FORMULATION AND EVALUATION OF COMPOSITE FLOUR AND BREAD FROM *TRITICUM AESTIVUM* (WHEAT), *IPOMOEA BATATAS* (SWEET POTATO) AND *VIGNA SUBTERRANEA* (BAMBARA GROUNDNUT)

BY

PATIENCE OMOIKHOJE GANSALLO

DEPARTMENT OF BIOCHEMISTRY,
AHMADU BELLO UNIVERSITY,
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DECLARATION

I declare that the work in this dissertation entitled **‘‘Formulation and Evaluation of Composite Flour and Bread from *Triticum aestivum* (Wheat),*Ipomoea batatas* (Sweet potato) and *Vigna subterranea*(Bambara groundnut)”** has been carried out by me in the Department of Biochemistry under the supervision of Professor S. Ibrahim and Dr A. Salihu. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this dissertation was previously presented for another degree or diploma at this or any other institution.

Patience Omoikhoje Gansallo__________________ _________________

Name of Student Signature Date

CERTIFICATION

This dissertation entitled ‘‘FORMULATION AND EVALUATION OF COMPOSITE FLOUR AND BREAD FROM *TRITICUM AESTIVUM*(WHEAT), *IPOMOEA BATATAS* (SWEET POTATO)AND *VIGNA SUBTERRANEA*(BAMBARA GROUNDNUT)’’ by PATIENCE OMOIKHOJE GANSALLO meets the regulations governing the award of the degree of Master of Science in Nutrition of the Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation.

Prof. S. Ibrahim Date
Chairman, Supervisory Committee

Dr. A. Salihu Date
Member, Supervisory Committee

Prof. M.N. Shuaibu Date
Head of Department

Prof. S.Z. Abubakar Date
Dean, Postgraduate School

DEDICATION

This work is dedicated to the almighty God for his infinite goodness and mercies. His grace and love has kept me and pulled me through. To him alone be all glory and honour. Amen.

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ABSTRACT

The formulation of composite flour for the production of bread and pastrieshas increased and is attracting much attention from researchers. Wheat, sweet potato and bambara groundnut flours were formulated at various ratios of 90:5:5 (C), 80:10:10 (D), 70:15:15 (E), 60:20:20 (F) respectively. 100gof whole wheat (A) and white wheat flour (B) served as controls. Bambara groundnutwas soaked and dehulled, the sweet potato washed, peeled andblanched. They were both oven dried (65^oC) and milled into flour. Whole wheat was sorted and also milled.Straight dough method was used for bread production. The functional, proximate, micronutrient and anti-nutrient compositions were determined using AOAC standard methods. Physical characteristics were determined using a weighing scale and the rapeseed displacement method. Organolepticproperties weredetermined using the nine point hedonic scale. The bulk density showed sampleA with a value of 0.81 mg/ml was significantly higher ($P<0.05$) than B and the composite blend (C and D). Sample C was significantly lower ($P <0.05$) than the composite blends (D to F).For the swelling capacity, sample B with a value of 0.47 ml/g was significantly higher ($P<0.05$) when compared to Aand composites (C to F).The results of the water absorption capacity and oil holding capacity showed sample F had values of 5.64 % and 2.63 ml/g respectively which weresignificantly higher ($P<0.05$) when compared with the controls and composites (C, D, E). Gelation capacity ranged from 12 to 14 %.Loaf and specific volume showed sample Awas significantly lower ($P<0.05$) than B and the composite blends, however sample Cwas significantly higher ($P<0.05$) when compared to the blends (D, E, F). Loaf weight and density results showed sample F was significantly higher ($P<0.05$) than other composites (C, D, E).Forash, crude lipid and crude protein contentssample F was significantly higher ($P <0.05$) when compared to the controls and the composites (C to E). Carbohydrate and fibre contents showed sample A was significantly (P< 0.05) higherthan B and the composites (C to F). Calcium, potassium and sodium levels showed sample F was significantly higher (P<0.05) than the controls andcomposites (C, D, E).For magnesium and zinc contents sample Dwas significantly higher (P <0.05) than the composites (C, E, F). Sample C had an iron content of 0.61 mg/100g which was significantly lower (P <0.05) than the controls and composites (D, E, F). Vitamin A, thiamine and vitamin C results showed sample A was significantly higher (P<0.05) than the other samples. In terms of riboflavin and vitamin E, sample F was significantly higher (P<0.05) than the controls and composites (C, D, E). For phytate and oxalate levels,sampleF was significantly higher (P<0.05) than the controlsand composites (C, D, E). For tannin, both controls were significantly higher (P<0.05) than the composites. The trypsin inhibitor content showed that sample D was significantly higher (P <0.05) than the controls.Organoleptic resultsshowed the overall acceptability of samples B and E were not significantly different (P>0.05) from one another. Shelf life of the samples was found to be an average of three days at room temperature(25 ± 2 °C) and two days at 37^{o}C.The bread with 40 g substitution showed increased nutrient composition.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF PLATES

LIST OF APPENDICES

ABBREVIATIONS

AOAC – Association of Analytical Chemists

AR – Analytical Grade

BD – Bulk Density

FAO – Food and Agricultural Organisation

GAIN – Global Agricultural Information Network

GC – Gelation Capacity

LGC – Least Gelation Capacity

OAC – Oil Holding Capacity

SC – Swelling Capacity

USDA – United States Department of Agriculture

WAC – Water Absorption Capacity.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Flour is well known as the main ingredient in bread production, as bread constitutes a staple food in the diet of many countries (Igbabul *et al*., 2014). Flour used for bakery products is mainly from wheat but could also be made from legumes or root tubers such as sweet potatoes, cassava, yam, cocoyam, soya beans, bambara groundnut, hamburger bean seeds and pigeon peas (Chinma *et al*., 2012). The unbridled importation of food by developing countries is detrimental to their local economy and threatens food security. Many developing countries spend a large proportion of their foreign exchange earnings on food especially wheat(FAO, 2009). By so doing, developing countries create wealth and employment for developed countries to the detriment of their local economy (Igbabul *et al*., 2014).

Food importations from continents like Europe, America and Asia to Nigeriahave some sustainability challenges. It is therefore of economic importance if wheat importation is reduced by substitution with other locally available raw materials (Onyeku *et al*., 2008). The Nigeria wheat policy is specifically targeted at partially substituting wheat using domestically grown crops(Ohimain, 2014). Over the years, Nigeria wheat importation policy changes along with political/regime change. The country planned to substitute wheat with cassava by 10% in 1979 – 1983 and 1999 – 2007 (Ohimain, 2014). It was reduced to 5% in 2007 – 2010 (Ohimain, 2014), while in 1987 – 1990, there was a complete ban on wheat importation in Nigeria (Falade and Akingbala, 2008). During the period of complete ban, wheat was grown in Northern Nigeria under irrigation schemes. It was also reported that domestic wheat production in Nigeria was a mere 2.7% of wheat consumption (Falade and Akingbala, 2008). The locally produced wheat was about 6 - 8 times more expensive than imported wheat hence the ban could not be sustained (Falade and Akingbala, 2008). In order to reduce the import dependency of developing countries, the Food and Agricultural Organization (FAO) in United Nations spurred research on composite bread (Onyeku *et al*., 2008).

Composite flour can be defined as a mixture of several flours obtained from roots, tubers, cereals and legumes with or without the addition of wheat flour and have been used extensively and successfully in the production of baked foods (Julianti *et al*., 2015). It has the advantage of improving the nutrient value of bread and other bakery products especially when cereals are blended with legumes. Composite flours from other crops have become the subject of numerous studies as possible additives to wheat, particularly for the developing countries in the production of bread and pastries (Julianti *et al*., 2015). Till date, most Nigerians have not been fully introduced to breads made from composite flour (Shittu *et al.,* 2007). This would cut the nation's expense on wheat importation and find wider utilization for the locally produced roots, tubers and legumes (Shittu *et al.,* 2007).

The use of composite flour is relevant in bread making as it promotes the use of high-yielding native plant species, increases nutritional values and improves domestic agriculture production(FAO, 2009). The use of flours from cereals, legumes and tubers for bread production is therefore expected to enhance the utilization of local crops as raw materials (Adeniji, 2015). Some of the documented advantages of composite flour for bread production in developing countries include savings of foreign exchange, promotion of high yielding species of various crops, a better supply of proteins for human nutrition, enhancement of domestic agriculture; create employment, rural income and development (Adeniji, 2015).

The production of composite flours using various crops for confectionary and bakery products has been carried out, among which were; cassava/wheat flour, wheat/ taro flour, wheat/pumpkin flour and tiger-nut/wheat flour (Ade-Omowaye *et al*., 2008; Shittu *et al*., 2008; Ammar *et al*., 2009; Shittu *et al*., 2013). These works showed that composite flour produced baked foods that were of higher nutrient quality than the 100% wheat products.

Sweet potato (*Ipomoea batatas*) is one of the world's most important food crops and an important staple in Nigeria and other developing countries (Olubunmi *et al*., 2017). It is a crop which is used as a vegetable, a source of starch and an ingredient in the formulation of animal feed (Igbabul *et al*., 2014). In Nigeria, sweet potato is consumed majorly as a snack (*asondo*prepared Tiv), boiled, fried as chips, roasted or used with fresh yams in pounded yam and as a sweetener in beverages (Olubunmi *et al*., 2017). Processing of sweet potato into flour would increase its utilization and can serve as a source of nutrients (Igbabul *et al*., 2014).

Protein deficiency is a major global problem particularly in developing countries like Nigeria(Semba, 2016). Certain legumes and oilseeds contain high level of protein that can be exploited in the formulation of composite flour (Kinn-Kabari, 2015). One of such legumes includes bambara-groundnut which has a high nutrient density and is recommended as a substitute in formulations to enhance nutritional value of foods (Kinn, 2015). Mixing of cereal with legume could improve the limiting amino acids content as well as the nutritive value of cereal based food products (Abdelrahman *et al*., 2012).

Therefore legumes can be successfully used in breads to obtain protein-enriched products with improved amino acid balance (Aghamirzaei *et al*., 2013).

Bread is serves as a well acceptable staple food for many families in developing countries. Data have that substituting wheat flour with legume flours could reduce the need of large-scale importation of wheat and also enhance the nutrient composition of bread (Kinn-Kabari, 2015).

1.2 Statement of Research Problem

The increase in consumption of bread and baked foods by human has resulted in the escalating cost of wheat (Oyeyinka *et al*., 2014). Annual average importation of wheat in Nigeria was estimated at 4 million metric tonnes (MMT) (USDA 2016). In 2015 Nigeria's importation of wheat was about 4.4MMT at a cost of $3.2billion (USDA, 2016). In 2017, imports of wheat increased to 5.0MMT (GAIN, 2018). Less attention has been focused on the need to explore alternative nutrient rich local flours from other crops as substitutes for wheat flour in the baking industry.

It has been reported that sweet potato, which can be processed into flour is abundantly produced in Nigeria and greatly lost due to lack of post-harvest storage facilities (Fetuga *et al*., 2014). Similarly, bambara groundnut is an important legume that is grown, readily available but is underutilized (Effa and Uko, 2017). Various studies have shown thatbread produced solely from white wheat flour has low protein content (Asselberg, 1998). Despite the nutritional values of sweet potatoes and bambaragroundnut, their utilization is limited.

1.3 Justification

The need for strategic development in the use of inexpensive local resources in the production of staple foods has been promoted by certain organizations which have led to the initiation of composite flour programmes (Mohammad *et al*., 2012). Mastromatteo *et al* (2013) and Onoja *etal* (2011) reported that consumption of baked foods is increasing due to increased urbanization, ready to eat convenience, availability of various products (bread, cakes, cookies) and easy accessibility. Flours from starchy tubers are inadequate in proteins and thus can be blended with legume flours such as bambara groundnut to enhance the nutritional composition (Afoakwa and Sefa-Dedeh 2001).

Sweet potato and bambara groundnut are nutrient rich, cheap, readily available and can be cultivated in different regions (Igbabul *et al*., 2014). Sweet potatoes and bambara groundnut can complement the amino acid content and nutrient composition of the wheat flour. Thus, adoption of these locally produced flours with wheat flour in the baking industry can greatly improve the nutritional value of bread and baked foods (Arise *et al*., 2015). Based on literature, there is little or no information on the use of composite flour of wheat and sweet potatoes/bambara groundnut for bread production.

1.4 Aim and Objectives

1.4.1 Aim

To formulate and evaluate a composite flour of wheat, sweet-potato and bambara groundnut and the bread produced from the flour blends.

1.4.2 Objectives

The specific objectives are to:

1. determine functional properties, proximate and anti-nutrient compositions of the flour blend of wheat, sweet-potato and bambara groundnut.
2. produce bread from the formulated composite flour and determine its physical characteristics.
3. determine the nutrient and anti-nutrient compositions of the bread produced.
4. determine the shelf life and organoleptic properties of the produced bread.

1.5 Null Hypothesis

There are no differences between the functional properties, nutrients and antinutrientscompositions, shelf life and organoleptic compositions of the bread produced from the formulated composite flour, whole wheat and white wheat flour.

1.6 Alternative Hypothesis

There are differences between the functional properties, nutrients and antinutrients composition, shelf life and organoleptic compositions of the bread produced from the formulated composite flour, whole wheat and white wheat flour.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Composite Flour

Composite flours are produced from roots and tubers such as yam, cassava, sweet potato, cocoyam amongst others in conjunction with legumes including cowpea, peas, chickpeas, lima beans, bambara groundnut, hamburger bean seed and pigeon peas (Arinathan *et al*., 2003). They are sometimes formulated in conjunction with wheat flour (Arinathan *et al*., 2003). Several studies have been conducted on the physical, functional and nutritional composition of bread produced from composite flours (Adeyemi and Idowu 1990; Abdelghafor *et al*., 2011; McWatter *et al*., 2004). Igbabul *et al* (2014) studied the effects of different flour substitutions on bread making quality. A variety of wheat flour substitutes have been tried in bakery formulations with varying success, for example, defatted wheat germ, flaxseed, sunflower seed, and lupine flour (Hall and Johnson, 2004(Arshad *et al*., 2007; Koca and Anil, 2007; Skrbic and Filipcev, 2008).

The baked products produced using composite flour were of good quality, with some characteristics similar to the wheat-flour bread, though the texture and the properties of the composite flour bakery products were different from those made from wheat flour, with an increased nutritional value and appearance (Hasmadi *et al*., 2014). The composite blends used were either binary or ternary mixtures of flours from other crops with or without addition of wheat flour (Hugo *et al*., 2000; Hasmadi *et al*., 2014). Noor *et al*., (2012) reported that local raw materials substitution for wheat flour is increasing due to the growing market for confectioneries. As a result, developing countries have encouraged the initiation of programmes to evaluate the feasibility of alternative locally available flours as a substitute for wheat flour (Abdelghafor *et al*., 2011). Food and agricultural organization (FAO) reported that the application of composite flour in various food products would be economically advantageous if the imports of wheat could be reduced or even eliminated, and that demand for bread and pastry products could be met by the use of domestically grown products rather than wheat (Jisha *et al*., 2008).

According to Sudha *et al.*, (2007), baked products are varied by the addition of value-added ingredients. Thus, the increasing number of applications of composite flour in numerous bakery and pastry products has spurred a growing number of studies on the effects of different types of materials used to produce flour on their physicochemical and functional properties. Mepba *et al.,* (2007) reported that the experience gained in the use of composite flours has demonstrated that, for reasons of both product technology and consumer acceptance, wheat is an essential component in many composite flours. It was also reported that the percentage of wheat flour required to achieve a certain effect on composite flours depends on the quality and quantity of wheat gluten and the nature of the product involved. It is therefore important that bakery and pastry products produced using composite flour, should have similar qualities to those made from wheat flour (Mepba *et al*., 2007).

The findings of Nwosu *et al.,* (2014) showed that up to 30% substitution of wheat flour with cassava flour in bread production could be achieved using malted soybean as an improver. This also resulted in breads whose sensory attributes and proximate compositions could be compared with breads produced from 100% wheat flour. Igbabul *et al.,* (2014) also showed that 20% yellow maize and 20% orange fleshed sweet potato could be used as wheat substitute to produce bread that would be well accepted by the consumers. The bread produced from wheat, yellow maize and orange fleshed potato had increased nutrient contents in terms of carbohydrate, fibre, fat, ash, calcium and Pro vitamin A (β-carotene). In another research trial, 10% and 20% sorghum flour blend with wheat flour resulted in acceptable breads and biscuits (Adebowale *et al*., 2012; Elkhalifa and El-Tinay, 2002).

2.1.1 Functional properties of composite flour

Functional properties are the physical and chemical properties that reflect the complex interaction between the composition, structure, molecular conformation and the properties of food components together with the nature of environment in which these are associated and measured (Suresh *et al*., 2015). Functional characteristics are important to evaluate and help to predict how proteins, fat, fibre and carbohydrates may behave in specific systems. Functional properties of composite flour are parameters that determine its application and end use. Some of the general functional properties that are of importance in food formulations are bulk density, water absorption capacity, oil holding capacity, gelation capacity and swelling capacity (Suresh *et al*., 2015).

2.1.1.1 *Water absorption capacity (WAC)*

Water absorption capacity is an important protein–water interaction that occurs in various food systems. Water absorption characteristics represent the ability of a product to associate with water under conditions where water is limiting such as dough and paste (Nwoji, 2004). It represents the ability of a protein matrix to absorb and retain bound, hydrodynamic, capillary, and physically entrapped water against gravity (Duc *et al*., 2015). Water holding capacity of legumes is very important as it affects the texture, juiciness, and taste of food formulations and in particular the shelf-life of bakery products (Duc *et al*., 2015).

Intrinsic factors affecting water-binding capacity of food proteins include amino acid composition, protein conformation and surface polarity/hydrophobicity (Barbut, 1999). Different protein structures and the presence of different hydrophilic carbohydrates might be responsible for variations in the water holding capacity of the flours. Flours with high water absorption have more hydrophilic constituents. Food processing methods have important impacts on the protein conformation and hydrophobicity and with respect to water-holding capacity; the denatured proteins bind more water through exposure of hydrophilic groups (Barbut, 1999).

2.1.1.2 *Oil holding capacity (OHC)*

The oil holding capacity of the flour blends suggests that they may be useful in food preparations that involve mixing like bakery products where oil is an important ingredient (Ajani *et al*., 2016). The oil absorption capacities of the composite flours tend to increase with increase in protein content since the protein in foods influences fat absorption (Ajani *et al*., 2016)**.** Interactions of water and oil with proteins are important in food systems as they have influence on the flavour and texture of foods. The ability of flours to absorb and retain oil could help to enhance flavor retention and improve mouth feel (Iwe *et al*., 2016).

Oil absorption capacity, thus measures the ability of food material to absorb oil. The presence of protein exposes more non-polar amino acids to the fat and enhances hydrophobicity as a result of which the flour absorbs more oil (Oluwalana *et al*., 2011). It was suggested that surface hydrophobicity could be the major determinant of fat binding capacity (Ibrahim, 2006). Increased oil absorption capacity could suggest that the flour contain higher amounts of non-polar amino acids which are commonly found in legume proteins (Oluwalana *et al*., 2011). Oil absorption capacity could be attributed to the physical entrapment of oils depicting the roles at which proteins complex with fat in food formulations (Akubor *et al*., 2013).

2.1.1.3 *Bulk density (BD)*

Bulk density is a physicochemical property, which depends on the particlesize and density of the flour. It is very important indetermining the packaging requirement, material handlingand application in wet processing in food industry(Igbabul *et al*., 2014). Consequently, increase in bulk density is desirable because it offers greater packaging advantage. Bulk density is also significant in the storage and transport of food products. It has been reported that the lower the bulk density, the higher the amount of flour particles that can bind together leading to higher energy values (Kumar *et al*., 2016). The result of bulk density (BD) is thus used to evaluate the flour heaviness, handling requirement and the type of packaging materials suitable for storage and transportation of the food materials (Oppong *et al*., 2015).

2.1.1.4 *Swelling capacity*

Swelling capacity is an indication of the water absorption index of the granules during heating (Adebowale *et al*., 2012). It is an evidence of non-covalent bonding between molecules within starch granules and also a factor of the ratio of α-amylose and amylopectin ratios (Adebowale *et al*., 2012).Swelling capacity of flours depends on size of particles and types of processing methods (Igbabul *et al*., 2014). Swelling capacities contribute to dough formation and stability, and is an important factor in baking thus contributing to texture of bread (Adebowale *et al*., 2012). It usually shows proofs that they will reconstitute easily to fine consistent dough or pudding during mixing. Swelling capacity is an important criterion in good formulations of bakery products (Igbabul *et al*., 2014).

2.1.1.5 *Gelation capacity*

The least gelation concentration (LGC) is defined as the lowest protein concentration at which gel remained in the inverted tube, and is used as index of gelation capacity (Suresh *et al*., 2015). Gelling properties has variations and this may be as a result of ratios of the different constituents such as protein, carbohydrate and lipid in different flours, suggesting that interaction between such components may also have a significant role in functional properties (Aremu *et al*. 2007).

Gelatinization is the process by which the internal structure of the granule disintegrates; releasing polysaccharide into the surrounding medium(Tako,*et al*., 2016**).** When starch granules are heated in water beyond a critical temperature, the granules absorb a large amount of water and swell. On certain temperature range, the starch granules undergo an irreversible process, which is marked by crystalline melting and starch solubilization (Singh, *et al*., 2005). Starch is known to induce gelation due to it interaction with protein. Least gelation concentration (LGC) for various legume flours ranged from 12% to 14%. The lower the LGC, the better is the gelating ability of the protein ingredient (Adebayo *et al*., 2013).

2.2 Sweet Potato

Sweet potato (*Ipomoea batatas*) is an important tuber crop which plays a major role worldwide as a staple food especially in developing countries (Laurie *et al*., 2015). *Ipomoea batatas*, belongs to the family Convulaceae. It is an important root vegetable that is large, starchy, and sweet tasting (Ayeleso, *et al*., 2016). The plant is an herbaceous perennial vine, bearing alternate heart-shaped leaves and medium-sized flowers (Mohanraj and Sivasankar, 2014). The edible tuberous root is long and tapered with a smooth skin(Mohanraj and Sivasankar, 2014). It is valued for its short growing period of 90 to 120 days, high nutritional content, and its sweetness (Saeed *et al*., 2012). It is called *Dankali* (Hausa), *Odunkun* (Yoruba) and *Nduku* (Igbo). It is one of the cheaply available food crop grown in Northern Nigeria (Saeed *et al*., 2012). It has a great potential because of its short maturity time and ability to grow under diverse conditions. *Ipomoea batatas* plays an important role as an energy and phytochemical source in human nutrition and animal feeding (Oduro, *et al*., 2008). United Nation's Food and Agriculture Organization (FAO) (2011) reported that sweet potato (*Ipomea batatas*) is an important crop in the developing world.

According to FAO (2011), sweet potato is one of the seven crops in the world that produce over 105 million metric tonnes of edible food products in the world annually. Sweet potato is amongst the world's most important and under-exploited food crops (Grant, 2003). It is commonly categorized as subsistence, "food security" or "famine relief" crop and its uses have diversified considerably in developing countries over the last four decades (Grant, 2003). Currently different varieties of sweet potato are cultivated and consumed in Nigeria. These cultivars contain different flesh colours ranging from white, yellow and orange

(Endrias*et al.*, 2016). As with all crops, the nutritional status of sweet potato cultivars vary from place to place depending on the climate, soil type, the crop variety and other factors (Ingabire and Hilda, 2011). Sweet potato is a very efficient food crop and produces more dry matter, protein and minerals per unit area in comparison to cereals (Ayeleso *et al*., 2016).

2.2.1 Nutritional composition of sweet potato tuber

Sweet potato is a rich source of starch. Despite its high carbohydrate content, sweet potato has a low glycemic index due to low digestibility of the starch (Ellong *et al*., 2014; Fetuga *et al*., 2014; Ooi and Loke, 2013). Its energy content mainly comes from starch, a complex carbohydrate. Sweet potato has a higher amylose to the amylopectin ratio. Amylose raises the blood sugar levels slowly in comparison to simple sugars, and is recommended as a healthy food substance (Mohanraj and Sivasankar, 2014).

The nutritional composition of sweet potato makes it important in meeting human nutritional needs. Thus besides simple starches, sweet potatoes are rich in complex carbohydrates, dietary fiber, iron, and vitamin content such as beta-carotene, vitamin B_2, vitamin C, vitamin E, iron, magnesium, potassium and zinc (USDA, 2009). However, sweet potatoes also contain potential plant toxins and anti-nutritional factors such as phytate, oxalate and tannin; however, blanching, boiling, roasting, frying and drying could reduce the levels of the anti-nutrients (Olayiwola *et al.,* 2009; Eluagu and Onimawo, 2010).

It was reported that sweet potatoes root usually have higher protein content than other roots and tubers, such as cassava and yams (Oloo *et al*., 2014). The compounds present in sweet potato are important because of their beneficial effects on health, therefore, are highly desirable in the human diet and functions as a functional food (Mohanraj and Sivasankar, 2014; Katan and De Roos, 2004).

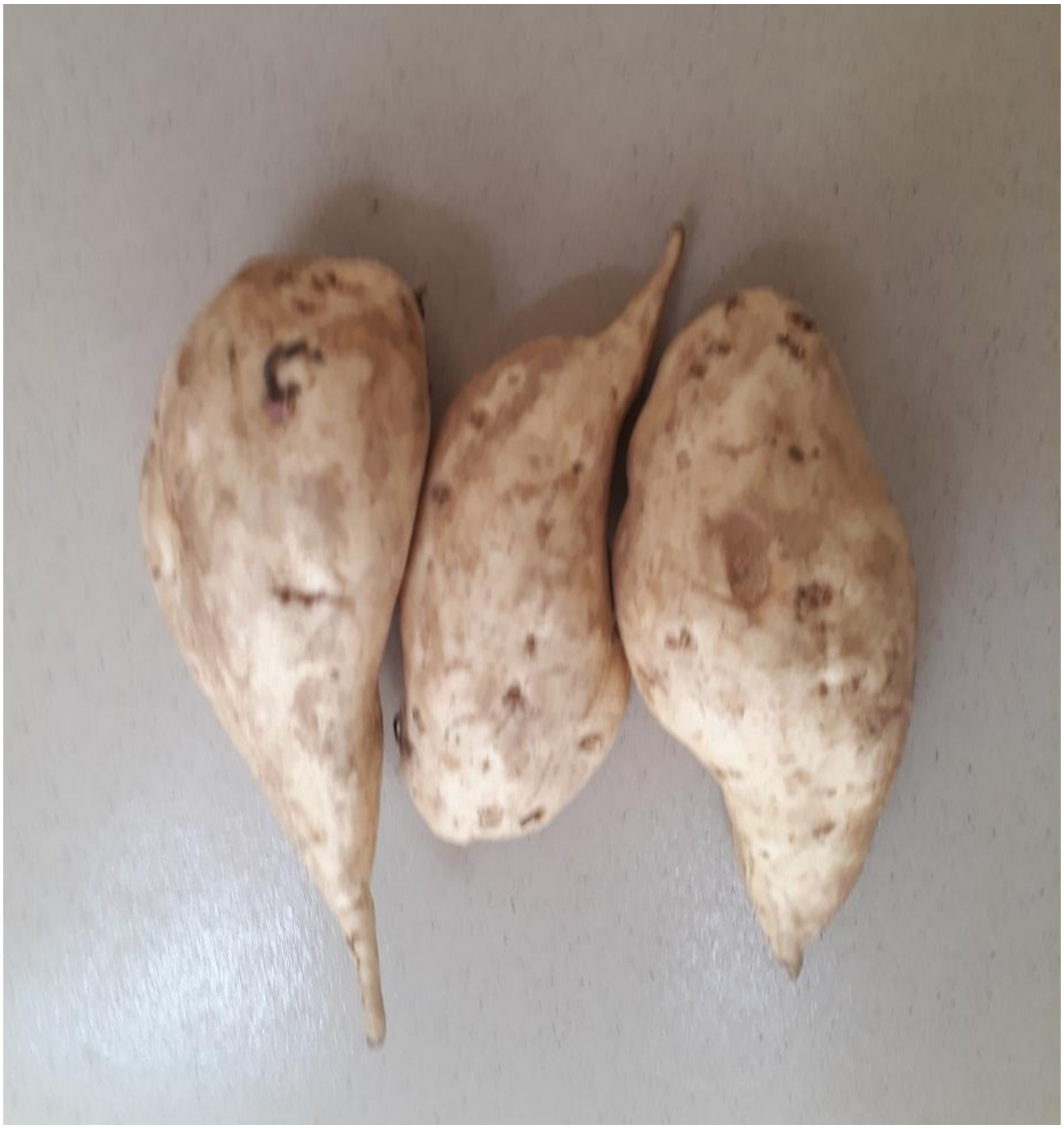
Plate 2.1: Variety of Sweet potato used for the research (Karras).

2.3 Bambara Groundnut

Bambara groundnut is a legume crop native to Africa commonly grown for its seeds by farmers(Mohammed *et al*., 2016). It is grown in many parts of Africa, Asia, Indonesia and South America (National Research Council.,2006). Bambara groundnut (*Vigna subterranea*) belongs to the family of Fabacae (leguminosae)(Mohammed *et al*., 2016**)**. The nuts are commonly known as *Gurjiya* or *Kwaruru* (Hausa, Nigeria), *Okpa* (Ibo, Nigeria*)*, *Epa-Roro* (Yoruba, Nigeria) (Bamishaiye *et al*., 2011). It is well known for its tolerance to drought, relative resistance to pests, diseases and the ability to produce yield in poor soils which are too poor to support the growth of other legumes (Zerihum, 2017).

The varieties of the seeds commonly grown in Nigeria are the cream, speckled or red (Amarteifio *et al*., 2010). However, it is most commonly milled to flour and consumed in different forms as *Moi-Moi* or *Okpa* (paste steamed into a gel), *Akara* (bean cake), soup thickener, and as composite flour (Ade-Omowaye *et al*., 2008). It is also boiled and consumed as snack while mature dried ones are either roasted or used to produce milk (Udeze *et al*., 2014). Products like vegetable milk (Kumar *et al*., 2016) and fermented condiments have been developed from bambara groundnut(Abiodun *et al*., 2017).

2.3.1 Nutritional composition of bambara groundnut

The seeds of ripe bambara groundnut contain about 20% protein, 60% carbohydrates and 7% oil and significant levels of minerals and vitamins (National Research Council, 2006). Lysine and Leucine are the predominant essential amino acids found in bambara groundnut (Mazahib *et al*., 2013). The proximate composition of the bambara groundnut was reported to be 9.7% moisture, 14-24%, protein, 5.9% fat, 2.9% ash, 4% crude fibre and 64.9%

carbohydrate (Olanipekun, *et al*., 2012). The high concentration of soluble fibre also enhances its quality as nutritious food (Olanipekun, *et al*., 2012).

The freshly harvested, semi-ripe bambara groundnut seeds can be roasted and eaten with palm kernel as a snack(Abiodun *et al*., 2017).The predominant fatty acids found in bambara groundnut are linoleic, palmitic and linolenic acids (Minka and Bruneteau, 2000). It has been reported that the nutritional complementarity of cereals and legumes has long been recognized (Kumar *et al*., 2016). Thus, the nutritional value of bambara groundnuts is related to its high lysine content, which makes it a good complement to cereals.

Cereals are low in lysine but high in sulphur containing amino acids that are generally known to be deficient in legumes proteins (Kumar *et al*., 2016).Legumes are known to be deficient in sulphur-containing amino acids, methionine and cysteine but rich in tryptophan and lysine. Bambara groundnut is one of the lesser known and under-utilized legumes that can be used in various food formulations including flour confectionery because of its high protein content (Ade-Omowaye *et al*., 2008).

The digestion and bioavailability of the nutrients in the bambara groundnut seeds for animals and human nutrition is limited by anti-nutrients such as tannins and trypsin inhibitors (Apata and Ologhobo, 1997). However, the tannin content in bambara groundnut is lower than that of cowpea (Asante *et al*., 2004) and pigeon pea (Fasoyiro and Arowora 2005). Thus, different processing methods such as soaking, dehulling, cooking and roasting significantly reduce the tannins and trypsin inhibitor levels in bambara nuts (Apata and Ologhobo (1997). Removal of the anti-nutrients would be necessary for effective utilization of proteins, carbohydrates and minerals in human nutrition (Apata and Ologhobo (1997).

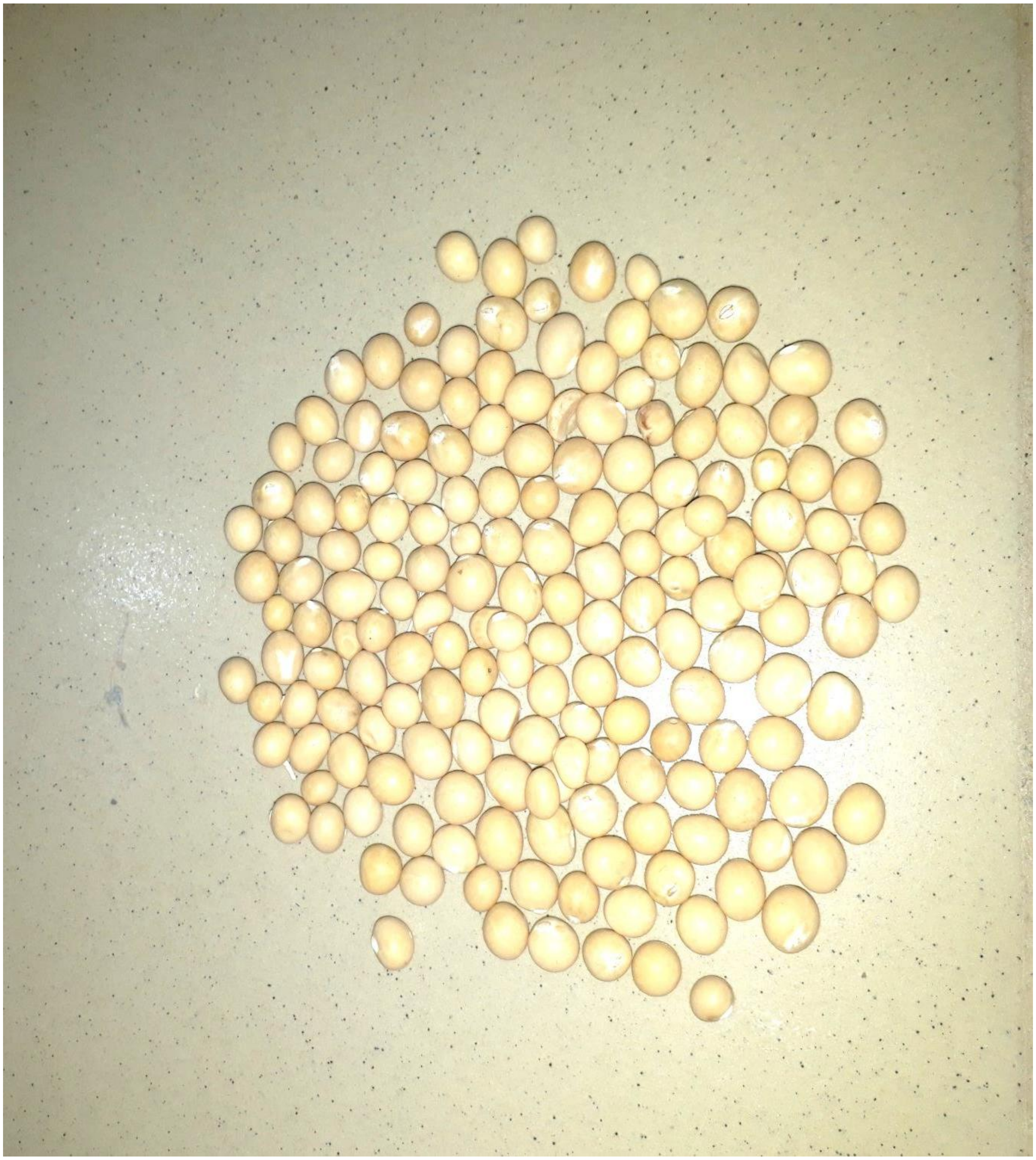

Plate 2.2:Variety of Bambara groundnut used for the research (Mubi white).

2.4 Wheat

Wheat (*Triticum aestivum*family *Poeecae*) is an old and important cereal crop mainly utilised for human consumption and livestock feed (Oluwatoyin *et al*., 2015). A wheat kernel comprises of three principal fractions – bran, germ and endosperm (Apprich *et al*., 2013). Wheat is of the family Poaceae (Oluwatoyin *et al*., 2015). There are various species of wheat, the most important is the common wheat (*Triticum aestivum*), used to make bread; durum wheat (*Triticum. durum*), used in making pasta such as spaghetti and macaroni; and club wheat (*Triticum. compactum*), a softer type, used for cake, crackers, cookies, pastries, and flours (Oluwatoyin *et al*., 2015). The adaptability and high yields of wheat have contributed to its success. Wheat is an important stable food crop for more than one third of the world population and contributes more calories and proteins to the world diet than any other cereal crops (Shewry, 2009). Wheat consumption is very healthy though importation is the critical challenge (Kumar *et al*., 2011).

2.4.1 Nutritional composition of wheat

Whole wheat contains macro and micro nutrients. Wheat contains carbohydrate 78.10%, protein 10%,fat2.10%, minerals 2.10% and considerable proportions of vitamins (thiamine and vitamin-B) and minerals (zinc, iron) (Kumar *et al*., 2011).The kernel of wheat is a storehouse of nutrients essential to the human diet (Vasil,2007). Wheat ismade up of the bran, germand endosperm. The barn, which is about 14.5% of the kernel weight, consists of a small amount of protein, larger quantities of the B-complex vitamins listed above, trace minerals, and indigestible dietary fibre(Topping, 2007). In the wheat endosperm, about 72% of the protein (gluten) is stored, and is about 83% of the kernel weight(Kumar *et al*., 2011). It is the source of the white flour used for bread and pastries. Wheat germ is the embryo of the wheat kernel. The germ or embryo of the wheat is relatively rich in protein, fat and several of the B-vitamins (Hayam, *et al*., 2015).

2.4.2 Wheat flour

Wheat flour could be made from whole wheat or processed into white flour. Whole wheat is highly nutritional as it contains fibre which is present in the wheat bran, minerals and vitamins (Shewry, 2009). However, whole wheat flour is poor in gluten and thus only used for the production of whole wheat bread(Shewry, 2009). Flour that are made from wheat include all-purpose flour, whole wheat flour, durum flour, semolina, gluten flour, self-raising flour and many more (Kumar *et al*., 2011). Wheat flour is used to prepare bread, produce biscuits and confectionary products(Kamaljit *et al*., 2010).The key characteristics, which has given it an advantage over other temperate crops, is the unique properties of dough formed from wheat flours, which allow it to be processed into different range of baked products (including breads, cakes and biscuits), pasta and noodles, and other processed foods (Hayam *et al*., 2015).

The type of wheat flour used for bread production is called hard wheat where the flour is milled from the endosperm of the wheat kernel, primarily for commercial bakers but is also available at retail outlets.(Kumar *et al*., 2011). Consumers prefer products of refined white flour due to its characteristic gluten concentration which gives it the viscoelastic property (Adams *et al*., 2002). These proteins have an effect on the textural ability of the flour and significantly affect the volume of the finished product. Though some nutrients in refined white flour are lost, they are mostly fortified after processing and substitution with other legumes and tubers will increase its nutrients density (Mohammed *et al.,* 2012.) Processing of whole wheat to refined white flour, the endosperm is highly utilized, as it contains the characteristic gluten proteins (Boz and Karaoğlu, 2013).

In developing countries the nutritional importance of wheat proteins cannot be underestimated, where bread, noodles and other products may provide a substantial proportion of the diet (Kumar *et al*., 2011). Pastries and bread baked from high quality composite flour or wheat flour can be measured by using physical dough-testing devices which evaluate the bread-making potential and performance characteristics of the fortified flour (Mohammed *et al.,* 2012.) Gluten proteins found in wheat plays a key role in guaranteeing the bakery quality of wheat, and influence water absorption, cohesion, viscosity, extensibility, elasticity, resistance to deformation, tolerance to kneading, ability to gas retention and dough-strengthening properties (Wieser, 2007).

Plate 2.3: Variety of whole wheat used for the research (Florence Aurore 8193, Samwhit-2)

2.5 Bread

Bread is an important staple food in most countries and is an important source of nutrients that are essential for human health (Aider *et al.*, 2012). The nutrient contents of bread depend on the chemical composition and baking processes used (Mohammed *et al*., 2008). Bread is made from processes involving mixing, kneading, proofing, shaping and baking. It is produced mainly from wheat flour, water, yeast and salt and recently composite flours (Dewettinck *et al*., 2008). Flour and various ingredients are used in a number of combinations and proportions in the preparation of bread.

There are various recipes and modes of preparing bread. Because of this, bread comes in a variety of sizes, shapes, and textures. Bread is a leavened food normally produced through fermentation of sugars that have been obtained from starch (commonly white wheat flour), and which results in chemical interactions between a number of components in the food. Certain ingredients are used during the bread making process for the purpose of ensuring the development of the continuous gluten protein network that is indispensable in guaranteeing the quality of bread (Kurek and Wyrwisz, 2015).

Bread is generally a perishable product with a shelf-life that is limited by the physicochemical deterioration known as staling, which leads to hardening and a dry texture connected with losing the moisture of bread (Peighambardoust and Aghamirzaei 2014). Retrogradation of amylose and amylopectin is a process that leads to staling of bread (Emna *et al*., 2016). The characteristics of bread such as loaf weight, volume, texture, color and specific volume (SV) are among the most important characteristics taken into account by consumers (Fagundes *et al*., 2018). The mechanical properties of bread are often associated with the perception of freshness and elasticity and influence the consumption decision (Fagundes *et al*., 2018). According to Ortolan and Steel (2017), the ability of the dough to expand and retain the gas formed is due to the gluten proteins present in the refined white wheat flour.Bread making is temperature dependent and involves a two-step progression. It consists of fermentation, in which CO_2 production linked with yeast activity is manifested in porous dough structure and the development of dough volume during baking where yeast activity is ended and the bread structure is concluded, thus the gluten cross- links and starch granules are disrupted (Ali *et al*., 2012). The concluding bread structure depends on dough ingredients, yeast activity, fermentation temperature, and gas bubble formation (Ali *et al*., 2012).

Baking of bread with wheat alone does not provide the necessary amino acids, thus, the need to blend with legume flour (Alozie*et al*., 2009). The enrichment of bread and other cereal based confectionaries with legume flours particularly in regions where protein utilization is inadequate has long been recognized. (Okoye and Okaka,2009). This is because legumes are nutritionally rich in protein and other nutrients (Jideani and Onwubali, 2009). Legumes thus can complement cereals when blended at optimum ratio (Okoye and Okaka, 2009). It is important to improve the amino acid profile of wheat and thus provide a blend of essential amino acids in the flour and their products.

These blends could have the potential of improving the nutritive value of bread thereby enhancing the adequacy of the nutrients intake of the population (Alozie *et al*., 2009). Thus blending would provide nutrients rich flour for utilization in production of many food products such as bread which would help in reducing protein-energy malnutrition and enhance use of underutilized crops (Alozie *et al*., 2009).

2.5.1 Bread production

Bread making process include mixing, dough resting, dividing and shaping, proofing, and baking. During mixing, fermentation, and baking, the dough is subjected to extensional deformations (including fracture), which are largely affected by temperature and water hydration (Rosell and Collar, 2008). Physical changes occur during the bread making process, in which gluten proteins are mainly responsible for bread dough structural formation, while starch is implicated in final textural properties and stability (Singh *et al*., 2005). Mixing is one of the key steps that determine the mechanical properties of the dough, and has consequence on the quality of the end product(Ortolan and Steel, 2017). During mixing the various ingredients are evenly distributed, the component of the wheat flour are hydrated, supplying the necessary mechanical energy for developing the protein network, and incorporates air bubbles into the dough (Cristina, 2011).

The dough has to be mixed for an optimum time to fully develop, and at this stage it offers maximum resistance to extension. Excessive mixing could change the dough properties from smooth and elastic to slack and sticky (Sliwinski *et al*., 2004), and consequently a decrease in the consistency is observed, which is attributed to the weakening of the protein network. Bread dough is a viscoelastic material that exhibits an intermediate rheological behavior between a viscous liquid and an elastic solid (Adams *et al*., 2002).

Bread dough must be extensible and elastic enough for expanding and holding the released gases (Bakare, 2016). The viscoelastic network of the gluten proteins plays a predominant role in dough formation and has an impact the textural characteristics of the finished bread (Adams *et al*., 2002). The viscoelastic properties of the dough depend on both quality and quantity of the proteins, and the size distribution of the proteins. Two proteins present in white flour (gliadin and glutenin) form gluten when mixed with water and give dough these special features. Gluten greatly influences the mixing, kneading, and baking properties of dough (Bakare, 2016).

The next level is proofing or fermentation, during this stage, yeast metabolism results in carbon dioxide release and growth of air bubbles previously incorporated during mixing, this leads to expansion of the dough. The growth of gas bubbles during proof and baking determines the characteristics of the bread structure, the volume and texture of the baked product (Cauvain, 2015). The yeast breaks down carbohydrates (starch and sugars) down into carbon dioxide and alcohol during alcoholic fermentation. The carbon dioxide produced in these reactions causes the dough to rise (ferment or proof), and the alcohol produced evaporates from the dough during the baking process (Cristina, 2011). Kneading or remixing of the dough favors the release of large gas bubbles, resulting in evenly distribution of the bubbles within the dough (Cauvain, 2015).

The intense heat of the oven penetrates the dough; the gases inside the dough expand, with a concomitant increase in the size of the dough. As the temperature rises, the rate of fermentation and production of gas cells increases, and this process continues until the temperature of yeast inactivation is reached (Ali *et al*., 2012). Endogenous enzymes present in the dough are inactivated at different temperatures during baking. The sugars and breakdown products of proteins released from the enzyme activity are available to sweeten the bread crumb and participate in Maillard or non-enzymatic browning reactions, which are responsible for the brown color of the crust (Cristina, 2011).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Materials

3.1.1 Sample Collection

Four kilograms (4kg) of white wheat flour(Nigerian Flour Mills Golden Prime) was purchased fromOKESSON, a mega distributor for bread bakeries in Abuja. Sweet potato (karras), wheat grains (sam whit-2) and bambaragroundnut (mubi white) were purchased from Zaki farm in Zaria. They were authenticated at Herbarium Department of Botany, Ahmadu Bello University, Zaria. The voucher numbers are sweet potato (01701), wheat grains (01590), bambara groundnut (075) and white wheat flour (0626).

3.2 Methods

3.2.1 Preparation of raw materials

3.2.1.1 *Preparation of bambaragroundnut flour*

Bambara groundnuts (2kg) were manually sorted to remove extraneous materials. They were soaked in clean water for 12 hours, manually dehulled and dried in an oven(OU-440, Gallenhamp, England) at 65°C for 24 hours. It was milled using a hammer mill (Cyclotec-1093, Foss, Sweden), and the flour obtained was made to pass through 0.25mm sieve to obtain uniform sizes. The flour was then packed in sealed plastic bag and stored at ambient temperature (25^{o}C) (Awolu, 2018).

3.2.1.2 *Preparation of sweet potato flour*

Sweet potato tubers (2kg) were sorted and washed to remove sand, dirt and other adhering materials. The tubers were sorted, peeled and sliced to obtain a thickness of 6 mm. The slices were then washed and blanched in hot water for 5 minutes to inactivate the enzymes that cause browning before drying in an oven(OU-440, Gallenhamp, England)at 65^{0}C for 24hrs. The dried slices were milled in a hammer mill(Cyclotec-1093, Foss, Sweden) to obtain flour. The flour was then sieved using 0.025mm sieve, packed in a sealed plastic bag and stored at ambient temperature (25^{o}C) (Nguyen, 2018: Adeleke and Odedeji, 2010).

3.2.1.3 *Preparation of whole wheat flour*

Wheat grains (2 kg) were cleaned to remove extraneous materials. They were then milled using a hammer mill(OU-440, Gallenhamp, England) and afterwards sieved using 0.25 mm sieve. The flour was packed in a sealed plastic bag and stored at ambient temperature(25^{o}C) (Ayele *et al*., 2017).

3.2.1.4 *Formulation of composite flours*

Composite flour consisting of different proportions ofwheat, sweet potato and bambara groundnut flour were prepared as in Table 1. The controls were hundred grams (100g) of whole wheat flour (Sample A) and hundred grams (100g) of white wheat flour (Sample B).

Table 3.1: Formulation of composite flour

Sample	Weight of flour (g)			
	Whole wheat	White-wheat flour	Bambara-groundnut	Sweet potato
A	100	-	-	-
B	-	100	-	-
C	-	90	5	5
D	-	80	10	10
E	-	70	15	15
F	-	60	20	20

A: 100g whole wheat flour. **B:** 100g white flour. **C:** 90gwhite wheat flour + 5g sweet potato flour + 5g bambaragroundnut flour. **D:** 80g white wheat flour + 10g sweet potato flour + 10g bambaragroundnut flour. **E:** 70g white wheat flour + 15g sweet potato flour + 15g bambaragroundnut flour. **F:** 60g white wheat flour + 20g sweet potato flour + 20g bambaragroundnut flour.

3.2.2 Characterization of the composite flour from wheat, sweet potato and bambara groundnut

3.2.2.1 *Determination of water absorption capacity*

The method described by Onwuka (2005) was used. One gram (1g) of the flour sample was weighed and put in a 15 ml centrifuge tube. It was then suspended in 10 ml of water. The tube was agitated for 1 minute at room temperature(30 ± 2°C). The samples were allowed to stand for 30 mins and centrifuged (CFB 700010C, Gallenhamp, England) at 2000 rpm for 30 min. The clear supernatant was discarded and the centrifuge tube was weighed with the sediment. The amount of water bound by the sample was determined by difference and expressed as the weight of water bound by 100g dry of flour.The percentage water absorption capacity was calculated.

$$\mathrm{WAC}\,(\%) = \frac{\text{Weight of water bound}}{\text{Weight of sample}}\ \mathrm{x}\ 100$$

3.2.2.2 *Determination of oil holding capacity*

Oil absorption capacity (OHC) was determined according to the method described by Onwuka (2005). One gram (1g) of the flour was mixed with 10 ml of refined corn oil in a centrifuge tube and agitated for 2 minutes. It was then allowed to stand at room temperature(30 ± 2°C) for 1 hr. It was centrifuged at 4000 rpm for 20 min. The amount of oil bound was determined by differenceand expressed as amount (ml) of oil bound by 100g dried flour.

$$\mathrm{OHC}(\mathrm{ml/g}) = \frac{\text{Amount of oil bound}}{\text{Weight of sample}}$$

Amount of oil bound = Volume of oil added – Volume of free oil.

3.2.2.3 *Determination of swelling capacity*

Swelling capacity was determined according to the method described by Robertson *et al*., (2000). About 0.2g of flour sample was mixed with 10 ml of distilled water in a calibrated cylinder at room temperature(30 ± 2°C). After equilibration for 18 hours, the bulk volume was recorded and swelling capacity expressed as volume occupied by sample per gram of original dry weight of the sample.

$$\text{Swelling Capacity (ml/g)} = \frac{\text{Change in Volume of Sample}}{\text{Original Weight of Sample}}$$

Change in volume = Bulk volume – Initial volume of sample.

3.2.2.4 *Determination of bulk density*

The bulk density (BD) of the sample was determined using the method described by Onwuka (2005). Ten grams of the sample was weighed into 50 ml measuring cylinder. The sample was packed by gently tapping the cylinder on the bench until a constant volume was obtained. The volume of the sample was recorded.

$$\text{Bulk Density (mg/ml)} = \frac{\text{Weight of Sample}}{\text{Volume of Sample after tapping}}$$

3.2.2.5 *Determination of gelation capacity*

The gelation capacity was done as described by Coffman and Gracia (1977). The sample dispersions of 2, 4, 6, 8, 10, 12, 14, 16, 18 and 20% (w/v) were prepared in 5ml distilled water indifferent test tubes. The sample test tubes were heated for 1 hour in a boiling water bath (FS100b, Decon, England), followed by rapid cooling under running tap water. The tubes were later cooled at 4^0C for 2hrs. The least gelation capacity was determined as the concentration when the sample from the inverted test tubes did not fall or slip from the tubes.

3.2.3 Production of bread from wheat, sweet potato and bambara groundnut composite flour

To each of hundred grams (100g) of samples A, B, C, D, E and F of the formulated flour, 2.5 g of yeast, 2g of sugar and 65mls of water were added. Ingredients were thoroughly blended in a mixer (63325, Hamilton Beach, India) to produce dough. The dough obtained after the mixing process was kneaded until consistent dough was obtained. The resulted dough was left to rest for 20minutes at room temperature (30 ± 2°C) (first proofing), then hundred grams (100g) piece of dough wasdivided, rolled and moulded. Each piece was placed in a metal pan and allowed to ferment for 45 mins at room temperature (final proofing). This is to enable the dough samples to ferment resulting in gas production and gluten development (Cauvian 2015). The dough samples were then baked in the oven (OV-440, Gallenhamp, England) at 230°C for 25 minutes. The baked loaves were carefully removed from the pans and allowed to cool at room temperature (30 ± 2°C) for one hour and packaged for analyses.

3.2.3.1 *Determination of physical properties of the produced bread from wheat, sweet potato and bambara groundnut composite flour*

The loaf weight: Loaf weight (W) of bread was measured after cooling for one hour on a weighing balance (AR2130, Ohaus, Japan) (Nwosu *et al*., 2014).

The loaf volume: The loaf volume of each bread sample was measured 50 minutes after the loaves were removed from the oven by using the rape-seed displacement method as described by Onwuka (2005). Soybean seeds were used in place of rape-seeds. This was then followed by the volume of the container from its graduation which was recorded as

V_1(ml). The container was then filled with soy bean seeds and a rule was used to press across the top of the box once to give a level surface. They were then poured out, weighed and recorded as W_1 (g). The weight of the seeds that filled the container is equivalent to the total weight of seeds that completely occupied the volume of the container. Then, half of the volume of the container was filled with the soy bean seeds, the loaf in each case laid flat at the centre of the container and then the remaining seeds were used to fill up the container. With a ruler, the seeds above the rim were cut off. The seeds displaced by the loaf in each case were collected, weighed and recorded as W_2 (g) (this weight of seeds corresponded to the volume of space displaced by the loaf sample placed in the container). The loaf volume for each bread sample was calculated thus

$$\text{Loaf Volume (ml)} = \frac{W_2 \times V_1}{W_1}$$

Where W_1= weight of seeds that filled the container, W_2= weight of seeds displaced by the loaf sample and V_1 = volume capacity of the container.

The specific loaf volume: The specific loaf volume for each sample was determined by dividing the loaf volume of each sample with the corresponding loaf weight (Nwosu *et al*., 2014).

$$\text{Specific loaf volume (ml/g)} = \frac{\text{Loaf volume}}{\text{Loaf weight}}$$

The density:The density for each sample was determined by dividing the loaf weight of each sample with the corresponding volume (Nwosu *et al*., 2014).

$$\text{Density (g/ml)} = \frac{\text{Loaf weight}}{\text{Loaf volume}}$$

3.2.4 Determination of proximate composition

3.2.4.1 *Determination of protein content*

The micro-Kjeldahl method as described by Association of Official Analytical Chemist AOAC (2005) was used to determine the crude protein. About two grams (2g) of the sample was put into the digestion flask. Ten grams (10g) of copper sulphate and sodium sulphate (catalyst) in a ratio of 5:1 respectively and 25 ml concentrated sulphuric acid (H_2SO_4) were also added to the digestion flask. The flask was placed into the digestion block in the fume cupboard and heated until frothing ceased giving clear and light blue green coloration. The mixture was then allowed to cool and diluted with distilled water to 250 ml. The distillation apparatus (Kjeltec 2200, FOSS, Sweden) was connected, and 10 ml of the mixture was poured into the receiver of the distillation apparatus, followed by addition of 10 ml of 40% sodium hydroxide. The released ammonia was then treated with 0.02M hydrochloric acid until the green colour changes to purple. Percentage of nitrogen in the sample was calculated using the formula below:

$$\text{Nitrogen}(\%) = \frac{(\text{Titre value} - \text{Blank})\ \text{x}\ 14\ \text{x}\ \text{N}}{\text{Weight of sample x } 1000}\ \text{x}\ 100$$

Crude Protein = %Nitrogen × 6.25 (Conversion factor)

N = Normality of HCl

14 = Each ml of HCl is equivalent to 14 mg nitrogen

3.2.4.2 *Determination of fat content*

The Soxhlet extraction method was used in determining the fat content of the samples (AOAC 2005). A 500 ml capacity round bottom flask was filled with 300 ml petroleum ether and fixed to the soxhlet extractor. About two grams (2g) of sample were placed in a labeled thimble. The extractor thimble was sealed with cotton wool. Heat was applied to reflux the apparatus for eight hours. The thimble was removed with care. The petroleum ether was recovered for reuse. When the flask was free of ether, it was removed and dried at 10 ^{o}C for one hour in an oven (NYC-101, Fulton, England). The flask was cooled in desiccators and weighed

$$\text{Fat (\%)} = \frac{\text{Weight Loss}}{\text{Weight of sample}} \text{ x } 100$$

Weight Loss = (Weight of flask + fat) – Weight of empty flask

3.2.4.3 *Determination of crude fibre*

Crude fibre was determined using the method of AOAC (2005). Five grams of each sample was weighed into a 500ml Erlenmeyer flask and 100 ml of Trichloroacetic acid (TCA) digestion reagent was added. It was boiledusing a hot plate (4B-5804D, Gallenhamp, England) for 40 mins. The flask was removed at the end of boiling and allowed to cool for 5 mins and then filtered through a 15.0 cm Whatman No 4 filter paper. The obtained filtrate was thrown off and the residue was returned to the fibre flask in which 100ml of 0.3N sodium hydroxide (NaOH) was added and heated for another 30 mins. The residue was removed and finally transferred into the crucible. The crucible and the residue were oven (OV-440, Gallenhamp, England) dried at 105^{0}C overnight to remove the moisture. The oven dried crucible containing the residue were cooled in a dessicatorand later weighed to obtain the W_1. The crucible with W_1 was transferred to the muffle furnace (6B79070, Gallenhamp, England) for ashing at 550^0C for 6 hours. The crucible containing ash was cooled in the dessicator and weighed to obtain W_2.

$$\text{Crude Fibre}(\%) = \frac{W_1 - W_2}{W_0} \times 100$$

W_1=weight of crucible+fibre+ash

W_2=weight of crucible+ash

W_0=Dry weight of sample

3.2.4.4 *Determination of ash content*

The method described by AOAC (2005) was used to determine the ash content of the samples. Five grams (5g) of each sample was weighed into crucibles in duplicate, and then the sample was incinerated in a muffle furnace (6B79070, Gallenhamp, England) at 550°C for six hours until a light grey ash was observed and a constant weight obtained. The samples were cooled in the desiccator to avoid absorption of moisture and weighed to obtain ash content.

$$\text{Ash } (\%) = \frac{\text{Weight of Ash}}{\text{Weight of Sample}} \text{ x } 100$$

3.2.4.5 *Determination of moisture content*

Moisture content was determined using the method described by AOAC (2005). Five grams of each sample was weighed into an empty crucible of known weight. It was then dried in the oven (OV-440, Gallenhamp, England)at 105^oC until a constant weight was observed.

The samples were cooled in desiccators and weighed. The moisture content wascalculated as follows:

$$\text{Moisture Content } (\%) = \frac{\text{Change in Weight}}{\text{Initial Weight of Before drying}} \times 100$$

3.2.4.6 *Determination of available carbohydrate content*

Carbohydrate content was determined by difference using the method of Egounlety and Aworh (1990), by subtracting the total sum of the percentage of fat, moisture, ash, crude fibre and protein content from hundred (100).

3.2.4.7 *Determination of dietary fibre*

Dietary fibre was determined using enzymatic gravimetric method (AOAC, 1995). One gramof each sample was weighed in a 400ml beaker. Then 40 mlof phosphate buffersolution at pH 6.0 was added and stirred to prevent lump formation. The solution was incubated at 95^{0}Cwith 50ml of heat stable ∝-amylase solution and continuous stirring occurred for 30 mins in a water bath(FS100b, Decon, England). Thesolution was allowed to cool at room temperature and pH adjusted to 7.0. Afterwards, 100 ml of protease solution was added and incubated in a water bath (FS100b, Decon, England) at 60^{o}C. It was mixed with 5 ml of 0.5N HCl solution, adjusted at pH 4.0. After then, 200 ml of amyloglucosidase solution was added and stirred at 60℃ in a hot plate (4B-5804D, Gallenhamp, England) for 30 mins. To extract the insoluble fiber, the solution was filtered using a glass filter with 1 g celite. The filtrate was washed with 15 ml of 78% ethanol, 95% ethanol and acetone in turn. After overnight, the residue in the glass filter was weighed for the insoluble fiber. Afterwards, the filtrate was collected and 95% ethanol and 10ml of distilled water were both added. For extract of soluble fiber, the solution was filtered using a glass filter with celite and the filtrate was washed with 15 ml of 78% ethanol, 95% ethanol and acetone, in turn. After overnight, the residue in the glass filter was weighed for the soluble fiber. The summation of the soluble and insoluble fibre was recorded as the total dietary fibre.

3.2.5 Determination of mineral composition of bread produced from wheat, sweet potato and bambara groundnut composite flour

The mineral content of the bread samples was determined by using the method described by AOAC (2005). For wet digestion of sample, one gram (1g) of each of the samples was put in digestion glass tubes. 12 ml of 1% nitric acid (HNO_3) was added to each of the sample and kept at room temperature. Then 4 ml of 5% perchloric acid ($HClO_4$) was added to each mixture and kept in the digestion box for digestion. The temperature was increased gradually, starting from 50^oC and increasing up to 250-300^oC until white fumes appeared. The mixtures were left to cool down at room temperature (30 ± 2°C)and the contents of the tubes were transferred to 100 ml volumetric flasks, filtered using whatman filter paper No 4 and the volumes of the contents were made to 100 ml with distilled water. The wet digested solution was transferred to plastic bottles labeled accordingly. The digest was used for mineral determination. The mineral elements such as iron (Fe), zinc (Zn), magnesium (Mg) and calcium (Ca) were determined by atomic absorption spectrophotometry (22 PC atomic absorption spectrophotometer,Spectrumlab, England), while sodium and potassium by flame photometry (FP902, PF Instruments, United Kingdom). Different electrode lamps were used for each mineral. Standard solution was prepared for each mineral.For the determination of calcium, 1.0 ml lithium oxide solution was added to the original solution to unmask calcium from magnesium.For determination of Mg, further dilution of the original solution was done using 0.5 ml of original solution and 99.5 ml of distilled water was added to it to make the volume up to 100 ml.Each element was quantified at a particular wavelength.

$$\text{Concentration of each mineral } \left(\frac{\text{mg}}{100\text{g}}\right) = \frac{\text{Cs} - \text{Cb (ppm)} \times \text{vol of filtrate}}{10 \times \text{weight of sample}} \times 100$$

The concentrations of minerals (ppm) were converted to milligrams (mg) by multiplying by the dilution factor and dividing by 1000.

3.2.6 Determination of vitamin composition of bread producedfrom wheat, sweet potato and bambara groundnut composite flour

3.2.6.1 *Determination of beta-carotene*

The carotenoid content was determined by the method describedby Ohizua *et al*., (2017). Standard riboflavin solutions were prepared. Six grams of the sample was mixed with 15 ml of 70% methanol (v/v), and filtered through a Whatman filter paper 4. The residue was extracted two more times with 15 ml acetone-petroleum ether 1:1 (v/v). The extracts were then transferred to 500 ml separating funnel. 5ml of 10% sodium hydroxide in methanol 1:1 (v/v) was added and the mixture allowed to stand for one and a half hours. Partition was achieved by adding 15 ml of petroleum ether and 20 ml of 20% sodium chloride and mixing gently. The hypophasic (lower) layer was discarded. The epiphasic (upper) layer was washed three times with 20 ml of distilled water to remove excess acetone, filtered through a small funnel containing 3 g anhydrous sodium sulfate to remove residual water.

The funnel was plugged with glass stopper to hold sodium sulfate. The filtrate was made up to 100 ml with petroleum ether and the absorbance was measured at 450 nm (the wavelength of maximum absorption for β-carotene in petroleum ether) using a UV/Visible spectrophotometer (UV-2600, Shimadzu, Japan).

$$\text{Beta carotene } (ug/g) = \frac{\text{A} \times \text{V(ml)} \times 10000}{2592 \ \times \text{W}}$$

Where: A = Absorbance,

2592 = Absorption co-efficient of carotenoid in solvent used petroleum ether

V (ml) = volume of the solution.

W - Weight of the sample in gram

Conversion factor 12 β-carotene = 1RAE

3.2.6.2 *Determination of Vitamin E*

Samples were extracted with methanol-BHT (butylhydroxytoluene) (1mg/ml) solution as described by Miranda *et al*., (2010). The separation was carried out using a symmetry column (150×4.6mm 5 μm). Methanol: acetonitrile (1:1 v/v) was used as mobile phase with a flow rate of 1.0 ml/min. Detection was performed by fluorescence usingan HPLC system (RF-10AXL, Shimadzu Co., Kyoto, Japan)at 295 nm and 325 nm as excitation and emission wavelengths for sample and standard respectively. The vitamin E concentrations were calculated in mg/100g using average peak area compared between standard and sample after duplicate injections.

3.2.6.3 *Determination of Vitamin C*

This was determined by method described by AOAC (2005). About 0.5g of pure ascorbic acid standard was dissolved in 60 ml of 20% glacial acetic acid and diluted to 250ml with distilled water. 10ml of this standard was pipetted into a conical flask and titrated with 2, 6-dichlorophenol indophenol (dye) solution until a faint pink color persisted for 15 seconds. Ten gram(10g) of the sample was homogenized with l00ml of glacial acetic acid. The suspension was filtered through a Whatman filter paper No l. Then10ml of the filtrate was pipetted into a conical flask containing 2.5ml acetone and was titrated with the dye solution (2, 6-dichlorophenol indophenol)until a faint pink color persisted for 15 seconds. Ascorbic acid was calculated as mg per 100g flour sample as:

$$\text{Ascorbic acid mg/100g} = \frac{\text{N} \times \text{ Titre value}}{\text{weight of sample}} \times 100$$

N = mg of ascorbic acid standard equivalent to 1ml of dye solution.

V = volume of dye used

3.2.6.4 *Determination of Thiamine*

About 70ml of 0.1 M hydrochloric acid was added to 3g of each sample in a beaker. Thesample was heated in boiling water in a water bath for 30mins. The mixture was then cooled to 50^0C and the pH was adjusted to 4.5 with 2M sodium acetate solution. Freshly prepared phosphatase mix (5ml) was added to the mixture and incubated at 37^0C for 12hrs with theaddition of a drop of suphur free toluene. The mixture was thereafter cooled to ambient temperature (30^0C), centrifuged at 2000rpm for 15 minutes and the supernatant was transferred to a 100 ml volumetric flask. The supernatant then madediluted to 100 ml with distilledwater. Thereafter, 5ml of 3% acetic acid solution was added and allowed to stand for 3hours, then 10 ml of acidicpotassium chloride solution was added. This was followed by the addition of 3 ml of alkaline potassium ferricyanide solution, 25ml of water saturated Isobutyl alcohol and3 ml of 15% sodium hydroxide solution one after the other. Standard thiamine solutions werealso prepared. The absorbance of the sample and standard solutions were recorded at excitation wavelength of 360nm and emission wavelength of 435nm. The concentration of thiamine in the sample was calculated from the calibration curve (AOAC, 1995).

$$\text{Thiamine}\,\frac{\text{mg}}{100\text{g}} = \frac{\text{sample absorbance} \times \text{weight of standard(mg)}}{\text{standard absorbance} \times \text{weight of sample (g)}} \times 100$$

3.2.6.5 *Determination of Riboflavin*

Riboflavin was determined by the method described by AOAC (2005). Two gram of sample was added to 50ml of 0.02M acetic acid solution and made up to 100ml. The mixture was transferred into 125ml Erlenmeyer flask and heated in boiling water in a water bath with intermittent shaking for one hour. The mixture was cooled and the pH was adjusted to 6.0 with 1M sodium hydroxide (NaOH). The mixture was mixed thoroughly and the pH was brought down to 4.5 with 1 M hydrochloric acid (HCl). The solution was diluted to100ml and then filtered. 10ml of the extract and 1ml distilled water were added to 2 test tubes respectively.Similarly, l0ml extract and lml riboflavin standard were also added to two test tubes, respectively. To the four test tubes, lml of 3% glacial acetic acid was added and mixed thoroughly. To all test tubes, 0.5ml of 0.3% potassium permanganate ($KMn0_4$) solution was added, mixed thoroughly and allowed to stand for 2min. Thereafter, 0.5ml of 3% hydrogen peroxide solution was added with thorough mixing, to allow the color to disappear within 10 sec. The riboflavin standard solutions of were also prepared.

The absorbances of the standard and test samples were recorded at 563nm. From the plot of the riboflavin standard, the concentration of riboflavin in the test sample was calculated.

$$\text{Riboflavin } \frac{\text{mg}}{100\text{g}} = \frac{\text{sample absorbance } \times \text{ weight of standard(mg)}}{\text{standard absorbance } \times \text{ weight of sample (g)}} \times 100$$

3.2.7 Determination of anti-nutritional factors

3.2.7.1 *Determination of tannin*

About one gram (1g) of each sample was dispersed in 10ml of distilled water. This was left to stand for 30 mins at room temperature (25 ± 2°C), being shaken every five minutes. At the end of 30 mins, the solution was centrifuged and supernatant collected. The supernatant (2.5 ml) was dispersed into aflask. Similarly 2.5 ml of standard tannic acid solution was dispersed into a separate flask. Afterwards, 1 ml of Folin-Denis reagent was measured into each flask, followed by 2.5ml of saturated sodium bicarbonate (Na_2CO_3)solution. The mixture was diluted to 50 ml mark of the flask and incubated for 90 mins at room temperature. The absorbance was measured at 250nm using a spectrophotometer. Readings were taken with the reagent blank at zero (Onwuka, 2005).

$$\text{Tannin}(\%) = \frac{A_n \times \text{C} \times 100 \times V_f}{A_s \times \text{W} \times V_a} \times 100$$

A_n = absorbance of test sample.

A_s = absorbance of standard solution.

C = concentration of standard solution

W= weight of sample used.

V_f= total volume of supernatant gotten

V_a= total volume of supernatant analyzed

3.2.7.2 *Determination of phytate*

Four grams (4g) of each sample was soaked in 100 ml of 2% hydrochloric acid (HCl) for 3 hours and then filtered through a Whatman filter paper No 4. About25 ml of the filtrate was put inside a conical flask and 5 ml of 0.3% of ammonium thiocyanate solution was added as an indicator. Thereafter, 53.5 ml of distilled water was added to get it the proper acidity and this was titrated against 0.00566 g/ml of standard iron (111) chloride ($FeCl_3$) solution containing about 0.00195g of iron per ml until a brownish yellow colouration persisted for 5 min.Afterwards the concentration of phytate was determined according to Onwuka, (2005).

$$\text{Phytate}(\%) = \text{Titre value} \times 1.19 \times 0.00195 \times 100$$

3.2.7.3 *Determinationoftrypsininhibitors*

This was determined by method described by Onwuka (2005). One gram (1g) of the sample was dispersed in 50ml of 0.5M sodium chloride (NaCl) solution. The mixture was stirred for 30 min at room temperature and centrifuged at 3,600 rpm for 30mins. The supernatant was filtered through Whatman No 4 filter paper and the pellet discarded. The filtrate was used for the assay. N-α- Bensoyl-DL-arginine-p-nitroanilide wasused as a substrate. Into a test tube containing 10ml of substrate and 2ml of the filtrate, 2 ml of standard trypsin was added.A blank using 2 ml of the standard trypsin and 10 ml of the substrate was also prepared. The contents of the test tubes were allowed to stand for 30min. Their absorbances were then measured spectrophotometrically at 410nm. The extent of inhibition of trypsin hydrolysis of the filtrate was used as a standard to measure the trypsin inhibition activities of the test sample. One trypsin inhibited unit (TIU) is equal to an increase of 0.01 in absorbance unit at 410nm. The trypsin inhibitor activity was expressed as the number of trypsin inhibited unit (TIU) per unit weight (g) of the sample analyzed.

$$\mathrm{TIU/g} = \frac{\text{Absorbance of sample}}{\text{Absorbance of standard}} \times 0.01\mathrm{F}$$

F = experimental factor, given by

$$\mathrm{F} = \frac{1 \times V_f}{\mathrm{W} \times V_a}$$

W = weight of the sample

V_f = total volume of the extract (filtrate)

V_a= volume of filtrate used for the assay.

3.2.7.4 *Determination of oxalate*

Oxalate was determined according to the method described by Onwuka (2005). About 2.0g of the sample was dispersed in 190ml of distilled water in 250ml volumetric flask. Ten ml of 6M hydrochloric acid (HCl) was added, then digested at 100°C for one hour, cooled and made up to 250ml mark before filtration. The filtrate was precipitated with 0.5M ammonium hydroxide and the precipitate was dissolved in 10ml of 20% sulphuric acid. The solution was titrated against 0.05M potassium permanganate.

$$\text{Oxalate (\%)} = \frac{\mathrm{T} \times 0.0025}{\mathrm{W}} \times 100$$

Where T= Titre value

0.00225ganhydrous oxalic acid = 1ml of potassium permanganate.

W= Weight of sample

3.2.8 Determination of the shelf life of bread produced from wheat, sweet potato and bambar groundnut composite flour

This was determined according to the methods described by Udeme *et al*., (2014). The bread samples were stored at room temperature(25 ± 2 °C) and at 37^0C; and observed for five days. Colourand odour changes were recorded. Visual observations for mold growth were also carried out on the samples stored. The various growths were observed under the microscope using the wet-mount method. The fungi were identified in each sample and recorded.

3.2.9 Sensory evaluation of bread produced from Wheat, Sweet potato and Bambara groundnut composite flour

Sensory evaluation was carried out using a 15 semi-trained panelist to assess the organoleptic attributes of the bread samples. This was done within three hours after baking. The organoleptic attributes assessed were; the taste, after taste, appearance, the aroma, the texture, the crust colour, the crumb colour and the overall acceptability. The panelists were selected randomly from the staff and students of the Ahmadu Bello University, Zaria. They were made to carry out the organoleptic assessment under controlled environment to avoid biased results. The bread samples wrapped with transparent polyethylene bags were presented in small sliced and coded with identical white papers. The panelists were instructed to rate the breads based on a 9-point hedonic scale ranging from 9=liked extremely to 1=disliked extremely. The raw scores were assembled and statistically analyzed using the methods described by Mepba *et al* (2007).

3.2.10 Data analysis

Results were expressed as mean values and standard deviation of three (3) determinations. The data obtained for the flour and bread samples were analyzed usingone way analysis of variance (ANOVA), using Statistical Packaging for Social Science (SPSS, IBM, Armonk-) version 20.0 software. The level of significance was set at $P < 0.05$. Duncan multiple range test was used to differentiate the means where significant differences exist.

CHAPTER FOUR

4.0 RESULTS

4.1 Functional Properties of the Composite Flour of Wheat, Sweet potato and Bambara groundnut

The functional properties of the composite flour are presented in Table 4.1. The result of the bulk density showed sample A which had a value 0.81 mg/ml was higher when compared to other samples (B to F).Sample A was significantly higher ($P<0.05$) than sample B which had a value of0.65 mg/ml.Samples C and D were significantly lower ($P<0.05$)than sample A. However, sample E and F were not significantly different ($P>0.05$) from sample A.Sample B was significantly lower ($P <0.05$) than the composite blends (D, E and F), although not significantly difference ($P>0.05$) from sample C. Amongst the composite blends (C to F), samples C and F had the least and highest bulk density respectively.

The results of the swelling capacity showed sample A with a value of 0.13 ml/g was significantly lower ($P<0.05$) than sample B which had a value of 0.47 ml/g. Samples C, D, E and F were significantly higher ($P<0.05$)than sample A. Sample B was significantly higher ($P<0.05$) than the composite blends(C to F). Sample C with a value of 0.40 ml/g was significantly the highest ($P<0.05$) when compared to samples D, E and F.

It was observed from the results of the water absorption capacity (WAC) that sample A with a value of 2.62 %was significantly lower ($P<0.05$) than sample B (4.46 %)and the composite blends (C to F). It was observed that sample B was not significantly different ($P>0.05$) from C, but was significantly lower ($P<0.05$) than the values obtained for the samplesD, E and F. Across the composite flours (C to F), C was significantly the lowest ($P<0.05$), howeverD was not significantly different ($P>0.05$) from E.

The oil holding capacity (OHC) showed sample A with a value of 0.66 ml/g was significantly lower ($P<0.05$) than sample B and the composite blends(C to F). Sample B had a value of 1.69 ml/g whichwas not significantly different ($P>0.05$) from C but significantly lower ($P<0.05$) than samples D, E and F. The results of the composite blends (C to F) showed sample C had a value of 1.72 ml/g which was significantly lower ($P >0.05$) than D, E and F.

The results of the gelation capacityshowed sample A had a value of 12.00 % which was significantly lower($P<0.05$) than sample B (10 %). Sample A was not significantly different ($P>0.05$) from C and F, but significantly lower ($P<0.05$) when compared to sample E. Sample B was significantly lower ($P <0.05$) than samples C, E and F, but not significantly different ($P>0.05$) from D. The values obtained for the composite blends(C to F) showed E was significantly the highest ($P<0.05$). Samples C and F had a value of 12 % which were not significantly different ($P>0.05$) from each other.

Table 4.1: Functional Properties of the Composite flour of Wheat, Sweet potato and Bambara groundnut

Samples	BD(mg/ml)	SC(ml/g)	WAC(%)	OHC (ml/g)	GC (%)
A	0.81 ± 0.01^{c}	0.13 ± 0.07^{a}	2.62 ± 0.21^{a}	0.66 ± 0.01^{a}	12.00 ± 0.01^{b}
B	0.65 ± 0.02^{a}	0.47 ± 0.14^{f}	4.46 ± 0.22^{b}	1.69 ± 0.04^{b}	10.00 ± 0.01^{a}
C	0.68 ± 0.02^{a}	0.40 ± 0.01^{e}	4.68 ± 0.01^{b}	1.72 ± 0.01^{b}	12.00 ± 0.01^{b}
D	0.74 ± 0.03^{b}	0.31 ± 0.01^{d}	5.15 ± 0.01^{c}	2.13 ± 0.02^{c}	10.00 ± 0.01^{a}
E	0.78 ± 0.03^{bc}	0.28 ± 0.01^{c}	5.31 ± 0.01^{c}	2.31 ± 0.01^{d}	13.50 ± 0.71^{c}
F	0.78 ± 0.03^{bc}	0.23 ± 0.01^{b}	5.64 ± 0.05^{d}	2.63 ± 0.02^{e}	12.00 ± 0.01^{b}

Values are presented as mean ± SD of three determinations. Means with different superscripts down the column are significantly different ($p < 0.05$).
BD: Bulk density, SC: Swelling capacity, WAC: Water absorption capacity, OHC: Oil holding capacity GC: Gelling capacity.
A: 100g whole wheat flour. **B:** 100g white wheat flour. **C:** 90gwhite wheat flour + 5g sweet potato flour + 5g bambaragroundnut flour. **D:** 80g white wheat flour + 10g sweet potato flour + 10g bambaragroundnut flour. **E:** 70g white wheat flour + 15g sweet potato flour + 15g bambaragroundnut flour. **F:** 60g white wheat flour + 20g sweet potato flour + 20g bambaragroundnut flour.

4.2 Proximate Composition of Wheat, Sweet potato and Bambara groundnut flours blend

The results of the proximate compositions are presented in Table 4.2. The result showed that sample A had a moisture content of 6.05 % which was not significantly different (P>0.05) from sample B (5.68 %). However, sample A was significantly lower (P<0.05) when compared to samples C, D, E and F. The composite blends (C to F) were significantly higher (P<0.05) than sample B. As the substitution increased across the composite flours (C to F), no significant difference (P>0.05) was observed.

For the ash contents, the results showed that sample A with a value of 1.45 % was significantly higher (P<0.05) than sample B and the composite blends (C and D). However sample A was significantly lower (P<0.05) than sample F but was not significantly different (P>0.05) from sample E. Sample B had a value of 0.89 % which was significantly lower (P<0.05) when compared to samples C, D, E and F. It was observed thatthe composite blends (C to F) showed a significant increase (P<0.05), with sample F having the highest value of 1.79 %.

The results of the crude lipid showed that sample A had a value of 7.90 % which was not significantly different (P>0.05) from sample B, though it was significantly higher (P<0.05) than sample C. Samples D, E and F were significantly higher (P<0.05) than sample A. Sample B had a value of 7.05 % which was significantly lower (P<0.05) than samples C, D, E and F. Amongst the composite blends (C to F), F had a value of 11.05 %which was significantly higher (P >0.05) when compared to C, D and E, however no significant difference (P>0.05) was observed between samples C and D.

For the crude protein contents, sample A (13.97 %) was significantly higher ($P<0.05$) than sample B, and when compared to samples C and D. However, sample A was significantly lower ($P<0.05$) than samples E and F. Sample B had the least value of 8.74 % which was significantly lower ($P<0.05$) than the composite blends (C to F). The values of the composite blends (C to F) showed significant increase ($P<0.05$) as the level of substitution increased, with sample F having the highest value of 15.26 %.

The results of the carbohydrate contents showed sample A had a value of 72.85 % which was significantly higher ($P<0.05$) than sample B (71.79 %) and the composite blends (C to F). Sample B was significantly higher ($P<0.05$) when compared to samples C, D, E and F. For the composite blends, significant decrease ($P<0.05$) was observed from C to F, as the level of substitution increased, with sample C having the highest value of 67.99 %.

The results of the crude fibre contents, showed sample A (1.25 %) was significantly higher ($P<0.05$) than sample B (0.01 %) and the composite blends (C to F). The values of samples C to F were significantly higher ($P<0.05$) than sample B. A significant increase ($P <0.05$) was observed in the composite blends (C to F), as F had the highest value of 1.05 %.

Table 4.2: Proximate Composition of Wheat, Sweet patato and Bambara groundnut flour Blend

Sample	Moisture (%)	Ash (%)	Crude lipid (%)	Crude protein (%)	Carbohydrate (%)	Crude fibre (%)
A	6.05 ± 0.07^{a}	1.45 ± 0.07^{d}	7.90 ± 0.71^{a}	13.97 ± 0.01^{e}	72.85 ± 0.01^{f}	1.25 ± 0.01^{f}
B	5.68 ± 0.14^{a}	0.89 ± 0.02^{a}	7.05 ± 0.01^{a}	8.74 ± 0.01^{a}	71.79 ± 0.20^{e}	0.01 ± 0.02^{a}
C	6.90 ± 0.28^{b}	1.10 ± 0.01^{b}	7.85 ± 0.07^{b}	10.46 ± 0.06^{b}	67.99 ± 0.11^{d}	0.45 ± 0.04^{b}
D	6.88 ± 0.25^{b}	1.31 ± 0.01^{c}	8.40 ± 0.57^{b}	11.76 ± 0.06^{c}	65.81 ± 0.35^{c}	0.60 ± 0.03^{c}
E	7.07 ± 0.39^{b}	1.51 ± 0.01^{d}	9.54 ± 0.35^{c}	13.08 ± 0.04^{d}	61.63 ± 0.05^{b}	0.90 ± 0.05^{d}
F	7.23 ± 0.11^{b}	1.79 ± 0.09^{e}	11.05 ± 0.07^{d}	15.26 ± 0.07^{f}	55.79 ± 0.86^{a}	1.05 ± 0.01^{e}

Values are presented as mean ± SD of three determinations. Means with different superscripts down the column are significantly different($p< 0.05$). **A:** 100g whole wheat flour. **B:** 100g white wheat flour. **C:** 90gwhite wheat flour + 5g sweet potato flour + 5g bambara groundnut flour. **D:** 80g white wheat flour + 10g sweet potato flour + 10g bambara groundnut flour. **E:** 70g white wheat flour + 15g sweet potato flour + 15g bambara groundnut flour. **F:** 60g white wheat flour + 20g sweet potato flour + 20g bambara groundnut flour.

4.3 Some Anti-nutritional Factors of Wheat, Sweet potato and Bambara groundnut flours blend

The results of some anti-nutritional factors of flour samples are presented in Table 4.3. It was observed that the phytate content of sample A (0.13 %) was significantly higher (P<0.05) than sample B (0.08 %). Sample A was not significantly different (P>0.05) from samples C and D, however it was significantly lower (P<0.05) when compared to sample E and F. Sample B was significantly lower (P<0.05)than the composite blends (C to F). The phytate content of sample C and D were not significantly different (P>0.05) from each other, however they were significantly lower (P<0.05) than samples E and F.

The tannin content of the flours showed sample A (3.20 %) was not significantly different (P >0.05) from sample B (3.08 %), although it was significantly higher (P<0.05) when compared to the composite blends (C to F). Sample B was significantly higher (P<0.05) when compared to samples C, D, E and F. As the level of substitution increased tannin content of sample C had a value of 2.40 % which was significantly higher (P<0.05) than samples D, E and F.

The values of the oxalate content showed sample A (0.33 %) was significantly lower (P<0.05) than sample B (0.36 %) and the composite blends (C to F). Sample B was significantly lower (P<0.05) when compared to samples C, D, E and F. However, the results of the composite blends (C to F) showed sample C had the least value of 0.43 % which was significantly lower (P <0.05) than D, E and F.

The results obtained for the trypsin inhibitors showed sample A with a value of 19.47 Tul/g was significantly lower (P<0.05) than sample B (21.37 Tul/g) and the composite blends (C to F). Sample B was significantly lower ($P<0.05$) when compared to samples C, D, E and F. Across the composite blends (C to F), sample D had the highest value of 36.53 Tul/g, though, sample D was not significantly different ($P>0.05$) from F.

Table 4.3 Some Anti− nutritional Factors of Wheat, Sweet patato and Bambara groundnut floursblend

Sample	Phytate (%)	Tannin (%)	Oxalate (%)	Trypsin inhibitor (Tul/g)
A	0.13 ± 0.01^{b}	3.20 ± 0.28^{f}	0.33 ± 0.03^{a}	19.47 ± 1.46^{a}
B	0.08 ± 0.01^{a}	3.08 ± 0.11^{e}	0.36 ± 0.01^{b}	21.37 ± 0.54^{b}
C	0.12 ± 0.01^{b}	2.40 ± 0.50^{d}	0.43 ± 0.01^{c}	32.93 ± 0.01^{d}
D	0.14 ± 0.01^{b}	1.83 ± 0.04^{c}	0.96 ± 0.71^{f}	36.53 ± 1.18^{e}
E	0.16 ± 0.01^{c}	1.13 ± 0.04^{b}	0.49 ± 0.01^{d}	23.51 ± 0.09^{c}
F	0.18 ± 0.01^{d}	0.20 ± 0.01^{a}	0.53 ± 0.01^{e}	35.36 ± 0.09^{e}

Values are presented as mean ± SD of three determinations. Means with different superscripts down the column are significantly different($p< 0.05$).
A: 100g whole wheat flour. **B:** 100g whitewheat flour. **C:** 90gwhitewheat flour + 5g sweet potato flour + 5g bambara groundnut flour. **D:** 80g white wheatflour + 10g sweet potato flour + 15g bambara groundnut flour. **E:** 70g white wheatflour + 15g sweet potato flour + 15g bambara groundnut flour. **F:** 60g whitewheat flour + 20g sweet potato flour + 20g bambara groundnut flour

4.4 Physical Characteristics of Bread Produced from Wheat, Sweet potato and Bambara groundnut flours blend

The physical characteristics of the bread samples are shown in Table 4.4. For the loaf weight sample A with value 356.63g was significantly higher (P<0.05) than sample B which had a value of 323.81g. Sample A was significantly higher (P<0.05) when compared to composite blends(C to E)but was not significantly different (P>0.05) from F. Sample B was significantly lower (P<0.05) than samples C, D, E and F. Samples D, E and F were significantly higher (P<0.05) than sample C as the level of substitution increased. Significant difference (P>0.05) was not observed between samples D and E. Samples E and F were also not significantly different (P>0.05) from each other.

The results of the loaf volume revealed sample A had a value of 925.50 ml which was significantly lower (P<0.05) than sample B (1509.50 ml) and the composite blends(C to F). Sample B was significantly higher (P<0.05) than samples C, D, E and F. The values of the composite blends (C to F) showed that as the level of substitution increased, C was significantly higher (P <0.05) than D, E and F.

The specific volume of the samples revealed sample A with a value of 2.60 ml/g was significantly lower (P<0.05) than sample B (4.66ml/g). Samples C, D, E and F were significantly higher (P<0.05) than sample A. Sample B was significantly higher (P<0.05) when compared to samples C, D, E and F. The results of the composite blends (C to F) showed that sample F with the highest substitution was significantly lower (P<0.05) than C, D and E.

The results of the density of loaves showed sample A with a value of 0.39 g/ml was significantly higher (P<0.05) than sample B (0.22 g/ml). Sample A was also significantly higher (P<0.05) when compared to samples C, D, E and F. Sample B was significantly lower (P<0.05) than samples C, D, E and F. However,across the composite blends (C to F), F was significantly higher (P<0.05) than samplesC, D, and E.

Table 4.4: Physical Characteristics of Bread Produced from Wheat, Sweet potato and Bambara groundnut flours blend

Sample	Loaf weight (g)	Loaf volume (ml)	Specific volume (ml/g)	Density (g/ml)
A	356.63 ± 5.47^{e}	925.50 ± 1.41^{a}	2.60 ± 0.04^{a}	0.39 ± 0.01^{f}
B	323.81 ± 1.15^{a}	1509.50 ± 0.71^{f}	4.66 ± 0.01^{f}	0.22 ± 0.01^{a}
C	336.45 ± 1.14^{b}	1455.25 ± 2.48^{e}	4.32 ± 0.01^{e}	0.23 ± 0.01^{b}
D	344.53 ± 1.38^{c}	1351.38 ± 4.42^{d}	3.92 ± 0.28^{d}	0.26 ± 0.01^{c}
E	347.55 ± 1.34^{cd}	1151.75 ± 8.13^{c}	3.32 ± 0.01^{c}	0.30 ± 0.01^{d}
F	351.04 ± 1.44^{de}	958.00 ± 1.41^{b}	2.73 ± 0.01^{b}	0.37 ± 0.01^{e}

Values are presented as mean ± SD of three determinations. Means with different superscripts down the column are significantly different($p< 0.05$).
A: 100g whole wheat flour. **B:** 100g white wheat flour. **C:** 90gwhite wheat flour + 5g sweet potato flour + 5g bambaragroundnut flour. **D:** 80g white wheat flour + 10g sweet potato flour + 10g bambaragroundnut flour. **E:** 70g white wheat flour + 15g sweet patato flour + 15g bambaragroundnut flour. **F:** 60g white wheat flour + 20g sweet potato flour + 20g bambaragroundnut flour.

4.5 Proximate Compositions of Bread Produced from Wheat, Sweet potato and Bambara groundnut flours blend

The results of the proximate compositions are presented in Table 4.5. It showed that for the moisture content, sample A had a value of 12.53 % which was significantly lower (P<0.05) than sample B (24.54 %) and thecomposite blends(C to F). Sample B was significantly lower (P<0.05) when compared to samples C to F. The results of the composite blends(C to F) showed sample F had a value of 31.20 % which was significantly higher (P <0.05) than C, D, and E.

In terms of the ash content sample A (1.79 %) was significantly lower (P<0.05) than sample B (1.61%) and samples C, E and F. No significant difference (P>0.05) was observed between samples A and D. Sample B was not significantly different(P>0.05) from sample C (1.62%), but was significantly lower (P<0.05) when compared to the composite blends (D to F). Across the blends (C to F), F with a value of 2.58 % was significantly higher (P <0.05) than C, D and E.

The results of the crude lipid content showed sample A (8.05 %) was significantly higher (P<0.05) than sample B (7.15 %) but was significantly lower (P<0.05) than the values obtained for samples C to F.Sample B was significantly lower (P<0.05) when compared to values obtained for the composite blends (C to F). Sample F had a value of 15.44 % which was significantly higher (P <0.05) than samples C, D and E, however samples C and D were not significantly different (P >0.05) from each other.

In terms of the crude lipid content, sample A (14.09 %) was significantly higher (P<0.05) than sample B (12.55 %), but significantly lower (P<0.05) than the values obtained for the composite blends (C to F).Samples C, D, E and F were significantly higher (P<0.05) when compared to sample B. The results of the blends showed a significant increase ($P<0.05$) from C to F, as the level of substitution increased with sample C having the lowest value of 15.88 %.

The carbohydrate content of sample A (63.53 %)was significantly higher ($P<0.05$) than sample B (54.14 %) and the composite blends(C to F). Sample B was significantly higher ($P<0.05$) when compared to samples C, D, E and F. Amongst the composite blends (C to F), the highest value was recorded in sample C and the least in sample F, thus significant decrease ($P<0.05$) was observed as the level of substitution increased.

The results of the crude fibre content showed sample Awith a value of 1.03 % wassignificant higher ($P<0.05$) than sample B and the blends(C, D, E and F) were significantly lower ($P<0.05$) than sample A. Sample B had a value of 0.10 % which was significantly lower ($P<0.05$) when compared to the composite blends (C to F). Sample F had value of 0.79 % which was significantly higher ($P <0.05$) than samples C, D and E.

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Table 4.5: Proximate Compositions of Bread Produced from Wheat, Sweet potato and Bambara groundnut flours blend

Sample	Moisture (%)	Ash (%)	Crude lipid (%)	Crude protein (%)	Carbohydrate (%)	Crude fibre (%)
A	12.53 ± 0.04^{a}	1.79 ± 0.01^{b}	8.05 ± 0.07^{b}	14.09 ± 0.16^{b}	63.53 ± 0.81^{f}	1.03 ± 0.04^{f}
B	24.54 ± 0.06^{b}	1.61 ± 0.02^{a}	7.15 ± 0.07^{a}	12.55 ± 0.06^{a}	54.14 ± 0.21^{e}	0.10 ± 0.01^{a}
C	25.70 ± 0.66^{c}	1.62 ± 0.03^{a}	10.54 ± 0.34^{c}	15.88 ± 0.18^{c}	48.53 ± 0.41^{d}	0.43 ± 0.03^{b}
D	28.04 ± 0.23^{d}	1.77 ± 0.03^{b}	11.30 ± 0.42^{c}	17.90 ± 0.50^{d}	42.17 ± 0.97^{c}	0.53 ± 0.04^{c}
E	30.19 ± 0.23^{e}	2.38 ± 0.03^{c}	14.45 ± 0.21^{d}	19.31 ± 0.08^{e}	37.94 ± 0.71^{b}	0.64 ± 0.03^{d}
F	31.20 ± 0.07^{f}	2.58 ± 0.04^{d}	15.44 ± 0.08^{e}	22.62 ± 0.17^{f}	31.77 ± 0.22^{a}	0.79 ± 0.01^{e}

Values are presented as mean ± SD of three determinations. Means with different superscripts down the column are significantly different($p< 0.05$).
A: 100g whole wheat flour. **B:** 100g white flour. **C:** 90gwhitewheat flour + 5g sweet potato flour + 5g bambaragroundnut flour. **D:** 80g white wheat flour + 10g sweet potato flour + 10g bambaragroundnut flour. **E:** 70g white wheat flour + 15g sweet potato flour + 15g bambaragroundnut flour. **F:** 60g whitewheat flour + 20g sweet potato flour + 20g bambaragroundnut flour.

4.6 Dietary Fiber Contents of Bread Produced from Wheat, Sweet potato and Bambara groundnut flours blend

The results of the dietary fibre contents of the bread samples are presented in Table 4.6. For the soluble fibre, sample A had a value of 1.04mg/100g which was significantly higher (P<0.05) than sample B (0.79 mg/100g). Sample A was significant higher (P<0.05) when compared to samples C and F, but was not significantly different (P>0.05) from samples D and E. Sample B was significantly lower (P<0.05) than the composite blends (C to F). The results of composite blends (C to F) showed that no significantdifference (P>0.05) was observed amongst samples C, D and E, howeversample F was significantly lower (P<0.05)than samples D and E.

The insoluble fibre contents of the bread producedshowed that sample A had the highest value of 1.84mg/100g which was significantly higher (P<0.05) than sample B and the composite blends (C to F). Sample B had a value of 1.10 mg/100g which was not significantly different (P>0.05) from C but significantly lower(P<0.05) when compared to samples D, E and F. It was observed that sample D recorded a value of 1.75 mg/100g which was significantly higher (P<0.05) when compared to samples C, E and F.

The results of the total dietary fibre showed sample A had a value of 2.88 mg/100g which was significantly higher (P<0.05) when compared to sample B and the composite blends (C to F). Samples C, D, E and F were significantly lower (P<0.05) when compared to sample B.Across the composite blends (C to F), sample D had a value of 2.69 mg/100g, which was significantly higher (P <0.05) than samples C and F, though not significantly different (P>0.05) from sample E.

Table 4.6: Dietary Fiber Content of Bread Produced from Wheat, Sweet potato and Bambara groundnut flour Blends

Samples	Soluble fibre	Insoluble fibre (mg/100g)	Total Dietary fibre
A	1.04 ± 0.01^{d}	1.84 ± 0.02^{e}	2.88 ± 0.04^{e}
B	0.79 ± 0.01^{a}	1.10 ± 0.02^{a}	1.89 ± 0.02^{a}
C	0.91 ± 0.02^{bc}	1.12 ± 0.05^{a}	2.03 ± 0.01^{b}
D	0.94 ± 0.04^{cd}	1.75 ± 0.02^{d}	2.69 ± 0.04^{d}
E	0.95 ± 0.01^{cd}	1.65 ± 0.01^{c}	2.60 ± 0.01^{d}
F	0.88 ± 0.03^{b}	1.50 ± 0.01^{b}	2.38 ± 0.04^{c}

Values are presented as mean ± SD of three determinations. Means with different superscripts down the column are significantly different($p< 0.05$).
A: 100g whole wheat flour. **B:** 100g white flour. **C:** 90gwhite wheat flour + 5g sweet potato flour + 5g bambaragroundnut flour. **D:** 80g white wheat flour + 10g sweet potato flour + 10g bambaragroundnut flour. **E:** 70g white wheat flour + 15g sweet potato flour + 15g bambaragroundnut flour. **F:** 60g white wheat flour + 20g sweet potato flour + 20g bambaragroundnut flour

4.7 Minerals Content of BreadProduced from Wheat, Sweet potato and Bambara groundnut flours blend

The results of the mineral contents of the bread samples are presented on Table 4.7. The result of the calcium contents showed sample A had a value of 216.75 mg/100g which was significantly lower ($P<0.05$) thansample B and the composite blends (C to F). Sample B with a calcium content of 340.00 mg/100g was not significantly different ($P <0.05$) from sample C, but was significantly lower ($P<0.05$) when compared to samples D, E and F. Across composite blends(C to F), F with a value of 593.75 mg/100g was significantly higher ($P <0.05$) than C, D, and E. It was observed that sample D was not significantly different ($P >0.05$) from sample E.

The magnesium content of the bread produced, showed that sample A with a value of 13.40mg/100g was significantly lower ($P<0.05$) than sample B and the composite blends (D, E and F). However, sample A was not significantly different ($P>0.05$) from sample C. Sample B had a value of 16.59 mg/100g which was significantly lower ($P<0.05$) than samples D and F, but significantly higher ($P<0.05$) than C. No significant difference was observed ($P>0.05$) between samples B and E. The results of the composite blends (C toF) showed sample C had the lowest magnesium content, while sample D with a value of 19.80mg/100g was significantly the highest ($P<0.05$) when compared to C, E and F.

The results of the potassium content showed sample A had the lowest value of 139.75mg/100g. Sample A was significantly lower ($P<0.05$) than samples B to F. Sample B with a value of 206.50 mg/100g was significantly lower ($P<0.05$) when compared to samples D, E and F. Amongst the composite blends (C to F),as the level of substitution increased, sample F was significantly the highest (P<0.05) with sample C having the least value of 217.50 mg/100g.

The sodium contentof the bread produced showed that sample A (72.50 mg/100g) was significantly lower (P<0.05) than sample B and the composite blends (C to F). Sample B had a value of 137.88 mg/100g which was significantly lower (P<0.05) when compared to samples C, D, E and F. The values of thesamples C to F showed sample C was not significantly different (P>0.05) from sample D, however it was significantly lower (P<0.05) when compared to samples E and F.

In terms of the iron levels, sample A with a value of 3.19mg/100g was significantly higher (P<0.05) than sample Bwhich had a value of 1.85mg/100g. Sample A was significantly higher (P<0.05) when compared to samples C (0.61 mg/100g) and F (2.51mg/100g) but significantly lower (P<0.05) than the values recorded for samples D (4.89 mg/100g) and E (4.55 mg/100g). Sample B had an iron content which was significantly higher (P<0.05) than sample C, although was significantly lower (P<0.05) than the composite blends (D to F). The results showed sample D and E were not significantly different from (P>0.05) each other, but were significantly higher (P<0.05) when compared to samples C and F.

The results of the zinc levels sample A had a value of 2.59 mg/100gwhich was significantly higher (P<0.05) than sample B (1.15 mg/100g). Sample A was significantly higher (P<0.05) when compared to the composite blends (C, E and F), however was significantly lower (P<0.05) than sample D which had a value of 2.74 mg/100g. Sample B was significantly lower (P<0.05) when compared to thecomposite blends (D and E) but not significantly different (P>0.05) from sample C. The results of samples C to F, showed that sample D had a value of 2.74 mg/100g which was significantly higher ($P < 0.05$) than samples C, E and F.

Table 4.7: Mineral Content of Bread Produced from Wheat, Sweet potato and Bambara groundnut flours blend

Sample	Ca	Mg	K	Na	Fe	Zn
			(mg/100g)			
A	216.75±4.60[a]	13.40±0.85[a]	139.75±2.48[a]	72.50±0.00[a]	3.19±0.24[d]	2.59±0.14[d]
B	340.00±14.14[b]	16.59±0.30[b]	206.50±4.95[b]	137.88±7.60[b]	1.85±0.02[b]	1.15±0.01[b]
C	377.90±17.11[b]	14.51±0.27[a]	217.50±3.54[b]	171.25±1.77[c]	0.61±0.01[a]	1.18±0.04[b]
D	468.75±44.19[c]	19.80±0.71[d]	282.50±0.00[c]	180.40±6.51[c]	4.89±0.13[e]	2.74±0.06[e]
E	467.50±3.54[c]	15.98±0.40[b]	325.25±3.89[d]	210.00±0.00[d]	4.55±0.11[e]	2.12±0.05[c]
F	593.75±15.91[d]	18.01±0.12[c]	383.75±19.45[e]	291.25±12.37[e]	2.51±0.19[c]	0.41±0.01[a]

Values are presented as mean ± SD of three determinations. Means with different superscripts down the column are significantly different($p < 0.05$).
A: 100g whole wheat flour. **B:** 100g white wheat flour. **C:** 90gwhite wheat flour + 5g sweet potato flour + 5g bambaragroundnut flour. **D:** 80g white wheat flour + 10g sweet potato flour + 10g bambaragroundnut flour. **E:** 70g white wheat flour + 15g sweet potato flour + 15g bambaragroundnut flour. **F:** 60g white wheat flour + 20g sweet potato flour + 20g bambaragroundnut flour.

4.8 Vitamins Content of Bread Produced from Wheat, Sweet potato and Bambara groundnut flours blend

The vitamin contents of the bread samples are represented in Table 4.8. The result showed that sample A was significantly higher (P<0.05) than samples B and the composite blends (C to F). Sample B was not significantly different (P>0.05) when compared to samples C, D, E and F. Amongst the composite blends (C to F), no significant difference (P>0.05) was observed, however there was slight increase as level of substitution with sweet potato and bambara groundnut increased.

The result of the thiamine levels showed that sample A had the highest value of 3.62 mg/100g which was significantly higher (P<0.05) than sample B (0.88 mg/100g) and thecomposite blends (C to F). Sample B was significantly lower (P<0.05)when compared to samples C, D, E and F. The results of the samples C, D, E and F showed that no significant difference (P >0.05) was observed.

Theriboflavin content of the bread produced showed sample A had a value of 2.21 mg/100g which was significantly higher (P <0.05) when compared to sample B and the composite blends (D and E), however was significantly lower (P <0.05) than samples C and F. Sample B had a value of 1.54 mg/100g which was significantly lower (P <0.05) than the samples C and F, although not significantly different (P >0.05) from sample D. The results of samples C toF, showed sample E had the least value while sample F had a value of 3.57 mg/100g which was significantly the highest (P <0.05) when compared to C, D and E.

Vitamin C results showed sample A had a value of 2.89 mg/100g which was significantly higher (P <0.05) than sample B and the composite blends (C to F). Sample B had a value of 0.80 mg/100g which was significantly lower (P <0.05) when compared to samples C, D, Eand F). Amongst the composite blends (C to F), sample C had the lowest value of 1.11 mg/100g. Sample F had a value of 2.26 mg/100g which was significantly higher (P <0.05) than C and D, however was not significantly different (P >0.05) from sample E. The results also showed samples D and E were not significantly different (P >0.05) from each other.

The vitamin E results showed that sample A (0.88mg/100g) was significantly higher (P <0.05) than sample B and the composite blends (C, D and E). However sample A was significantly lower (P <0.05) than sample F. Sample B was significantly lower (P <0.05) than samples C, D, E and F. The results of samples C to F showed sample F had a value of 1.26 mg/100g which was significantly higher (P <0.05) than C, D and E, although samples C and D were not significantly different (P >0.05) from each other.

Table 4.8: Vitamin Content of Bread Produced from Wheat, Sweet potato and Bambara groundnut flours blend

Sample	Vitamin A (μg/g)	Thiamine (mg/100g)	Riboflavin (mg/100g)	Vitamin C (mg/100g)	Vitamin E (mg/100g)
A	0.26 ± 0.08^{b}	3.62 ± 0.31^{c}	2.21 ± 0.01^{c}	2.89 ± 0.27^{e}	0.88 ± 0.01^{d}
B	0.02 ± 0.01^{a}	0.88 ± 0.01^{a}	1.54 ± 0.01^{b}	0.80 ± 0.01^{a}	0.42 ± 0.01^{a}
C	0.03 ± 0.01^{a}	1.27 ± 0.01^{b}	2.55 ± 0.01^{d}	1.11 ± 0.01^{b}	0.55 ± 0.01^{b}
D	0.03 ± 0.02^{a}	1.26 ± 0.01^{b}	1.63 ± 0.01^{b}	1.88 ± 0.01^{c}	0.59 ± 0.01^{b}
E	0.05 ± 0.01^{a}	1.28 ± 0.02^{b}	1.05 ± 0.21^{a}	2.06 ± 0.01^{cd}	0.75 ± 0.02^{c}
F	0.06 ± 0.03^{a}	1.31 ± 0.01^{b}	3.57 ± 0.01^{e}	2.26 ± 0.05^{d}	1.26 ± 0.04^{e}

Values are presented as mean ± SD of three determinations. Means with different superscripts down the column are significantly different($p < 0.05$).
A: 100g whole wheat flour. **B:** 100g white wheatflour. **C:** 90gwhite wheatflour + 5g sweet potato flour + 5g bambaragroundnut flour. **D:** 80g white wheatflour + 10g sweet potato flour + 10g bambaragroundnut flour. **E:** 70g white wheatflour + 15g sweet potato flour + 15g bambaragroundnut flour. **F:** 60g white wheatflour + 20g sweet potato flour + 20g bambaragroundnut flour

4.9 Some Anti–nutritional f actors of Bread Produced from Wheat, Sweet potato and Bambara groundnut flours blend

The results of some anti-nutritional factors of bread samples are presented in Table 4.9. The result showed that the phytate content of sample A (0.13 %) was significantly higher (P<0.05) than sample B (0.09 %). It was observed that sample A was not significantly different (P>0.05) from samples C and D, however it was significantly lower (P<0.05) when compared to sample E and F. Sample B was significantly lower (P<0.05) when compared with the composite blends (C to F).The phytate content of sample C and D were not significantly different (P>0.05) from each other, however they were significantly lower (P<0.05) than samples E and F.

The result of the tannin content showed sample A was not significantly different (P>0.05) from sample B, although it was significantly higher (P<0.05) when compared to the composite blends (C to F). Sample B was significantly higher (P<0.05) when compared to samples C, D, E and F. As the level of substitution increased tannin content of sample C had a value of 2.43 % which was significantly higher (P<0.05) than the other composite blends (D to F), with sample F having a value of 0.41 %.

The values of the oxalate content showed sample A (0.26 %) was significantly higher (P<0.05) than sample B (0.13 %). Sample A was not significantly different (P<0.05) from sample E, however it was significantly lower (P<0.05) when compared to sample F. The oxalate levels of samples C and D were significantly lower(P<0.05) than sample A. The oxalate content of sample B was significantly lower (P<0.05) when compared to the composite blends (C to F). However, as substitution increased, the results of the composite blends (C to F) showed sample C had the least value of 0.17 % and sample F the highest value of 0.29 %.

The results obtained for the trypsin inhibitors showed sample A was not significantly different ($P>0.05$)from sample B, although A was significantly lower ($P<0.05$) when compared to the composite blends (C to F). Sample B was significantly lower ($P<0.05$) when compared to samples C, D, E and F. Across the composite blends (C to F), sample D was significantly the highest ($P<0.05$), however sample C was not significantly different ($P>0.05$) from E.

Table 4.9: Some Anti-nutritional f actors of Bread Produced from Wheat, Sweet potato and Bambara groundnut flours blend

Sample	Phytate (%)	Tannin (%)	Oxalate (%)	Trypsin inhibitor (TIU/g)
A	0.13 ± 0.01^{b}	$2. 75 \pm 0.07^{e}$	0.26 ± 0.01^{d}	2.22 ± 0.06^{a}
B	0.09 ± 0.01^{a}	2.93 ± 0.11^{e}	0.13 ± 0.01^{a}	2.31 ± 0.01^{a}
C	0.13 ± 0.01^{b}	2.43 ± 0.18^{d}	0.17 ± 0.01^{b}	2.77 ± 0.02^{b}
D	0.12 ± 0.01^{b}	1.82 ± 0.02^{c}	0.23 ± 0.01^{c}	3.84 ± 021^{d}
E	0.14 ± 0.01^{c}	1.18 ± 0.04^{b}	0.26 ± 0.01^{d}	2.74 ± 0.01^{b}
F	0.18 ± 0.01^{d}	0.41 ± 0.01^{a}	0.29 ± 0.01^{e}	3.54 ± 0.09^{c}

Values are presented as mean ± SD of three determinations. Means with different superscripts down the column are significantly different($p< 0.05$).

A: 100g whole wheat flour. **B:** 100g white flour. **C:** 90gwhite wheat flour + 5g sweet potato flour +5g bambaragroundnut flour. **D:** 80g white wheat flour + 10g sweet potato flour + 10g bambaragroundnut flour. **E:** 70g white wheat flour + 15g sweet potato flour + 15g bambaragroundnut flour. **F:** 60g white wheat flour + 20g sweet potato flour + 20g bambaragroundnut flour

5.0 Organoleptic Properties of Bread Produced from Wheat, Sweet potatoand Bambara groundnut flours blend

The results of the organoleptic test are presented inTable 5.0. The resultsobtained for the tasteshowedthat sample A was significantly lower (P<0.05)when compared to sample B and samples (C to F). It was observed that sample B was significantly higher (P<0.05) than the compositeblends (C to F), however no significant difference (P<0.05)was observed across the composite blends (C to F) as the level of substitution increased.

The result of the aftertaste showed sample A with a value of 5.20 was significantly lower(P<0.05) than sample B which had a value of 7.80. Samples C, D and E were significantly higher (P<0.05) than sample A. The result of sample B was significantly higher (P <0.05) than the composite blends (C, D and F), however it was not significantly different (P>0.05) from sample E. It was observed that as the level of substitution increased, no significant difference (P>0.05) was observed amongst the composite blends (C to F).

For the result of aroma, sample A (5.43) was significantly lower(P<0.05) when compared to sample B (7.60) and the composite blends (C to E). It was observed that sample A was not significantly different (P>0.05) from F. Sample B was not significantly different (P>0.05) when compared to samples C, D and E, however it was significantly higher (P<0.05) than sample F, The result also showed that no significant difference (P>0.05)was observed across the composite blends (C to F), although sample C had the highest value of 6.93.

In terms of the crust colour, the value of sample A was significantly lower (P<0.05) than samples B and E. Sample A was not significantly different (P>0.05) from samples C, D and

F. Sample B had a value of 7.80 which was significantly higher (P<0.05) than samples C to F.The composite blends (C to F) were not significantly different (P >0.05) from each other as levels of substitution increased.

For the crumb colour, sample A had a value of 5.50 which was significantly lower (P<0.05) than sample B, and samples C and D. However, samples E and F were not significantly different (P>0.05) from sampleA. The value of sample B (7.67) was significantly higher (P<0.05)when compared to samples E and F, though it was not significantly different (P >0.05) from samples C and D. The composite blends (C to F) were not significantly different (P >0.05) from each other and the highest value of 6.87 was observed in sample D.

The results of the texture showed sample A (5.33) was significantly lower (P<0.05) than sample B and the composite blends C, D and E. Sample F was not significantly different (P>0.05) from sample A. Sample B (7.50) was significantly higher (P<0.05) than sample F (6.00) but was not significantly different (P >0.05) when compared to the composite blends (C, D and E).Nosignificant difference(P>0.05)was observed across samples C, D, E and F, though sample F had the least value of 6.00.

The results of the appearance showed samples A which had a value of 5.33 was significantly lower (P<0.05) than sample B (8.07).Sample A was significantly lower (P<0.05) than samples C, D and E, however nosignificantly difference (P>0.05)was observed with sample F. Sample B was significantly higher (P<0.05) when compared to samples C, D, E, and F. Across the results of the composite blends (C to F), no significant difference (P>0.05) was observed.

The overall acceptance of the bread produced showed sample A had a value of 5.29 which was significantly lower ($P<0.05$) than sample B (8.00) and the composite blends (C to F). Sample B was not significantly different ($P>0.05$) from sample E, although it was significantly higher ($P<0.05$) when compared to samples C, D and F. The results of samples C, D, E and F showed that no significant difference ($P>0.05$) was observed, though sample D had the lowest value of 6.53.

Table 5.0: Organoleptic Properties of Bread Produced from Wheat, Sweet potato and Bambara groundnut flours blend

Property	Sample					
	A	B	C	D	E	F
Taste	$5.27±1.03^{a}$	$8.20±0.94^{c}$	$6.67± 0.98^{b}$	$6.93± 1.58^{b}$	$7.13± 1.41^{b}$	$6.47± 1.81^{b}$
After Taste	$5.20±0.94^{a}$	$7.80±1.15^{c}$	$6.60±1.68^{b}$	$6.47±1.96^{b}$	$7.00±1.13^{bc}$	$6.07±1.87^{ab}$
Aroma	$5.43±0.65^{a}$	$7.60±0.83^{c}$	$6.93±0.96^{bc}$	$6.73±1.39^{bc}$	$6.80±1.37^{bc}$	$6.20±1.86^{ab}$
Crust colour	$5.64±1.15^{a}$	$7.80±1.08^{c}$	$6.67±1.40^{ab}$	$6.67±1.35^{ab}$	$6.80±1.66^{b}$	$6.60±1.40^{ab}$
Crumb colour	$5.50±1.35^{a}$	$7.67±1.40^{c}$	$6.73±1.79^{bc}$	$6.87±1.41^{bc}$	$6.53±1.46^{ab}$	$6.27±0.96^{ab}$
Texture	$5.33±1.29^{a}$	$7.50±1.16^{c}$	$6.80±1.86^{bc}$	$7.13±1.25^{c}$	$6.87±1.06^{bc}$	$6.00±1.60^{ab}$
Appearance	$5.33±1.25^{a}$	$8.07±0.88^{c}$	$6.80±1.86^{b}$	$6.87±1.50^{b}$	$6.87±1.55^{b}$	$6.33±1.29^{ab}$
Overall acceptability	$5.29±1.00^{a}$	$8.00±0.85^{c}$	$6.67±1.18^{b}$	$6.53±1.46^{b}$	$7.20±1.15^{bc}$	$6.60±1.68^{b}$

Values are presented as mean ± SD, n =15. Means with different superscripts across the row are significantly different($p< 0.05$)
A: 100g whole wheat flour. **B:** 100g white flour. **C:** 90gwhitewheat flour + 5g sweet potato flour + 5g bambaragroundnut flour. **D:** 80g white wheat flour + 10g sweet potato flour + 10g bambaragroundnut flour. **E:** 70g whitewheat flour + 15g sweet potato flour + 15g bambara groundnut flour. **F:** 60g white wheat flour + 20g sweet potato flour + 20g bambaragroundnut flour.

5.1 Shelf Life of Bread Produced from Wheat, Sweet potato and Bambara groundnut flours blend

The results of the shelf life of the bread samples are presented in Table 5.1. It was observed that at room temperature (25 ± 2 °C) samples A, B and C showed mold growth on the fifth day, while the composite blends (D, E and F) showed mold growth on the fourth day. At incubation temperature of 37^{o}C, mold growthwas observed in samples A and B on the fourth day, while those of the composite blends (C, D, E and F) were observed on the third day. The microscopic examination of the molds found in sample A and B at room temperature (25 ± 2 °C) showed the presence of *Aspergillus sp*and in the case of the composite blends (C, D, E and F);*Rhizopussp*was found in addition to *Aspergillus sp*. At 37^{o}C, microscopy revealed the presence of *Mucor sp* besides the other two species found at room temperature (25 ± 2 °C) for all the bread samples.

Table 5.1: Shelf life (days) of Bread produced from Wheat, Sweet potato and Bambaragroundnut flours blend

Bread Sample	Room temperature (25 ± 2 °C)		Temperature(37°C)	
	Days of appearance of mold growth	(Fungi)	Days of appearance of mold growth	(Fungi)
A	5	*Aspergillus sp.*	4	*Aspergillus sp; Rhizopus sp; Mucor sp.*
B	5	*Aspergillus sp.*	4	*Aspergillus sp; Rhizopus sp; Mucor sp.*
C	5	*Aspergillus sp; Rhizopus sp.*	3	*Aspergillus sp; Rhizopus sp;Mucor sp.*
D	4	*Aspergillus sp; Rhizopus sp.*	3	*Aspergillus sp; Rhizopus sp;Mucor sp.*
E	4	*Aspergillus sp; Rhizopus sp.*	3	*Aspergillus sp, Rhizopus sp;Mucor sp.*
F	4	*Aspergillus sp; Rhizopus sp.*	3	*Aspergillus sp; Rhizopus sp; Mucor sp.*

A: 100g whole wheat flour. B: 100g white flour. C: 90gwhite wheat flour + 5g sweet potato flour + 5g bambaragroundnut flour. D: 80g whitewheat flour + 10g sweet potato flour + 10g bambaragroundnut flour. E: 70g white wheat flour + 15g sweet potato flour + 15g bambaragroundnut flour. F: 60g white wheat flour + 20g sweet potato flour + 20g bambaragroundnut flour.

CHAPTER FIVE

5.0 DISCUSSION

Bread is a confectionary product commonly consumed by the masses. It is important that the nutritional composition of bread is improved, and this has led to increased research on the formulation of composite flours. In this study, local food sources (bambara groundnut and sweet potato) were used to substitute white wheat flour for bread production. This study showed that composite flour in varying ratios wereformulated from wheat, sweet potato and bambara groundnut.

The functional properties of the flour determine the application and use of the flour for various products. The bulk density reflects the weight of the sample. The result of the bulk density is a reflection of the particle size and density of the flour (Ajanaku *et al*., 2011). The whole wheat had the highest bulk density. This could be attributed to the presence of the bran which contains a high level of fibre.The bulk density of the flour samples increased as the substitution of white wheat flour with sweet potato and bambaragroundnut increased. This could be attributed to the presence of fibre and starch in the sweet potato and bambara groundnut which made the flour denser.

The increase in the bulk density could also be as a result of increased particle size of the flour blends. Thisresults agree with the work of Abiodun *et al* (2017) where composite flour blend of wheat and bambara groundnut was used for doughnut production. They observed that bulk density was affected by substitution of wheat flour. The findings also agree with the work of Ohizua*et al*(2017)where theystudied composites ofunripe banana, pigeon pea and sweet potato.Their study also revealed an increase in bulk density which could be as a result of the composites which were denser. The higher bulk density could result in the reduction of the degree of expansion of flour blends(Kumar *et al*., 2016).

The swelling capacity of any sample depends on the granules and its particle size (Ajanaku *et al*., 2011). The results showed that the swelling capacity of the whole wheat flour had the least value. This could be attributed to the blending of the bran and germ of the whole wheat, whichhinders the development of gluten proteins and thus affects the volume of the dough. The white wheat flour which has been processed and contains high levels of gluten proteins had the highest swelling capacity whichgives the dough its texture and strength.

Swelling capacity in this study decreased as the level of substitution increased. This could be attributed to the presence of fibre in sweet potato and bambara groundnut. Presence of fibre reduces the strength of the dough as they acts as strands inhibiting gluten development. Thus, substitution of white wheat flour affects the swelling capacity. The reduction in the swelling capacity could result in the reduction in the volume of bread or pastry produced. These values agreed with the study conducted by Adeyeye and Akingbala (2015), where composite flour blend of wheat and sweet potato was used for production of cookies. Similar results wereobtained by Ajanaku *et al* (2011), where they observed reducedswelling capacity from composites of wheat and brewery spent grain.

The water absorption capacity is the optimal amount of water a product can take to achieve its desired consistency, and this is greatly affected by the constituents (Nwoji, 2004). The results showed the whole wheat flour recorded the least value. This could be as a result of the reduced content of starch and proteins. The white wheat flour had a higher value when compared to the whole wheat flour. This could be as a result of the high levels of starch known to be present in the endosperm of the processed white wheat flour, and thus encourage the uptake of water. The water absorption capacity (WAC)recorded higher valuesas substitution levels increased. This could be attributed to the presence of starch and proteins in sweet potato and bambara groundnut. Starch and proteins are hydrophilic and thus encourage the uptake of water. It could also be as a result of the processing of the bambara groundnut which have the tendency to bind more water due to the nature of the proteins.

Similar increase in water absorption capacity was recorded in the findings of Ohizua *et al*(2017). Thefindings0 of Adeleke and Odedeji (2010), where composite of wheat and sweet potatowere used, showed lower values than those recorded in this study, however thiscould be attributed to the presence of lower amount of starch and proteins in the composite flour which have hydrophilic constituents. Better water absorption and retention suggests better performance in texture of baked products (Awolu, 2018).

The oil holding capacity of flour (OHC) is important as it improves the mouth feel and retains the flavour. The oil absorption capacity denotes how much oil is bound to matrices in particular food system (Oluwana *et al*., 2011). The results showed that the whole wheat had the least value. This could be as a result of lower amounts of proteins and fat. The results of the oil holding capacity showed an increase as substitution of sweet potato and bambara groundnut increased. This could be attributed to the presence of linoleic and linolenic acids in bambara groundnut.The presence of protein in bambara groundnut exposes more non-polar amino acids to the fat thus, enhances more absorption of oil by the composite flour. This result was similar to the findings of Igbabul *et al*(2012) on thecomposite flour of wheat, sweet potato and hamburger bean, who suggested that higher

OHC may be related to the presence of non- polar amino acids in the flour blends. The mechanism of oil absorption is attributed mainly to the physical entrapment of oil and the binding of fat to a non polar chain of protein (Ajani *et al*., 2016).

The increasing concentration of protein enhances the interaction among the binding forceswhich in turn increases the gelling ability of the flour (Lawal, 2004).Gelation capacity indicates that flour blends may be good binders during the production of pastries and bread. The variation in gelation of samples suggests that interactions between the food components may have significant role in functional properties as it varies fromflour to flour depending on the relative ratios of their structural constituents like protein, carbohydrates, and lipids(Aremu *et al*., 2007).

The white wheat flour had the lowest gelling capacity when compared to the composite flours. The composite flours had increased gelling capacity, which could be due to the presence of higher levels of starch. Starch is known to induce gelation due to its ability to interact with proteins. The results were within the range for gelation capacity which is 12 %to 14 % (Suresh*et al*., 2015). The result agrees with the findings of Ohizua *et al* (2017) where the value of gelation capacity was as high as 14%. The values were lower than those reported by Ajani*et al* (2016), where composite flour of wheat and bread fruit was studied.

The moisture content of foods is usually used as an indicator of food quality. It is important to measure the moisture content in breads because of its potential impact on the sensory, physical, shelf life and microbial properties of the bread. The findings of the proximate compositions of the flour showed the white wheat flour had a moisture content which was the least.This could be attributed to the reduced particle size which limits the uptake of water. The composite flours had higher moisture content when compared to the white wheat flour. This could be as a result of theincreased particle size and processing of sweet potato and bambara groundnut which enhanced the uptake of water. Though, they were within the acceptable range of 7 % for flours specified by SON (SON, 2004). Thisfindings were similar to those reported by Adeyeye and Akingbala (2015) where composite of sweet potato and maize were used for the production of composite flour. The values they obtained were attributed to the substitution effects by sweet potato and maize.

The ash content is a measure of the minerals present in the flour samples. The result showed that the white wheat flour had the lowest ash contents. The composite flours had increased ash content as the level of substitution increased. This could be attributed to the presence of minerals in sweet potato and bambara groundnut, which enhanced their levels. Thus consumption of the composite flour will improve the levels of minerals when compared to the white wheat flour. These findings were slightly lower than the results obtained by Onoja *et al* (2014), where composites of orarudi and wheat flour was used for bread production. Their findings were also attributed to increased levels of minerals in the composite flour as a result of substitution.

Lipids content usually plays a role in the shelf life stability of flour samples. The presence of lipids enhances the flavor and taste of baked products. The results of the crude lipid showed that white wheat flour had the least value. This could be attributed to the processing which reduced the lipid content. The composite flour showed increased lipid content. This could be due to the presence of linoleic and linolenic fatty acids in bambara groundnut. The high oil content of the composite breadcouldaffect the shelf stability. These results were higher than the findings reported by Igbabul *et al* (2012), who worked on the composites of wheat, sweet potato and hamburger bean.

Inclusion of legumes can increase the nutritional value of cereal based foods. Legumes can be used in bread and pastries to obtain protein-enriched products with improved amino acid balance. The results of the crude protein showed the white wheat flour had the least protein content. Substitution increased the protein content of the composite flour due to the presence of a legume, bambara groundnut in the composite flour, thus it could improve the amino acid profile. Bambara groundnut has a crude protein content range of about 14 to 24% (Mazahib *et al*., 2013). This result is similar to that reported by Arise *et al*(2015) where composite flour blend of wheat, plaintain and bambara groundnut were used. They observed inclusion of bambara groundnut improved the protein contents of the composite flour.

Carbohydrate in foods provides energy to the body for metabolic activities and work. The results of the carbohydrate content obtained showed the whole wheat flour had the highest values. This could be attributed to the presence of the bran in the whole wheat. Cereals are known to contain high levels of carbohydrate. The composite flours showed reduced carbohydrate content as substitution increased when compared to the white wheat flour. This could be attributed to the fact that white wheat flour which has been processed contains high levels of starch. Though the composite flours also contain starch, the presence of protein could reduce the carbohydrate content.Findings in this study suggest that bread couldserve as source of energy for metabolic process in the mammalian body. This findings were similar to those obtained by Igbabu *et al* (2015), where incorporation of hamburger bean to wheat reduced the carbohydrate content.

The results of the crude fibre content of the flour samples showed that the whole wheat flour had the highest content. This could be attributed to the presence of fibres in the bran of the whole wheat flour. The composite flours had increased fibre content as the level of substitution increased when compared to the white wheat flour. This could also be due to the higher content of fibre in sweet potato and bambaragroundnut. These results were lower than the findings reported by Fagunde *et al* (2018), where composite of wheat and cobia was used for bread production. They observed higher crude fibre content due to substitution with cobia.

The loaf and specific volume are indications of the proofing ability of the flour. The presence of gluten gives the dough its viscoelastic property. The process of mixing, kneading and proofing helps the development of the gluten (Sliwiski *et al*., 2004).Theresults of the loaf and specific volume showed the whole wheat bread had the leastvalue, this could be attributed to the presence of the bran and germ which hinders the development of gluten and inhibits rising. The white wheat bread had the highest value; this could be as a result of the high gluten content which enhanced the texture and the volume. The loaf and specific volume of the composite blends decreased and were thus affected by levels of substitution. This could once again be attributed to the substitution effect of white wheat flour with sweet potatoand bambara groundnut and presence of fibre which hindered the gluten development. Similar findings were observed in the study conducted on composites of wheat, maize and orange fleshed sweet potato by Igbabul *et al*(2014). This was attributed to the decrease in structure forming proteins (gluten) in white wheat flour which lowered the ability of the dough to rise during proofing leading to reduction in the bread volume (Igbabul *et al*., 2014).

The resultsobtained for the loaf weight and density showed the whole wheat bread had the highest values, which could be as a result of the bran of the whole wheat which made the flour denser. The substitution increased the weight and density of the composite blends when compared to the white wheat bread. This could be as a result of the substitution with sweet potato and bambara groundnut which contain starch and fibre and made the loaves denser. This result agrees with those reported by Ameh *et al*(2013), where bread made from composite of wheat and undefatted rice bran had increased loaf weight and density as substitution increased. This was attributed to the density of the individual flours incorporated.

Moisture content of food products have been shown to affect biochemical activities of microorganisms, thereby affecting food spoilage during storage. In this study, the whole wheat and white wheat bread had the lowest moisture content; this could be attributed to the low water absorption capacity. The composite blends had increased moisture as substitution increased; this could be as a result of the higher water absorption capacity of sweet potato and bambara groundnut due to increased particle size. The higher moisture content reduced the shelf life of the composite bread. The moisture content of the bread samples is within acceptable limits, compared to the maximum value of 37 % specified by SON (SON, 2004). These results agreed with that reported by Eke *et al* (2013) where increased moisture content was observed due to incorporation of various flours. It is also reported that roots and tubers retain more moisture than cereals (Ogunlakin *et al*., 2012).

It has been reported that samples with high ash contents are expected to have high concentrations of various mineral elements, which could help speed up metabolic processes and improve growth and development (Habtamu, 2014).The results of the ash content showed the white wheat bread had the least value. The ash content was higher across the composite blendswith increasing level of sweet potato and bambaragroundnut. This observation could be as a result of the mineral contents in the sweet potato and bambara groundnut. Thus composite blends contained high ash content which reflects their levels of minerals. These were similar with the findings of Abebe *et al* (2018), where composite blend of wheat and anchote soyabean were used for bread production.

The result of the crude lipid content showed the whole wheat was higher when compared to the white wheat bread. This could be attributed to the presence of lipids in the germ of the whole wheat flour. Substitution of white wheat flour with sweet potato and bambara groundnut increased the crude lipid content.The increase could be as a result of the presence of linoleic and linolenic fatty acids in bambara groundnutwhich improved the lipid contents of the bread samples. The study by Ameh *et al* (2013) where bread was produced from wheat and undefatted rice branshowed similar trend though the values were lower than those reported in this study. The presence of high fat could cause rancidity and reduce the shelf life of the bread samples.

This study showed the crude protein content of the whole wheat and white wheat bread loaves had the least values. This could be attributed to the poor protein content of cereals. Blending with sweet potato and bambara groundnutincreased the crude protein content of the composite blends. This enhancement could be as a result of the substitution with bambara groundnut, a legume high in protein. This showed the composite blends have improved nutritional composition in terms of proteins.This result also agrees with the findings of Arise *et al* (2015) where composite flour blends of wheat, plaintain and bambara groundnut were studied. The increase observed in the protein content was attributed to the presence of bambara groundnut in the flour blends.

The findings in this study showed increased carbohydrate contents in the whole wheat and white wheat bread when compared to the composite blends. This could be attributed to the presence of fibre in the whole wheat flour and starch in the white flour. The decrease in the carbohydrate content in the composite blendsis expected because of the substitution in varying ratios of bambara groundnut which is high in protein and fat and could reduce the carbohydrate content. Similar results were reported by Abiodun *et al* (2017), where doughnut was produced from wheat and bambara groundnut. Thus, incorporation of legume reduced the carbohydrate content of the composite flour.

Fibres exhibit beneficial physiological effects to human body, as they stimulate and accelerate intestinal contraction and transit, and increase feces volume (Ahmed *et al*., 2010). Dietary fiber is the indigestible part of plant material that helps increase roughage and bulk of stool, maintains a healthy intestine, and decreases the time waste material spends in the gastrointestinal tract (Abiodun and Ehimen, 2018). Theresult of this study showed the whole wheat contained a higher level of fibre. This could be attributed to the presence of fibre in the bran of the whole wheat.

The increased crude fibre content observed in this study from the composite blendscould be as a result of the presence of fibre in the sweet potato and bambaragroundnut. Thus the composite blends could improve the consistency of stool. The increased crude fibre content of the bread samples led to the decrease in the volume of the loaves, as presence of fibre hinders the development of gluten. This agrees with the study conducted by Abimbola *et* *al*(2017) who developed composite flour from wheat and bambara groundnut.The presence of fibre could help in the absorption of blood glucose.

Reduction in the soluble, insoluble and total dietary fibre contents were obtained in the white wheat bread. This could be attributed to the removal of the bran of hard wheat during processing, as the bran contains high levels of fibre. The results of the dietary fibre showed substitution affected the soluble, insoluble and total dietary fibre contents. These indicate that sweet potato and bambara groundnut are good sources of fibrewhen compared to the white wheat bread. This study has shown that substitution of white wheat flour with sweet potato and bambaragroundnut could greatly improve the fibre content.Abiodun and Ehimen (2018) observed similar findings with biscuits produced from composite flour of unripe banana, sweet potato and pigeon peas. The improved contents of dietary fibre were observed to be due to its presence in the individual composites.

Minerals are chemical constituents that are used by the body in many ways. Although they yield no energy, they have important roles to play in many activities in the body (Bolarinwa *et al*.,2017). Minerals are vital to the functioning of many body processes. They are critical players in the functioning of the nervous system, other cellular processes, water balance and structural (e.g. skeletal) systems (Eruvbetine, 2003).The results showed the whole wheat bread had lower levels of calcium, potassium and sodium. This could be attributed to the lower levels of these minerals in whole wheat.

The results obtained also showed increased levels of calcium, potassium and sodium in the composite blends when compared to the white wheat bread.The increase observed could be due to the composition of the minerals in sweet potato and bambaragroundnut used in the blends. Thus the composite blends had improved content of calcium, sodium and potassium when compared to the white and whole wheat bread. The study of Abebe *et al*(2018) on composites of wheat, anchote and soybean flours showed similar results, which were attributed to the mineral contents of the different crops and compositions used. The consumption of 100 g of thecomposite bread will provide more than 10 % of recommended dietary allowance for calcium and 5 % of the adequate intake for potassium and sodium. The recommended dietary allowance for calcium is 800- 1000 mg per day.The adequate intake for potassium is at least2800mg/day and that of sodiumless than 2000 mg/day (Dickinson, 2002, EFSA, 2017).

The results of the magnesium content showed the whole wheat bread had the least value. This could be attributed to the low level of magnesium in whole wheat. The results showed that the levels of substitution affected the levels of magnesiumin the composite blends; this could possibly be due to the sweet potatoes which are known to contain magnesium. The consumption of 100 g of the composite bread will provide at least 5 % of recommended dietary allowance for magnesium. The recommendeddietary allowance for magnesium is 300 – 350 mg/day (EFSA, 2017).

The results of the zinc and iron levels showed the whole wheat and white wheat bread had higher levels of the minerals, which indicates that they are present in these flours. The results of these minerals in the composite bread showed varying levels. Sweet potato is known to contain iron and zinc. Similar findings were recorded by Igbabul *et al*(2014) where no definite trend was also observed across some mineral levels.The consumption of 100 g of the composite bread will provide more than10 % of recommended dietary allowance for zinc and iron. The recommended dietary allowance for zinc is 3 - 11 mg/day and Iron 10 – 15 mg/day (EFSA, 2017).

Vitamin A is an essential nutrient required for maintaining immune function. The whole wheat bread had the highest level of vitamin A when compared to the white wheat bread. This could be attributed to the processing effect of white wheat flour which reduced the level of the vitamin. The results of the study revealed a slight increase in vitamin A content of the composite blends when compared to the white wheat bread. It could be due to the presence of beta carotene in sweet potato which was incorporated. This result differ slightly from those of Igbabul *et al* (2012) who observed significant increase as a result of the use of orange flesh sweet potato which is fortified with pro-vitamin A. Consumption of 100 g of the composite bread will provide less than 2 % of recommended dietary allowance for vitamin A. The recommended dietary allowance for vitamin A is 400 – 900 micrograms/day (EFSA, 2017).

B-group of vitamins, are essential in carbohydrate, fat and protein metabolism. Thiamine plays a central role in the generation of energy from carbohydrates, while riboflavin is involved in the energy production for the electron transport chain, the citric acid cycle, as well as the catabolism of fatty acids (Gropper and Smith, 2013). In this study, whole wheat flour had the highest thiamine content, which could be due to the presence of thiamine in the germ of the whole wheat. The thiamine levels in the composite bread samples were higher when compared to the white wheat bread. This could be attributed to the presence of thiamine in bambara groundnut, thus improved the content in the bread samples.It was observed that the whole wheat bread had higher riboflavin content when compared to the white wheat bread. This could be due to the higher levels of riboflavin in the bran and germ of the whole wheat. The bread with the highest levelof substitution of sweet potato and bambara groundnut contained a greater level of riboflavin. This could be as a result of the presence of riboflavin in sweet potato which improved the level of this nutrient. Ameh *et al* (2013) reported similar findings of increased levels of thiamine and riboflavin in composites of wheat and undefatted rice bran. Their findings were attributed to the incorporation of white wheat flour with legumes, tubers, roots and other cereals which contained the vitamins. The consumption of 100 g of the composite bread will provide more than 50 % of recommended dietary allowance for thiamine and riboflavin. The recommended dietary allowance for thiamine is 0.5 – 1.2 mg/day and riboflavin is 0.8 – 1.3 mg/day (EFSA, 2017).

Vitamins C and E help to regulate body processes. The results of the vitamin C levels showed the whole wheat bread had the highest content. This could be attributed to the presence of this vitamin in whole wheat. The level of vitamin C increased in the composite blends as the substitution of white wheat flour with sweet potato and bambara groundnut increased when compared to the white wheat bread. This could be attributed to the higher levels of vitamin C in the sweet potato and bambara groundnut.

For the vitamin E levels in the various bread samples, white wheat bread had the least content when compared to the whole wheat and the composite bread. This showed the processing of white wheat flour reduced the level of the vitamin. The result also showed that substitution with sweet potato and bambara groundnut increased the vitamin E content of the composite blends, which could be due to the presence of the vitamin in the flours incorporated. Thus the bread from the composite flours had improved vitamin C and E contents. The results of the vitamin levels agree with the study conducted by Eke *et* *al*(2013) where bread samples from composite flours had improved vitamin levels. Consumption of 100 g of the composite bread will provide at least 5 % of recommended dietary allowance for vitamin C and E. The recommended dietary allowance for vitamins C is 25 - 90 mg/day and E is 6 - 15 mg/day (EFSA, 2017).

Anti-nutrients are substances that reduce the nutritional values of food by reducing the bioavailability, digestibility, and utilization of nutrients (Bolarinwa *et al*., 2017). In this study, phytate content was higher in the whole wheatflour when compared to the white wheat flour. The same result was observed in the whole wheat and white wheat bread. This showed that the processing of white wheat reduced the content. It was observed that phytate content increased in the composite blendsas the level of substitution increased.This could be attributed to the presence of phytate in the sweet potato that was incorporated. The phytate levels were lower than those reported by Bolarinwa *et al*(2017) who worked on malted sorgum and soy composite flour. High levels of phytates in human nutrition are toxic and limit the bioavailability of some minerals(such as iron, calcium and zinc) by the formation of insoluble compounds with them (Abebe *et al*., 2018). The levels of phytate were within the recommended range as about250mg/100g is the permissible range and 80 mg/g diet is detrimental to health (Malomo *et al*., 2011).

Tannin-protein complexes are insoluble and this decreases the protein digestibility by inhibiting the activities of digestive enzymes (Ekop *et al*., 2008). Fermentation and other processing methods are known to improve the nutritional quality of legumes and cereals by causing significant changes in their chemical composition and elimination of anti-nutritional factors. The findings of this work showed that the whole wheat and white wheat samples had the highest content of tannins. This could be attributed to the presence of tannins in both flours.Decrease in tannin content was observed as the level of substitution increased in the composite blends. This could be due to the processing effect of sweet potato and bambara groundnut, and the fermentation processwhich occurred during the kneading of the dough.Onoja *et al*(2014) reported higher levels of tannin in the study conducted on composite flour developed fromfermented water yam, cocoyam, plaintain, yam bean, cowpea, pigeon pea and cornflour. This was attributed to the levels of tannin in the individual flours.The levels of tannins were within the recommended range as about 80 mg/g diet is detrimental to health (Malomo *et al*., 2011).

Oxalates can form complexes with most essential trace elements, therefore making them unavailable for enzymatic activities and other metabolic processes (Ekop *et al*., 2008). The results of the oxalate content showed that the whole wheat and white wheat flours had the least content when compared to the composite blends. This could be attributed to the lower levels of oxalate in wheat. As the level of substitution with sweet potato and bambara groundnut increased, the oxalate content increased. This could be attributed to the presence of oxalate in the sweet potato flour.It was observed that the levels of oxalate were lower in the bread samples when compared to the flour. This could be attributed to the fermentation process during the kneading of the dough. Thetoxic range or lethal dose of oxalates has been reported to be between 3-5 g for man (Ekop *et al*., 2000).Thisstudy therefore reveals a safe margin for the analyzed bread and flour samples.

The result of the trypsin inhibitors showed the whole wheat and the white wheat flour samples had the least contents. This could be due to low levels of tannins in wheat.This study also showed that the trypsin inhibitor content increased in the composite flour.This increase could be due to substitution with bambara groundnut.Bambara groundnut is known to have high levels of trypsin inhibitors. However, the levels of the trypsin inhibitors were lower in the bread samples when compared to those of the flour. This could be attributed to the fermentation process and the temperature of baking. These results were similar to the findings of Abiodun and Ehimen, (2018) who studied biscuits produced from unripe banana, pigeonpea and sweet potato. It was observed that the increased trypsin inhibitor content could be attributed to its presence in the individual composites.

The sensory attributes shows the level of acceptability of a product. There is a high consumer acceptance of pastries made from white wheat flour when compared to composite flours. The differences could be also attributed to the unique baking qualities of white wheat flour (Adeyeye and Akingbala, 2015). The parameters were taste, after taste, texture, crumb colour, crust colour aroma, appearance and overall acceptability. The parameters of the whole wheat bread were within the range of five for all assessed (neither like nor dislike). The white wheat bread samples had the highest value for all the parameters. This could be attributed to the strong consumer presence. The results of the parametersassessed for the composite blends showed they were all within the acceptable range.

The results also reveal that the taste, crust colour and appearance of the composite blends were lower when compared to the white wheat bread.This could be attributed to the beany colour, taste and flavor of the samples due to substitution with bambara groundnut. It has been observed that people are familiar with the quality attributes in the bread from white wheat flour. In terms of the overall acceptability, the white wheat bread and the composite blend (E) were the most preferred. Similar result was observed in the findings of Arise *et al* (2017) who studied biscuits produced from composites of wheat, plaintain and bambara groundnut.

In the case of the shelf life, the bread samples were stored at room temperature (25 ± 2 °C) and at 37^{o}C. They were stored at 37^{o}Cdueto the possibility of being produced in a hotter location. It was observed that at an increased temperature (37^{o}C) the shelf life of the composite blends reduced when compared to the white and whole wheat bread. This could be attributed to the reduced moisture content of the whole and white wheat flours. The shelf life showed reduction as the level of substitution increased in the composite blends. Thus, reduction in shelf life could be attributed to the presence of sweet potato and bambara groundnut, which led to high moisture and lipid contents that induced spoilage.High moisture and lipid content in foods reduce their shelf life.Similar findings in the shelf life of breads from the composites of wheat and sweet potato were observed in the study conducted by Udeme *et al* (2014), where they stayed an average of five days.It was reported that the spoilage could be due to the presence of fungi, which could be as a result of the raw materials, processing, handling, and storage.

CHAPTER SIX

6.0 SUMMARY, CONCLUSION AND RECOMMENDATION

6.1 Summary

This study showed that blending of sweet potato and bambaragroundnut with white flour had significant effect on the functional properties of the flour blends. This could be observed from the increased loaf density,reduction in the loaf volume and increased moisture of the composite blends (C to F). The level of blending with sweet potato and bambara groundnut flours also improved the nutrient profile of the composite blends (C to F) when compared to the white wheat bread in terms of the ash, crude lipid, crude protein, crude fibre and dietary fibre contents.However a reduction was observed in the carbohydrate content of the composite blends. This study also showed that the increased level of substitution with sweet potato and bambara groundnut also improved the mineral contents (calcium, potassium and sodium). Thus, the composite blends (C to F) showed increased levels of these nutrients.

Slight variations were observed in few parameters (dietary fibre, iron, zinc, thiamine and riboflavin)as the levels of substitution increased in composite flour. The study also showed that blending with sweet potato and bambara groundnut led to increase in the levels of some anti-nutrients (phytate, oxalate and trypsin inhibitors), however the levels of the anti-nutrients in all the bread samples were very low and within the permissible ranges. The sensory scores showed that the composite blends were within acceptable range (a value of 6-7 which signifies slight or moderate likeness), however, the most acceptable were the bread from sample B (100g white flour) and sample E (70g white flour, 15gsweet potato, 15gbambara groundnut). The study also showed that blending with sweet potato and bambara groundnut increased the moisture and crude lipid content of the bread samples which caused a reduction in the shelf life.

6.2 Conclusion

The study showed that the bread with forty grams substitution of sweet potato and bambara groundnut (Sample F) had the most improved nutritional composition in terms ofmacronutrients (fat, protein) and micronutrients (calcium, sodium, potassium, vitamin A, thiamine, riboflavin, vitamin C,Vitamin F). The study also showed that sample F had sensory scores which were within acceptable rangeand contained some anti-nutritional factors that were within the permissible range.

6.3 Recommendation

1. Based on this study, the composite bread with forty grams substitution of sweet potato and bambara groundnut is recommended for consumptionas it could provide protein, energy and micro-nutrient to consumers.
2. A study should be undertaken using the formulated composite flour blend for other pastries.
3. The amino acid composition of the composite flour and bread should be studied.

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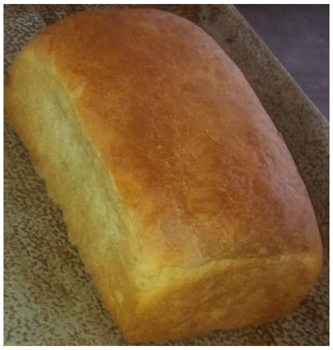
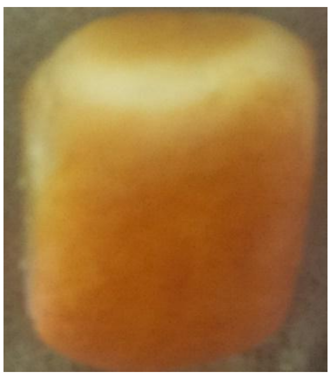
Appendix 1

Samples of Bread Produced



ABC




DEF

A: 100g whole wheat flour. **B:** 100g white flour. **C:** 90gwhite flour + 5g sweet potato flour + 5g bambaragroundnut flour. **D:** 80g white flour + 10g sweet potato flour + 15g bambaragroundnut flour. **E:** 70g white flour + 15g sweet patato flour + 15g bambaragroundnut flour. **F:** 60g white flour + 20g sweet potato flour + 20g bambaragroundnut flour

Appendix 2

Letter of Introduction to Panelist

Department of Biochemistry

Ahmadu Bello University. Zaria.

Date____________________

Dear Respondent,

REQUEST FOR RESPONSE TO QUESTIONAIRE

I am a postgraduate student from the Department of Biochemistry, Ahmadu Bello University. Zaria. I am currently undertaking an MSc research work entitled "FORMULATION AND EVALUATION OF COMPOSITE FLOUR AND BREAD FROM *TRITICUM AESTIVUM*(WHEAT)*IPOMOEA BATATAS*(SWEET POTATO) AND *VIGNA SUBTERRANEA*(BAMBARA GROUNDNUT)". You have been selected as one of the respondents to supply the required information for this study. I therefore solicit your cooperation to respond objectively to the questions. It is purely for academic work and all information supplied by you will be strictly treated in confidence.

Yours faithfully,

Patience Gansallo.

Appendix 3

Sample of Questionnaire Administered

SENSORY EVALUATION ON BREAD

Instruction: Tick (X or /) where applicable.

Date:

Participant's Data:

A. Sex: Male Female

B Age: 20-30 30-40 40-50

C. Occupation: Public Servant Student

Sensory Parameters; Taste, After taste, Aroma, Crust colour, Crumb colour, Texture, Appearance and Overall acceptability.

Key: EL= Extremely like (9); VML= Very much like (8); ML= Moderately like (7); SL =Slightly like (6); NLnDL = Neither like nor dislike (5); SD = Slightly dislike (4); MD =Moderately dislike (3); VMD = Very much dislike (2); ED = Extremely dislike (1).

S/N	Sensory parameters	EL (9)	VML (8)	ML (7)	SL (6)	NLnDL (5)	SD (4)	MD (3)	VMD (2)	ED (1)
1	Taste									
2	After taste									
3	Aroma									
4	Crust colour									
5	Crumb colour									
6	Texture									
7	Appearance									
8	Overall acceptability									