITA Research Brief*, *6.*(3), 8.

International Institute of Tropical Agriculture (2005). Pre-emptive management of the virulent cassava mosaic disease in Nigeria. Annual report, July 2003-June, 2004. International Institute of Tropical Agriculture, Ibadan, Nigeria.

IITA. (2007). *Cowpea*. Retrieved from Www.iita.org/cms/details/cereal_legumes,

Imungi, J. K. and Wabule, M. N. (1990). Some chemical characteristics and availability of vitamin A and vitamin C from Kenya varieties of papaya. *Ecology of Food and Nutrition Journal* 24, 115-120.

Institute of Medicine Food and Nutrition Board(2001)., Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc (2001). Washington, DC: National Academy Press.

Jaarsveld, P.J.v., Faber, M., Tanumihardjo, S.A., Nestel, P., Lombard, C.J. and Bernade, A.J.S. (2005), β-Carotene–rich orange-fleshed sweet potato improves the vitamin A status of primary school children assessed with the modified-relative-dose-response test, *American Journal of Clinical Nutrition*, 81: 1080-1087.

James, N. and West, L. (1997). Starch modification: challenges and prospects. *Starch/ Starke*, *49*(2), 127–131.

Kapinga R., Lemaga B., Ewell P., Zhang D., Tumwegamiire S., Agili S, and Nsumba,J. (2011). *Increased promotion and evaluation of high β carotene sweetpotato as part of the food based approaches to combat Vitamin A deficiency in sub-Saharan Africa (SSA.*

Kays, S.J. (1985). Sweetpotato products:a natural resource for the tropics. In F. CRC Press, Boca Raton (Ed.), (JC Bouwkam).

Kays, S. J. (2005). Sweetpotato production worldwide: Assessment, trends and the future. In *Acta Horticulturae* (Vol. 670, pp. 19–25).

King,J.C. and Cousins,R.J.. (2006). In: Shils ME, Shike M, Ross AC, Caballero B, Cousins, RJ, eds. Modern Nutrition in Health and Disease. In M. L. W. & W. Baltimore (Ed.), (10th ed., pp. 271–85).

Kordylas, J. M. (1990). *Processing and preservation of tropical and subtropical foods.* London: Macmillan.

Kusano, S. and Abe, H. (2000). Antidiabetic activity of white skinned sweetpotato(Ipomoea batatas L.) in obese Zucker fatty rat. *Biological Pharmacology*, *23*(1), 23–26.

Laelago,T., Haile, A.and Fekadu. T. (2015). Production and Quality Evaluation of Cookies Enriched with β-Carotene by Blending Orange-Fleshed Sweet Potato and Wheat flours for Alleviation of Nutritional Insecurity. *International Journal of Food Science and Nutrition Engineering*, *5*((5)), 209–217.

Lancaster , P.N., Ingram , J.S., Lin , H.Y. and Coursey, D. G. (1982). Traditional Cassava Based Foods, Survey of Processing Techniques. *Economic Botany*, *36*, 12–25.

Lebot, V. (2009). The Tropical Root and Tuber Crops: Cassava, Sweet Potato, Yams and Aroids. In *CABI Crop Production Science in Horticulture*, (p. 420 p). Cambridge, UK.: CABI Publishing.

Low, J. W.and van Jaarsveld, P. J. (2008). The potential contribution of bread buns fortified with ??-carotene-rich sweet potato in Central Mozambique. *Food and Nutrition Bulletin*, *29*(2), 98–107. http://doi.org/10.1177/156482650802900203

Low, J., Walker, T., and Hijmans., R. (2001). The potential impact of orange-fleshed sweetpotatoes on vitamin A intake in Sub-Saharan Africa. *The VITAA Project, Vitamin A and Orangefleshed Sweetpotatoes in Sub-Saharan Africa 2001.*

Mahungwu, N.M., Yamaguchi , Y., Almazan, A.M. and Hatin, S. . (1987). Reduction of cyanide during processing of cyanide of cassava into some traditional African foods. *Journal of Food Agriculture*, *1*, 11–15.

Maret W, Sandstead HH. (2006) Zinc requirements and the risks and benefits of zinc supplementation. *Journal of Trace Elements in Medicine and Biology 20*:3-18. [Pubmed abstract]

Martí, H. (2000). Calidadesculinaria y nutritiva de la ba- tata. INTA, EstExpAgropec San Pedro [on line]. Retrieved from Available in http://www.inta.gov.ar/sanpedro/info/doc/hor/

Matsui , K.N., Larotonda, F.D.S., Paes, S.S., Luiz, D.B., Pires, A.T.N. and Laurindo, J. (2004). Cassava bagasse-Kraft paper composites: analysis of influence of impregnation with starch acetate on tensile strength and water absorption properties. . *Carbohydrate Polymers*, *55*, 237–243.

Mazzei, M.E., Puchulu , M.and Rochaix, M. A. (1995). *Tabla de composiciónquímica de alimentos*, CENEXA, Buenos Aires.

Mensink, R. P., Zock,P.L,Kester, A.D and Katan,M.B . (2003). Effects of dietary fatty acids and carbohydrates on the ratio of serum total to HDL cholesterol and on serum lipids and apolipoproteins: a meta-analysis of 60 controlled trials. *American Journal of Clinical Nutrition (American Society for Clinical Nutrition)*, *77.*(5), 1146–55.

Meulenbeld, G. J. (1999). *"Introduction". A History of Indian Medical Literature*. (G. E. Forsten., Ed.).

Mezaize, S., Chevallier ,S., Le- Bail, A. and De Lamballerie,M. . (2009). Optimization of glutenfree formulations for French-style breads. *Journal of Food Science*, *74*(3), 140–146.

Ministry of Food and Agriculture (MOFA). (2005). *Cassava development in Ghana. A review of cassava in Africa with country case studies on Nigeria, Ghana, the United Republic of Tanzania, Uganda and Benin.* (FAO, Ed.). Rome. Retrieved from available http://www.fao.org/docrep/009/a0154e/A0154E07.htm#ch4 [2012-10-14]

Miyazaki , Y., Kusano, S., Doi, H. and Aki, O. (2005). Effects on immune response of antidiabetic ingredients from white skinned sweet potato (Ipomoea batatas L.). *Nutrition 21*, *21*, 358–362.

MOFA and SRID. (2009). MoFA. Statistics, Research and Information Dir Ectorate Agriculture., (SRID). Ministry of Food and.

Montagnac ,J.A., Davis ,R.C.and Tanumihardjo,. S.A . (2009). Nutritional value of Cassava for use as a staple food and recent advances for improvement. *Comprehensive Reviews in Food Science and Food Safety.*, *8.*, 181–194.

Mosha, T. C. E., Sadick, M. A. and Laswai, H. S. (2010). Development and Evaluation of Organoleptic Quality and Acceptability of Cassava-based Composite Crackers for Supplementing Primary School Children. *Tanzania Journal of Agricultural Sciences, Vol. 10*,(No. 1), 8–21.

Ndife, J., Kida, F. and Fagbemi, S. (2014). Production and quality assessment of enriched cookies from whole wheat and full fat soya. *European Journal of Food Science and Technology*, *Vol.2*,(, No.2), , pp.19 –29.

Nieman, D.C., Butter, W. and Nieman, C. N. (1992). Nutrition: Wm (pp. 9, 540). Dubuque, IA: C. Brown Publishers.

NMCE. (2007). *Report on copra. National Multi-commodity Exchange of India Limited*.

Nneli, R. O. and Woyike, O. A. (2008). Anti-ulcerogenic effects of coconut (Cocos nucifera) extract in rats. *Phytotherapy Research*, *22*, 970–972.

Nweke, F. (2005). *The cassava transformation in Africa. A review of cassava in Africa with country case studies on Nigeria, Ghana, the United Republic of Tanzania, Uganda and Benin*. Rome. Retrieved from Available http://www.fao.org/docrep/009/a0154e/A0154E02.htm#ch1 [2012-10-22]

Nzigamasabo , A.and Ming, Z. H. (2006). Traditional Cassava Foods in Burundi-A Review. *Food Review International*, *22*(1), 1–27.

Odebode, S. O., Egeonu, N., and Akoroda, M. O. (2008). Promotion of sweetpotato for the food industry in Nigeria. *Bulgarian Journal of Agricultural Science*.

Odedina, S.A.and Adebayo, K. (2012). *Commercial Production of Cassava in the Humid Tropics.* Nigeria.

Oduro, I., Ellis , W.O., Dziedzoave, N.T.and Nimako-Yeboah, K. (2000). Quality of gari from selected processing zones in Ghana. *Food Control*, *11*, 297–303.

Ofosu-Budu, K. G., Obeng-Ofori, D., Afreh-Nuamah, K., and Annobil, R. (2008). Effect of phospho-compost on growth and yield of cowpea (Vigna unguiculata). *Ghana Journal of Agricultural Science.*, *40*(2), 169–176.

Ogunsua, A. O. (1989). Total cyanide levels in bread made from wheat cassava composite flours. *International Journal of Food Science Technology*, *24*(361-365).

Olapade, A. A., and Adeyemo, A. M. (2014). Evaluation of cookies produced from blends of wheat, cassava and cowpea flours. *International Journal of Food Studies*, *3*(October), 175–185.

Olapade, A. A. and Aworh, O. C. (2012). Chemical and nutritional evaluation of extruded complementary foods from blends of fonio (Digitaria Exilis stapf) and cowpea (Vigna Unguiculata l. walp)flours. *International Journal of Food and Nutrition Sciences*, *1*(3), 4–9.

Onabalu, A.and Bokanga, M. (1998). The promotion of cassava as a commodity for the food industry: A case study in Nigeria. In *Presented at the CFC workshop on local processing and vertical diversification of cassava in Southern and Eastern Africa, 15-19 June 1998.* Mukono, Uganda.

Onwueme, I.C. (1978). The Tropical Tuber Crops: Yams Cassava Sweet Potato And Cocoyam's. *Wiley New York*, 234–236.

Owiredu, I., Laryea, D. and Barimah, J. (2013). Evaluation of cashew nut flour in the production of biscuit,. *Nutrition and Food Science, 44.*((3):), 204–211.

Owusu, V. and Donkor, E. (2012). Adoption of Improved Cassava Varieties in Ghana. *Agricultural Journal*, *7*(2), 146–151.

Oxford English Dictionary. (2009). *No Title*.

Oyewole, O. B. (2002). The powers at the roots: Food and its Microbials Allies. In *15th Inaugural lecture University of Agriculture, Abeokuta-Nigeria*. Abeokuta-Nigeria.

Padmaja, G. (2009). *Uses and Nutritional Data of Sweetpotato*. (I. G. L. and G. & E. Thottappilly, Eds.). The Sweet potato, Springer, Dordrecht,. http://doi.org/10.1007/978-14020-9475-0_11

Paniappan, S. (2002). The Mystery behind coconut water. *The Hindu*.December 12^{th} ,2002

Peters, D. (2004). Use of sweet potato in pig production in Asia: agricultural and socio- economic aspects. *Pig News and Information*, *25*(1), 10.

Philpott, M., Gould, K.S., Lim, C. and Ferguson, L. R. (2004). In situ and in vitro antioxidant activity of sweetpotatoanthocyanins,. *Journal of Agricultural Food Chemistry, 52(6): 15111513.*, *52*(6), 1511–1513.

Picha, D.H.and Padda, M. . (2009). Nutraceutical compounds and antioxidant content of sweet potatoes. *Louisiana Agriculture*, *52*(2), 24–25.

Prain, G., Wheatley, L. and Nguyen, D. D. (1997). The potential of root crop processing for rural development in Vietnam. In *In: International Potato Center (CIP) Programme Report 1995-1996, Lima, Peru. International Potato Center*. Lima, Peru. International Potato Center.

Prasad,A.S. (1995). Zinc: an overview. *Nutrition*, *11*, :93–9.

Prasad A.S. (1996). Zinc deficiency in women, infants and children. *Journal of the American Coll Nutrition*, *15*, :113–20.

Prasad, A.S., Beck, F.W., Grabowski, S.M., Kaplan, J. and Mathog, R.H. (1997). Zinc deficiency: changes in cytokine production and T-cell subpopulations in patients with head and neck cancer and in noncancer subjects. *Proceedings from Association of American Physicians*, *109:*, 68–77.

Rink ,L., Gabriel, P. (2000). Zinc and the immune system. *Proceedings of the Nutrition Society*, *59*, 541–52.

Sandstead HH. (1994). Understanding zinc: recent observations and interpretations. *Journal of Laboratory and Clinical Medicine*, *124:*, 322–7.

Savanna Agricultural Research Institute. (2012). Production Guide On Cowpea (Vigna unguiculata)Council for Scientific and Industrial Research,Ghana, 1–5.

Scalbert . A, Manach, C., Morand, C., Rémésy, C. and Jiménez, L. (2005). Dietary Polyphenols and the Prevention of Diseases. *Critical Reviews in Food Science and Nutrition*, *45*(4), 287–306. http://doi.org/10.1080/1040869059096

Scott, G. J. and Ewell, P. (1992). Sweetpotato in African Food Systems. In: Product Development for Root and Tuber crops., *3*.

Setyona, A., Damardjati, D. and Malian, H. (1991). Sweet potato and cassava development: present status and future prospects in Indonesia. In *In:Scott, G.J.,Wiersema,S.andFerguson,P.I.(eds) Product Development for Root and Tuber Crops . CIP, Lima, Peru, pp. 29–40.*

Sindi, K., Kirimi, L., and Low, J. (2013). *Can Biofortified Orange Fleshed Sweetpotato Make Commercially Viable Products and Help in Combatting Vitamin A Deficiency ? By :* Slavin, J. L. (2005). Dietary fiber and body weight. *Nutrition Vitali*ty (21:), 411–418.

Solomons,N.W. (1998). Mild human zinc deficiency produces an imbalance between cellmediated and humoral immunity. *Nutrition Review, 56*, :27–8.

Srivastava,S., Genitha,T. R.and Yadav,V. (2012). Preparation and Quality Evaluation of Flour and Biscuit from Sweet Potato. *Journal of Food Processing Technology*, *3*(12), 3–5.

Srirotha, K., Santisopasrib, V., Petchalanuwatc , C., Kurotjanawonga, K., Piyachomkwand, K.and Oates, C. G. (1999). Cassava starch granule structure-function properties: influence of time and conditions at harvest on four cultivars of cassava starch. *Carbohydrate Polymers*, *38*(161-170).

Steed, L. E. and Truong, V.D. (2008). Anthocyanin content, antioxidant activity, and selected physical properties of flowable purple-fleshed sweetpotato purees. *Journal of Food Science*, *73*(5), 215–221.

Stull ,J.W. and Taylor ,R.R. (1981). The Use of Whole Cowpeas in Processed Food Products. *Forage and Grain: A College of Agriculture Report*.

Taylor, J. R. , Schober, T. J., and Bean, S. (2006). Novel food and non-food uses for sorghum and millets. *Journal of Cereal Science*, *44*, 252–271.

Teow, C. C., Truong, V.D., McFeeters, R. F., Thompson, R. L., Pecota, K. V. and Yencho, C.G. (2007). Antioxidant activities, phenolic and β-carotene contents of sweetpotato genotypes with varying flesh colours. *Food Chemistry*, *103*, 829–838.

Tewe, O. O., Ojeniyi, F. E., and Abu, O. A. (2003). *Sweetpotato Production, Utilization, and Marketing in Nigeria*.

Teye, E. (2010). *Developing appropriate storage technology for sweet potatoes (Ipomoea batatas lam) in the coastal savanna h zone of ghana*. University of Cape Coast.

Truong ,V.D.and Avula,R.Y. (2010). *Sweetpotato Puree-Flours-Book Chapter-*.

Ukwuru, M.U. and Egbonu ,S.E. (2013). Recent development in cassava-based products research. *Academia Journal of Food Research*, *1*(1), 1–13. http://doi.org/10.15413/ajfr.2012.0105

Van Jaarsveld, P.J., Faber,M.,Tanumihardjo,S.A., Nestel,P., Lombard,C.J. and Benadé,A.J. (2005). β-Carotene-rich orange fleshed sweet potato improves the vitamin A status of primary school children assessed with the modified-relative-dose– response test. *American Journal of Clinical Nutrition*, *81*, 1080–1087.

Walter, W.M. J. and Schwartz, S. J. (1993). Controlled Heat Processing for "Jewel" Sweetpotatoes for puree production. *Journal of Food Quality*, *16*, 71.

Wang , Y.J., White, P., and Pollak, J. J. L. (1993). Characterization of starch structures of 17 maize endosperm mutant genotypes with Oh 43 inbred line background. *Cereal Chemistry*, *10*, 171–179.

Wardlaw, G. M. (2004). Perspectives in Nutrition. ((6th ed.). McGram Hill Companies, New York, U.S.A.

Wireko-Manu, F. D., Ellis , W. O. and Oduro, I. (2010). Production of a non-alcoholic beverage from sweet potato (Ipomoea batatas L.). *African Journal of Food Science*, *Vol. 4*((4)), 180–183.

Woolfe, J. A. (1992). *Sweetpotato: An untapped Food Resource* (1st Editio). Cambridge University Press, Cambridge UK.

World Health Organization. (2008). Worldwide Prevalence of Anaemia 1993–2005: WHO Global Database on Anaemiaexternal link disclaimer.

Yamakawa, O. and Yoshimoto, M. (2002). Sweetpotato as food material with physiological functions. *ActaHortic. (ISHS)*, *583*, 179–185. Retrieved from http://www.actahort.org/books/583/583_20.htm

Yong, J. W. H., Ge, L., Ng, Y. F. and Tan, S. N. (2009). The chemical composition and biological properties of coconut (Cocos nucifera L.) water. *Molecules*, *14*(12), 5144–64.

Zaidul, I.S.M., Yamauchi, H., Kim , S.J., Hashimoto N.and Noda, T. (2007). RVA study of mixtures of wheat flour and potato starches with different phosphorus content. *Food Chemistry*, *102*, 1105–1111.

Zhang, Z., Wheatley, C. and Corke, H. (2002). Biochemical changes during storage of sweet potato roots differing in dry matter content. *Postharvest Biology and Technology*, *24*, 317–325.

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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

$$\% \text{ moisture content} = \frac{W_a - W_b}{W_a - W_c} \times 100$$

W_a = Weight of can + sample

W_b = Weight of can + dried sample

W_c = Weight of can

Calculation for ash content

The ash content of sample was calculated as

% ash content = c – a x 100

b – a

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 % ether extract = B/C x 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:

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

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;

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

Where; Absorbance = readings on the spectrophotometer measured in nanometres (nm) Graph factor = Sum of Absorbance readings of P standards

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

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

Total volume used after digestion = 250 ml

Weight of sample = 1.0 g

Formula for calculating β-carotene

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

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

APPENDIX B-SENSORY QUESTIONNAIRES

NAME: DATE:

AGE: Gender:

Please you have been presented with four (4) coded samples. Kindly assess the samples based on your degree of likeness for the following listed attributes using the scale shown below. Please taste where appropriate then rinse your mouth with water provided before going to the next sample.

1. Dislike very much 4.Like moderately 2.
Dislike moderately 5.Like very much
3. Neither like nor dislike

Sample code	Colour	Hardness	Crunchiness	Aroma	Sweetness	Aftertaste	Overall acceptability

Kindly comment on the product.

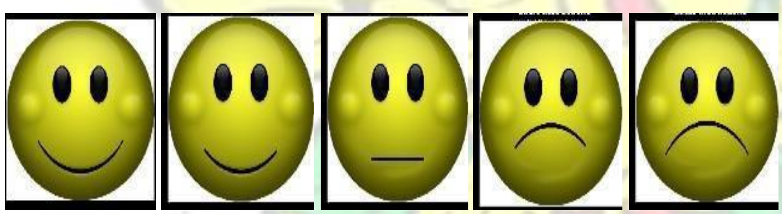
Which of the samples will you buy if on the market?

How much would you buy this product (for 25g) on the market?

NAME:: DATE:

AGE: GENDER:

Please you have been presented with five (5) coded samples. Kindly assess the samples based on your degree of likeness for the following listed attributes using the scale shown below. Please taste where appropriate then rinse your mouth with water provided before going to the next sample.



5 4 3 2 1

1. Dislike very much 4.Like moderately 2. Dislike moderately 5.Like very much
3. Neither like nor dislike

Sample code	Colour	Hardness	Crunchiness	Sweetness	Aftertaste	Overall acceptability
154						
935						

378

287

608

Please do you have any comment on the product?

Which of the samples will you buy if on the market?

Which of these products is closest to the *agbozume* biscuit you know?

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APPENDIX C-STATISTICAL TABLES

Output on hardness

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
sample463	53	3.72	.968	1	5
sample189	53	3.72	.769	1	5
sample727	53	3.70	.822	1	5
sample535	53	3.91	.966	1	5

Friedman Test

Ranks

	Mean Rank
sample463	2.42
sample189	2.42
sample727	2.40
sample535	2.75

Test Statistics[a]

N	53
Chi-Square	4.366

df			3
Asymp. Sig.			.225
Monte Carlo Sig.	Sig.		.226
	95% Confidence Interval	Lower Bound	.114
		Upper Bound	.339

a. Friedman Test

Descriptive Statistics

Output on colour preference

KNUST

	N	Mean	Std. Deviation	Minimum	Maximum
sample463	53	3.34	.999	1	5
sample189	53	3.77	1.012	1	5
sample727	53	3.92	.703	1	5
sample535	53	3.83	.935	1	5

Friedman Test

Ranks

	Mean Rank
sample463	2.05
sample189	2.62
sample727	2.66
sample535	2.67

Test Statistics[a]

N		53
Chi-Square		13.340
df		3
Asymp. Sig.		.004
Monte Carlo Sig.	Sig.	.000

Descriptive Statistics

95% Confidence Interval		Lower Bound	.000
		Upper Bound	.055

a. Friedman Test

Output on aroma preference

	N	Mean	Std. Deviation	Minimum	Maximum
sample463	53	3.72	.968	1	5
sample189	53	3.72	.769	1	5
sample727	53	3.70	.822	1	5
sample535	53	3.91	.966	1	5

Friedman Test

Ranks

	Mean Rank
sample463	2.42
sample189	2.42
sample727	2.40

Descriptive Statistics

sample535	2.75

Test Statistics[a]

N			53
Chi-Square			4.366
df			3
Asymp. Sig.			.225
Monte Carlo Sig.	Sig.		.226
	95% Confidence Interval	Lower Bound	.114
		Upper Bound	.339

a. Friedman Test

Output on aftertaste preference

	N	Mean	Std. Deviation	Minimum	Maximum
sample463	53	3.74	.944	2	5
sample189	53	3.68	.976	1	5
sample727	53	3.49	.953	1	5

Descriptive Statistics

sample535	53	4.00	.920	2	5

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Friedman Test

Ranks

	Mean Rank
sample463	2.54
sample189	2.44
sample727	2.16
sample535	2.86

Test Statistics[a]

N			53
Chi-Square			12.354
df			3
Asymp. Sig.			.006
Monte Carlo Sig.	Sig.		.019
	95% Confidence Interval	Lower Bound	.000
		Upper Bound	.055

a.Friedman Test

W J SANE NO BADWENA

Descriptive Statistics

KNUST

Output on sweetness preference

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
sample463	53	3.62	1.060	1	5
sample189	53	3.43	1.065	1	5
sample727	53	3.64	1.076	1	5
sample535	53	3.92	.997	2	5

Friedman Test

Ranks

	Mean Rank
sample463	2.38
sample189	2.25
sample727	2.49
sample535	2.88

Test Statistics[a]

N			53
Chi-Square			10.604
df			3
Asymp. Sig.			.014
Monte Carlo Sig.	Sig.		.019
	95% Confidence Interval	Lower Bound	.000
		Upper Bound	.055

a.Friedman Test

KNUST

Output on overall acceptability

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
sample463	53	3.42	.969	1	5
sample189	53	3.53	.992	1	5
sample727	53	3.42	.989	1	5
sample535	53	4.06	.886	2	5

Friedman Test

Ranks

	Mean Rank
sample463	2.27
sample189	2.45
sample727	2.25
sample535	3.02

Test Statistics[a]

N	53
Chi-Square	15.587
df	3
Asymp. Sig.	.001

Monte Carlo Sig.	Sig.		.000
	95% Confidence Interval	Lower Bound	.000
		Upper Bound	.055

a. Friedman Test

KNUST

Statistical tables for nutrient composition
Proximate composition

Oneway

		Sum of Squares	df	Mean Square
moisture	Between Groups	31.911	4	7.978
	Within Groups	.045	5	.009
	Total	31.956	9	

NYANSAPO W ɔ SANE NO BADWENMA

fat	Between Groups	135.765	4	33.941
	Within Groups	2.006	5	.401
	Total	137.770	9	

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Notes

Output Created		24-MAY-2016 22:13:18
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	Cases Used	Statistics for each analysis are based on cases with no missing data for any variable in the analysis.
Syntax		ONEWAY moisture fat fibre protein ash carbohydrate BY VAR00001 /MISSING ANALYSIS /POSTHOC=TUKEY ALPHA(0.05).
Resources	Processor Time	00:00:00.06
	Elapsed Time	00:00:00.06

[DataSet0]

NYANSAPƆ WƆ SANE NO BADWENMA

ANOVA

I

88

fibre	Between Groups	.247	4	.062
	Within Groups	.026	5	.005
	Total	.273	9	
protein	Between Groups	8.301	4	2.075
	Within Groups	2.139	5	.428
	Total	10.440	9	
ash	Between Groups	.326	4	.082
	Within Groups	.003	5	.001
	Total	.329	9	
carbohydrate	Between Groups	114.727	4	28.682
	Within Groups	2.888	5	.578
	Total	117.615	9	

84
11

152

49

KNUST
NANSAPↃ WↃ SANE NO BADWENMA

Homogeneous Subsets

moisture

Tukey HSD

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

KNUST

VAR00001	N	Subset for alpha = 0.05		
		1	2	3
1.00	2	1.3000		
2.00	2		2.3600	
5.00	2			3.1000
4.00	2			
3.00	2			
Sig.		1.000	1.000	1.000

fat

Tukey HSD

VAR00001	N	Subset for alpha = 0.05		
		1	2	3
5.00	2	7.3500		
2.00	2	8.1250		

3.00	2	9.6850	9.6850	
4.00	2		11.1300	
1.00	2			17.6900
Sig.		.068	.286	1.000

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

fibre Tukey
HSD

VAR00001	N	Subset for alpha = 0.05	
		1	2
1.00	2	.1300	
2.00	2	.1350	
5.00	2	.1800	
4.00	2	.2100	
3.00	2		.5500
Sig.		.797	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

protein Tukey
HSD

VAR00001	N	Subset for alpha = 0.05	
		1	2
1.00	2	5.1361	
5.00	2	6.1873	6.1873
2.00	2	6.8882	6.8882
4.00	2	7.2106	7.2106
3.00	2		7.7787

KNUST

Sig.		.114	.244

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

KNUST

ash

Tukey HSD

VAR00001	N	Subset for alpha = 0.05		
		1	2	3
1.00	2	.3276		
2.00	2		.5219	
5.00	2		.5656	
4.00	2		.5762	
3.00	2			.8897
Sig.		1.000	.267	1.000

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

carbohydrate Tukey HSD

VAR00001	N	Subset for alpha = 0.05	
		1	2
3.00	2	74.6466	
1.00	2	75.4163	
4.00	2	76.3932	
2.00	2		81.9699
5.00	2		82.6171
Sig.		.281	.903

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

T-Test

Notes

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	Cases Used	Statistics for each analysis are based on the cases with no missing or out-ofrange data for any variable in the analysis.

Syntax		T-TEST GROUPS=factor(1 2) /MISSING=ANALYSIS /VARIABLES=colour hardness crunchiness sweetness aftertaste OA /CRITERIA=CI(.95).
Resources	Processor Time	00:00:00.05
	Elapsed Time	00:00:00.04

[DataSet0]

Group Statistics

factor		N	Mean	Std. Deviation	Std. Error Mean
colour	1.00	52	3.8654	1.25290	.17375
	2.00	52	3.7308	1.42959	.19825
hardness	1.00	52	3.4615	1.25965	.17468
	2.00	52	3.8077	1.28397	.17805
crunchiness	1.00	52	3.3269	1.30941	.18158
	2.00	52	3.7115	1.27320	.17656
sweetness	1.00	52	3.9231	1.26563	.17551

	2.00		51	4.0392	1.21591	.17026
aftertaste	1.00		52	3.7692	1.23058	.17065
	2.00		52	3.8654	1.29900	.18014
OA	1.00		52	4.1346	1.22120	.16935
	2.00		52	3.9808	1.37898	.19123

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Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2tailed)	Mean Difference	Std. Error Difference	Lower	Upper
colour	Equal variances assumed	3.758	.055	.511	102	.611	.13462	.26361	-.38825	.65749
	Equal variances not assumed			.511	100.275	.611	.13462	.26361	-.38836	.65759
hardness	Equal variances assumed	.545	.462	-1.388	102	.168	-.34615	.24943	-.84090	.14860
	Equal variances not assumed			-1.388	101.963	.168	-.34615	.24943	-.84091	.14860
crunchiness	Equal variances assumed	.140	.709	-1.519	102	.132	-.38462	.25327	-.88698	.11775
	Equal variances not assumed			-1.519	101.920	.132	-.38462	.25327	-.88698	.11775
sweetness	Equal variances assumed	.011	.915	-.475	101	.636	-.11614	.24462	-.60140	.36913
	Equal variances not assumed			-.475	100.958	.636	-.11614	.24453	-.60121	.36894
aftertaste	Equal variances assumed	.000	.992	-.388	102	.699	-.09615	.24814	-.58833	.39602
	Equal variances not assumed			-.388	101.703	.699	-.09615	.24814	-.58835	.39604
OA	Equal variances assumed	1.234	.269	.602	102	.548	.15385	.25544	-.35281	.66051
	Equal variances not assumed			.602	100.530	.548	.15385	.25544	-.35290	.66059

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