EFFECT OF PROCESSING ON FUNCTIONAL PROPERTIES, NUTRIENTS COMPOSITION, GLYCEMIC INDEX AND SENSORY ATTRIBUTES OF FINGER MILLET (*ELEUSINE CORACANA*) FOOD PRODUCTS

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JANUARY, 2018

DECLARATION

I declare that the work in the dissertation entitled " Effect of Processing on Functional Properties, Nutrients Composition, Glycemic Index and Sensory Attributes of Finger Millet *(Eleusine coracana)* Food Products" has been performed by me. 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 any university.

Aliyu, Maimunatu Ladidi	**Signature**	**Date**

CERTIFICATION

This dissertation entitled "EFFECT OF PROCESSING ON FUNCTIONAL PROPERTIES, NUTRIENTS COMPOSITION, GLYCEMIC INDEX AND SENSORY ATTRIBUTES OF FINGER MILLET *(Eleusine coracana)* FOOD PRODUCTS" by, Maimunatu Ladidi ALIYU meets the regulations governing the award of the Degree of Master of Science of Ahmadu Bello University, Zaria, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This work is dedicated to the Almighty God, the creator of heaven and earth.

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ABSTRACT

The effect of various processing methods (roasting, germination and fermentation) on functional properties, nutrient composition, glycemic index and sensory attributes of finger millet (*Eleusine coracana*) food products (Pap and Tuwo) were evaluated in context of management of type II diabetes. The cereal grain was purchased from a local market in Kaduna metropolis and the analytical method used followed standard procedures. Result obtained indicate that, functional properties of unprocessed and processed flour showed no significant difference (P>0.05) in bulk density. The fermented sample had higher water absorption and swelling capacity (1.67 ±0.06 g/ml and 939.00±3.00%) than unprocessed flour (1.40±0.10g/ml) while germinated had the highest (39.10±1.30 g/100ml) solubility and lowest (263.67±12%) swelling capacity. The flour from germinated seeds showed the lowest (2.0%) gelation capacity and higher (84°C) gelatinization temperature. Proximate composition showed no significant difference (P>0.05) in the carbohydrate content of flour from unprocessed (86.32±2.11%), roasted (86.43±0.31%), and fermented (85.64±0.54%) seeds, except for flour from germinated seeds that had the lowest value of 80.99±2.10%. Likewise, food products (pap and tuwo) from unprocessed(86.89±1.21 and 86.6±0.31%), roasted (85.71±0.32 and 86.99±1.41%), germinated (87.24±0.54 and 85.64±1.45%), and fermen ted (86.05±1.10 and 86.22±1.32%) seeds. Higher fiber content was observed in flour (4.90±0.12%) and tuwo (3.57±0.06%) from germinated seeds compared to value shown in flour, Pap and tuwo (3.54±0.06, 1.74±0.06 and 2.90±0.05%) from fermented seeds. There was no significant (P > 0.05) difference in the moisture content of flour samples from unprocessed and processed seeds. Likewise the food products, although higher values were observed in flour and pap (8.26±0.17 and 91.25±0.12%) from fermented seeds compared to the lowest value in flour and pap (6.80±0.19 and 84.99±0.02%) from roasted seeds. Significant differences (P<0.05) were observed between unprocessed and processed finger millet seeds in the antinutrient composition. Flour from unprocessed sample had significantly higher content of phytate (483.72±0.29 mg/100g), cynogenic glycosides (2.66±0.07 mg/100g), alkaloids (1.75±0.05%), oxalate (36.14±0.39mg/100g, and tannins (851.12±0.04 mg/100g) compared to the processed samples. Flour (501.33±1.53 µ/g) and food products (Pap and Tuwo) from germinated seeds had highest (82.60±1.00 and 63.63±1.89µ/g) phenol content respectively. Micronutrient concentration showed significant difference (P<0.05)between
unprocessed and processed finger millet flour and food products (Pap and tuwo). Higher content of phosphorus (16.10±1.20mg/100g), iron (24.00±4.60mg/100g), magnesium (12.00±1.20mg/100g) and calcium (16.00±2.10mg/100g) was recorded in flour from unprocessed seeds compared to processed samples. Pap from germinated seeds had higher content of iron(14.00±2.60 mg/100g) and calcium (13.00±1.20 mg/100g) compared to samples from roasted (11.00±1.80 and 12.00±1.20mg/100g) and fermented (11.00±1.60 and 10.00±1.10 mg/100g respectively) of the sample. Likewise phosphorous content is higher (9.00±1.60mg/100g) in tuwo from germinated seeds than sample from unprocessed (6.00±1.60g/100g). Flour and food products (pap and tuwo) from unprocessed seeds had higher total dietary fiber (19.80±0.50, 16.50±0.50 and

18.70±0.50 g/100g) compared to the values shown in Flour, Pap and Tuwo (11.40±0.50, 10.40±0.05 and 11.21±0.50 g/100g) from fermented seeds. The amino acids profile shows that, Tuwo from germinated had higher Leucine (10.39g/100g), phenylalanine (5.58 g/100g), methionine (2.40g/100g) content, than the fermented, unprocessed and the lowest was observed in tuwo from roasted seeds. Processing significantly ($P < 0.05$) affected the glycemic index of the food products as pap (28.51±10.11%) and tuwo (28.59± 14.21%) from unprocessed seeds showed lower glycemic index compared to processed samples (pap and tuwo): roasted (32.44±14.05 and 32.74± 8.10 %), germinated (40.56±12.10 and 51.04 ± 11.2 %), and fermented (35.71±14.10 and 40.24 ± 13.12 %). Lowest blood glucose response to pap and tuwo (9.31± 1.53 and 8.21± 2.04mmol/L), from unprocessed seeds in the diabetic subjects was observed compared to product from germinated seeds having the highest value (13.28± 1.21 and 14.31± 1.22mmol/L). The same trend was observed in normal subject as lowest blood glucose response to pap and tuwo (4.22± 0.3 and 4.22± 1.1mmol/L) from unprocessed seeds was also shown compared to products from germinated seeds (7.02± 0.9 and 6.53± 1.5mmol/L) showing higher values. Sensory analysis revealed that Pap and Tuwo from roasted and germinated seeds were the most prefered compared to food products from the unprocessed and fermented. The results suggest that, processing methods (roasting, germination and fermentation) decreased the anti-nutrient content, improved amino acids content, and improves the sensory attributes and general acceptability of food products from finger millet. It however, significantly ($P < 0.05$) increased the glycemic index and glycemic response of the food, making it not to be very suitable for the management of type II diabetes.

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CHAPTER ONE

1.0 Introduction

Diabetes Mellitus is a metabolic disorder and has been defined as a condition in which the pancreas no longer produces sufficient insulin or cells stop responding to the insulin produced, therefore, the glucose in the blood cannot be taken up by the cells of the body (Goldhaber *et al.*, 2011). Diabetes mellitus is the most common endocrine disorder that presently affects 415 million people of the world population and the majority are aged between 40 and 59 and 80% live in low and middle income countries (IDF, 2015). Current figures indicate that people living with diabetes is expected to rise from 382 million in 2013 to 642 million by 2040, if no urgent action is taken (IDF, 2015).

The World Health Organization described diabetes as a chronic disease that causes serious complications such as; cardiovascular disease, chronic renal failure, retinal damage (which can lead to blindness), nerve damage (of several kind) and micro vascular damage, which may cause impotence and poor healing of wounds, particularly of the feet, which can lead to gangrene and may require amputation (WHO, 2015).

Diabetes is a global problem with devastating human, social and economic impact leading to disabilities such as; reduction in quality of life and massive rise in direct and indirect medical cost. International Diabetes Federation (IDF, 2015) recommended adequate treatment of diabetes with increased emphasis on blood glucose control, lifestyle factors such as smoking, consumption of alcohol, keeping a healthy body weight by increasing physical activity and a healthy eating habit which include the consumption of whole grains.

According to Global Report on Diabetes (WHO, 2016), 499 billion US dollars were spent on health care for diabetes in 2011, 548 billion in 2013 and 673 billion in 2016, but the disease is still ravaging many parts of the world especially Africa where more than three quarters of deaths from diabetes in 2013 occurred in people under 60 years which is a prime productive years (WHO, 2016).

People with diabetes cut between the ages of 20 – 79 years (IDF, 2013). There is no country in the world that is an exception in diabetes epidemic and in states and territories worldwide; it is the poor and disadvantaged that are suffering the most. A study estimated that, losses in GDP worldwide from 2011 to 2030 for direct and indirect cost of diabetes management will total 1.7 trillion US dollars, out of which 900 billion for high income countries and 800 billion for low and middle income countries (WHO, 2016).

International Diabetes Federation (IDF) in 2011 revealed that Nigeria with less than 5% health insurance coverage has the highest rate of diabetes in Africa with over 5 million people living with the disease (IDF, 2016) compared to the previous figure of 1 million affected people reported in 2000. South Africa ranked second with 1.9 million followed by Kenya with 769, 000.

A study conducted in Nigeria estimated the morbidity to be about 4 million people, even though there are no accurate data on the prevalence of the disease, which indicated that 4 million Nigerians may be suffering from diabetes, but hospital records show a yearly increase in the number of newly diagnosed cases (Osibogun *et al.,* 2015).

African finger millet (*Eleusine coracana*) belongs to the family Poaceae (Gramineae) which is an annual plant widely grown as a cereal in the arid areas of Africa and Asia. It is called Tamba in Hausa, Oka in Yoruba and in Igbo. The millet seed coat reserves several phenolic compounds like flavonoids, polymeric tannins and anthocyanins, some of which are effective inhibitors of pancreatic amylase and intestinal α – glucosidase (Adekule, *2012*). It is also a rich source of phytates and minerals (Shobana *et al.,* 2006). Traditionally, finger millet food preparations are known for their higher sustaining power, lower glycemic response and higher satiety scores compared with other cereal foods which are usually recommended for diabetic patients (Singh and Raghuvanshi, 2012).

Finger millet has significant potential as food and feed in addition to its current usage as forage. It is a drought – tolerant crop and can be grown under difficult ecological conditions. For this reasons it is widely grown in tropical regions of world including Africa and Asia. It is comparable and even superior in some of the nutritional characteristics to major cereals, with respect to its energy value, protein, fat and mineral content (Shobana *et al., 2007*). The use of finger millet for human consumption is limited to non – availability in convenient form. The millet is mostly used as whole flour for traditional food preparation and hence confined to traditional consumers and to people of lower economic status. Finger millet can be consumed raw after soaking and sprouting in form of salads but most of them require cooking to improve digestibility and palatability.

Dietary polyphenols and phytates are known for their ability to reduce carbohydrate digestibility and thereby regulate postprandial glycaemic response (Thompson *et al.,* 1987). Moreover, polyphenols are known to inhibit glucose

absorption and prevent Advanced Glycation End (AGE) product formation (Saleh *et al.,* 2013).

Though, considerable progress in the research for the treatment and management of diabetes has been made, a lot still needs to be done to improve the lives of the people, for instance, in the attainment of the Millennium Development Goals (MDGs) 1 (reduction of poverty and extreme hunger), 4 (reduction of infant and under five mortality), 5 (reduction of maternal mortality), and 6 (eradication of infectious diseases), which is currently called Sustainable Development Goals (SDGs), no mention was made of diabetes or related non – communicable diseases (NCOs). This reflects the misconception that these are diseases of affluence, but it is no longer true, because studies have shown an increasing prevalence of the disease even among poor urban dwellers in developing countries (WHO, 2013).

A good nutrition plan serves as the cornerstone of any diabetes management, therefore, eating healthy and increased physical activity helps prevent and effectively manage diabetes and related diseases. Consumption of whole grains, cereals and products provides the primary sources of nutrition and health benefits for diabetes and non-diabetes. These benefits include; keeping the blood glucose level within the acceptable range, reduction of cholesterol level, prevention of constipation (Chandrasekara and Shahidi, 2012).

Finger millets meals are normally prepared from whole grain which is high in fiber and minerals. It is a good source of magnesium, manganese and phosphorus. Research (Shobana *et al*.,2013) has shown that magnesium is associated with reduced risk of heart attack, phosphorus is important for the

development of the body tissues and energy metabolism(Bauman *et al.*, 2000). It is also rich in phytochemicals including phytic acid which is believed to lower cholesterol level and reduce the risk of cancer (Shobana *et al.,* 2009). The grain contains essential amino acids e.g. isoleucine (4.4g/100g), leucine (0.5g/100g), methionine (3.1g/100g) and phenylalanine (5.2g/100g) which are deficient in other cereals. It contains B vitamins especially niacin, B6, folic acid, and other mineral elements such as calcium, iron, potassium and zinc (Yang *et al.,* 2012).

The term local diet or foods means indigenous foods that can be found in a rural setting or community, most of which are minimally processed, in season, locally grown, available and affordable. It differs greatly from region to region and most often specific to a location (Knowler *et al.,* 2002). Although a healthy and adequate diet is recommended, but the specific details may vary depending upon individuals personal needs and goals, (individuals at risk for diabetes, heart disease, obesity etc). A healthy dietary plan that emphasizes weight management and healthy health is important. Personal preferences and life style are also valuable considerations, such as whether individual is a vegetarian, vegan or eats in a particular way either for religious or cultural reasons. Both in health and diseases, people require different amount of nutrients and calories depending on age, activity level, body size, and physiological status.

The main dietary requirements of a diabetic patient are the same as those without diabetes (WHO, 2013), but is the regimentation of food intake that constitutes the corner stone of diabetic therapy such as timing of food intake, the caloric value of the food and the proportions and quantity of carbohydrates, fats and proteins. Therefore, education, communication and knowledge of vital locally grown, available and affordable foods that can be used to build strong

immunity, helps prevents diseases and specifically manage diabetes mellitus is important.

1.2 Statement of the Problem

People are increasingly dying in large numbers everyday due to chronic diseases such as diabetes, obesity, hypertension, coronary heart disease, atherosclerosis and certain cancer including colon and breast cancer (WHO, 2015).

The traditional African diets, that are locally available, accessible and affordable which was low in animal foodstuffs, fats, cholesterol, but high in carbohydrate, antioxidants and fibre was associated with low occurrence of atherosclerosis, appendicitis, obesity, hypertension, coronary heart disease, diabetes, gallstones, and certain cancers, according to Walker (2000). This scenario has changed rapidly with urbanization of African populations to a westernized diet (change of lifestyle, from traditional to modern), lack of physical activity, obesity, obstruction of beta cells function (e.g. pancreatitis), peripheral resistance to insulin, severe malnutrition in childhood which is referred to as malnutrition – induced diabetes (IDF, 2014). In addition, there is a lot of consumption of refined foods like rice, spaghetti, noodles, refined maize flour, semovita, semolina etc.

Dietary polyphenols and phytates are known to have the ability to reduce carbohydrate digestibility and thereby regulate postprandial glycaemic response (Thompson *et al.*,1987). Moreover, polyphenols are known to have health benefits such as inhibiting glucose absorption and prevent advanced glycation end product (AGE) formation (Banerjee *et al.,* 2012).

In spite of all its nutritional and medical importance, finger millet has not been exploited to its full potential and it is grossly neglected both scientifically and internationally. It receives less research compared to that lavished on other cereals such as wheat, rice, and maize. Globally, many countries have never heard of the crop, incuding many parts of Nigeria especially South South, South West, South East, some parts of North Central region even in the North West where it is cultivated. Untill recently finger millet is an under utilized cereal and those that grow it have allowed it to waste away in the perspective of a "poor person's crop," a "famine food," or, even worse, a "bird seed. (Adekule, 2012). This has resulted in increased marginalization and accelerated loss of its genetic diversity. It is believed that in a few years it will be hard to find finger millet even in places where it is the predominant cereal.

The lack of modern technologies for their effective processing and utilization has made the grain entirely a subsistence crop which is used primarily for the production of traditional foods, almost none of which are commercialized. Food uses of finger millet have been confined to traditional consumers (Anderson, 2004). In Africa production and processing of finger millet is still limited to areas where they are cultivated thereby hampering the development of processing industries based on this grain. For instance, the utilization of sorghum a less common cereal, is being increased by using it to produce novel commercial products, the same is very limited with finger millet (Shobana and Malleshi, 2007).

The presence of antinutritional factors is another major constraint which adversely affects the utilization of plant proteins in animal and human diet. The finger millet seed coat reserves several compounds like phytates (Shobana *et al.*,

2013), phenolics, flavonoids, condensed tannins and anthocynanins some of which are effective inhibitors of pancreatic amylase and intestinal α-glycosidase (Chethan and Malleshi, 2007).

The seeds are difficult to convert into flour because of its tiny size according to East African Standard (EAS, 2010). Its consumption and utilisation for diabetic management would have been complete if its usefulness and best processing methods are known. Improvement on the processing methods would enhance production of sufficient good-quality flour which would be available to meet the demand of food shortage in some developing countries. In order to improve the potential of finger millet, maximise its utilisation, enhance its acceptability and produce good- quality flour, there is need to evaluate the nutritional quality of finger millet flour and foods produced using various processing techniques like roasting (dry heat treatment), fermentation and germination.

1.3 Justification

Diabetes mellitus is a global problem with devastating human, social and economic impact leading to disabilities such as; reduced quality of life and massive rise in direct and indirect medical cost (IDF, 2016). Nigeria with less than 5% health insurance coverage has the highest rate of diabetes in Africa (Osibogun, 2015). While global incidence of diabetes is increasing in an exponential manner, not much has been done to explore the anti-diabetic potentials of local food products. The traditional African diet that are locally available, affordable have been abandoned to westernized diet that include high energy, refined foods and fat.

The global incidence of diabetes is increasing in an exponential manner. It has been shown that the consumption of foodstuffs containing complex carbohydrates with high level of dietary fibre and health benefiting phytochemicals like polyphenols and phytates (Bouchenak and Lamri, 2013); Pulse Canada, 2013), could improve the condition (Shobana *et al., 2013*). At present, diabetic individuals are advised to avoid the consumption of mixed diets (different components of food groups) which leads to complication faster and most Nigerian diets have not been evaluated for suitability in diabetic management.

1.4 Aim and Objectives

The aim of this work is to determine the effect of processing (roasting, fermentation and germination) on some functional properties, nutrient composition, glycemic index and sensory attributes of finger millet (*Eleusine coracana*) food products (pap and tuwo).

Specific Objectives:

The objectives are:

i. To determine the effect of processing (roasting, fermentation and germination) on some functional properties (bulk density, water and oil holding capacity, swelling power and solubility) of finger millet flour.

ii. To determine the effect of processing (roasting, fermentation and germination) on nutrients composition (proximate, minerals, amino acids, dietary fibre) and anti-nutrient composition of finger millet flour and food products.

iii. To determine the effect of processing (roasting, fermentation and germination) on the glycemic index of food products (Pap and tuwo) developed from processed finger millet food ptoducts (Pap and tuwo)

iv. To determine the effect of processing method on sensory attributes of common food products made from processed finger millet.

1.5 Null Hypothesis

Processing has no effect on functional properties, nutrient composition of flour, glycaemic index and sensory attributes of finger millet food products.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

Cereal grains are the major source of calories and proteins for the people of Nigeria. Those receiving less than 20% of the calories and protein intake from cereal mainly consist of those in southern Nigeria, where starchy roots and tubers are staple foods (Nkama and Gbenyi, 2001). Cereals mostly cultivated in Nigeria are sorghum, millet, rice and maize. The major states that produce millet (pearl) in Nigeria are Borno, Yobe, Jigawa, Kano, Katsina, Zamfara, Sokoto and Kebbi states but, finger millet is cultivated mostly in Southern Kaduna located in the North Western Region of Nigeria. Millets are usually cultivated under extremely harsh conditions of high temperature, low and erratic precipitation, short growing seasons and acidic and infertile soils with poor water holding capacity (Nkama and Ikwelle, 1998).

Traditional technologies available for processing of millet include, threshing, cleaning, washing, dehulling, soaking, germination, wet and dry milling and fermentation while roasting of cereals is rarely practiced (Makuru, 1992). Research has shown that, germination improves the nutritive value of cereals and legumes. Germination has also been found to decrease the levels of antinutrients present in cereals and maximizes the levels of some of the utilizable nutrients (Saleh *et al.,* 2013).

Fermentation has been found to increase pepsin digestibility of millet protein, decrease the concentration of phytic acid and polyphenols with improvement in the availability of minerals (Khetarpaul and Chauhan, 1989).

2.1 Food Processing

The genetic make-up of a plant or animal, the type of soils in which plants are grown or in which animals subsist, the type of fertilizer used, and the agro-ecological conditions of the area determines the nutrient content, health benefits of a plant or animal food material. At the pre and post-harvest handling level, the state of maturity at harvest, food processing and preparation methods, packaging, and storage conditions affect the nutrient content of a food. The effect of processing on the nutrient content of food depends on the sensitivity of the nutrient to various conditions prevailing during the processing, some of which include pH, light and oxygen. Sensitivity of nutrients to processing methods vary with the type of nutrient, with some nutrients increasing and others decreasing with different processing methods. The concentration of the nutrients in the food and its characteristics determine the level of nutrient retention. Most processes are heat-related and improve the digestibility of foods, making nutrients more available by sometimes inactivating the anti-nutrients found in food and thus increasing their bioavailability.

In many low-income countries diets are primarily composed of cereals and legumes which contain anti-nutrient (myo-inositol hexaphosphate), known to inhibit the absorption of divalent metal ions (Liu *et al.,* 2012). These diets contain few animal-sourced foods which are rich in health benefit effects (Kavitha and Parimalavalli, 2014). Dietary combinations of foods that have high levels of anti-nutrients are consumed mostly by rural populations and may have complexities regarding bioavailability and utilization of nutrients. This calls for serious consideration of the assessment of the indigenous food preparation

methods and diet combinations with implications on nutritional status and disease management.

According to Levenstein (2003) processing is defined as the application of thermal, mechanical, chemical, biological and other techniques for the production of safe and nutritious food stuffs. It can also be defined as the set of methods and techniques used to transform raw ingredients into food or to transform food into other forms for consumption by humans or animals either in the home or by the food processing industry.

Benefit of processing are; toxin removal, preservation, easy marketing, distribution tasks, increasing food consistency, increases seasonal availability of many foods, enable transportation of delicate perishable foods across long distances, and makes many kind of food safe to eat by deactivating spoilage and pathogenic microorganisms (Kavitha and Parimalavalli, 2014).

The disadvantages of food processing are: lowers nutritional value of foods e.g. cereals, milling of which the bran is removed and it contains nutrients (such as polyphenol etc) that have high health benefits.; processed foods often have a higher ration of calories to other essential nutrients than unprocessed foods, a phenomenon referred to as “empty calories”; and processed food ingredients are often produced in high quantities and distributed widely amongst value added food manufactures. Failure in hygiene standards in “low level” manufacturing facilities that produce a widely distributed basic ingredient can have serious consequences for many final products (Mathanghi and Sudha, 2012).

2.2. Finger Millet Production

Finger millet is a staple food for millions of people in Africa, India, and Nepal. Precise area for finger millet cultivation is not known because this crop had often been clubbed with other millets (FAO, 1991). The estimated global annual production of finger millet is about 4.5 million tons of grain, of which approximately two million tons is produced in Africa while the Asian continent (mainly India and Nepal) produces the remainder. Pearl millet is the second important crop in Africa and is estimated as 8% of the cultivated area and 11% of production of all millets in the world (Siwela *et al.*, 2007). Uganda is the highest producer of finger millet in Africa followed by Tanzania, and then Kenya (FAO, 1991). In Nepal, finger millet, locally known as kodo, is the fourth staple food crop after rice, maize, and wheat. Here the crop is grown on about 26,000ha of land with an average productivity of 1,100kg/ha (Dida and Devas, 2006). In Nigeria, finger millet is not popular, mainly due to its adaptation to growing on marginal lands where subsistence farmers live. Its popularity is mainly in the North-West of Nigeria particularly southern Kaduna, in Kaduna state due to its good response to low levels of fertilizer application and the crop's tolerance to cold temperatures.

Nigeria is recognized as an important source of the public goods associated with crop genetic diversity conservation, as it is a primary or secondary center of diversity for several crops. The tremendous variation in altitude, temperature, rainfall, soil type and ecological setting, as well as the diverse social and cultural condition together with different levels of market integration are some of the possible explanations for the existence of remarkable genetic variation of crop varieties in the country (Badau *et al.*, 2013).

Finger millet popularly known as Tamba is not an indigenous food crop to Nigerians, but gaining gradual recognition especially among low income earners and diabetic patients. There are three dominant and widely occurring varieties (black, brown and white) in the Southern Kaduna area in Kaduna State.

The black seeded variety, as described by the farmers, is suitable for making local drinks, and has a better fermentation quality and storability quality. The farmers perception on the ability to tolerate bird attack may be associated with high tannin content of black seeded varieties. On the other hand, the white seeded variety, has no detectable tannin and reported to be highly preferred by birds (Badau *et al.,* 2013).

2.3 Functional Properties

Functional properties are those characteristics that governs the behaviour of nutrients in foods during processing, storage and preparation as they affect food quality and acceptability (Onwuka,2005). These are unique properties that are used for the development of several food products. Although the functional properties of food materials are attributed mainly to its protein, other components such as carbohydrate, fat and crude fibre make important contribution. Currently, research efforts on food proteins are aimed at modifying low cost, low functional proteins to enhance their functionalities. How proteins interact and function in a finished product is of importance, hence the interest in measuring functionality (Akubor *et al*. 2001).

Importance of determining functional properties include:- identifying how the protein has been affected by the processing method employed; screening nutrients and extrapolate functionality test results to performance in the finished

product; understanding why specific nutrients function as they do e.g. protein; and to understand how the nutrients interact with each other and within mixtures or systems. The functional properties of foods are related to the raw food material viz nature, composition and conformation, temperature during cooking, toasting, drying, texturization, pH, and the physical and chemical modification taking place during processing. The functional properties that are important in relation to the processed products of interest (Pap and Tuwo) include: water absorption capacity, bulk density, swelling power, solubility, gelation capacity and gelatinization temperature.

2.3.1 Water absorption

This is a useful indication of whether protein can be incorporated with aqueous food formulations, especially those involving dough handling such as processed cheese, sausages and bread dough. Measurement of water and oil absorption provide data for selecting a raw food protein material. Water absorption of foods is a function of ionic strength. pH, temperature, size and shape of the protein molecules. Heat treatment increases the water absorption of seed flours. During heating, major proteins are dissociated into subunits that have more water binding sites than the native or oligometric protein. Gelatinization of starch and swelling of crude fibre may also occur during heating, leading to increased water absorption. This property enables bakers to add more water to doughs and so improving handing characteristics and maintaining freshness in the bread. However, high water absorption is not necessarily useful since a material with high water absorption capacity may imbibe a disproportionate amount of water and would dehydrate other components in the system. Proteolytic activity during

fermentation and germination cause increase in the number of polar groups, which would increase hydrophilicity of the seed proteins (Akubor *et al.*, 2001).

2.2.3 Bulk Density

Bulk density is the mass per unit volume of a substance. It is an indication of the porosity of a product which influences package design. Bulk density could be used in determining the packaging requirement of flour as it relates to the load the sample could carry if allowed to rest directly on one another. Bulk density also relates to the mouth feel and flavour of the food the flour is incorporated in. Low bulk density of a flour would be an advantage in the preparation of complementary foods. Bulk density is affected by moisture content and it reflects particle size distribution of the flour. An increase in bulk density of flour enahcnes fat absorption (Onimawo *et al*. 2001).

2.2.4 Gelatinization

Starch gelatinization is a process of breaking down the intermolecular bonds of starch molecules in the presence of water and heat, allowing the hydrogen bonding sites (the hydroxyl hydrogen and oxygen) to engage more water. This irreversibly dissolves the starch granule in water. Water acts as a plasticizer.

Three main processes happen to the starch granule: granule swelling, crystal or double helical melting, and amylose leaching. During heating, water is first absorbed in the amorphous space of starch, which leads to a swelling phenomenon. Water then enters via amorphous regions the tightly bound areas of double helical structures of amylopectin. At ambient temperatures these crystalline regions do not allow water to enter. Heat causes such regions to

become diffuse, the amylose chains begin to dissolve, to separate into an amorphous form and the number and size of crystalline regions decreases. Under the microscope in polarized light starch loses its birefringence and its extinction cross. Penetration of water thus increases the randomness in the starch granule structure, and causes swelling, eventually soluble amylose molecules leach into the surrounding water and the granule structure disintegrates.

The gelatinization temperature of starch depends upon plant type and the amount of water present, pH, types and concentration of salt, sugar, fat and protein in the recipe, as well as starch derivatisation technology used (Onwuka,2005). Some types of unmodified native starches start swelling at 55 °C, other types at 85 °C. The gelatinization temperature of modified starch depends on for example on the degree of cross-linking of the amylopectin, the degree of acid treatment, and acetylation. Gel temperature can also be modified by genetic manipulation of starch synthase genes. Gelatinization temperature also depends on the amount of damaged starch granules. These will swell faster. Damaged starch can be produced, for example, during the wheat milling process, or when drying the starch cake in the starch plant. There is an direct correlation between gelatinization temperature and glycemic index. Gelatinization improves the availability of starch for amylase hydrolysis. It is also used constantly in cooking to make the starch digestable or to thicken/bind water in roux, sauce, or soup.

2.4 Proximate Composition of Finger Millet

The seed coat of the millet is an edible component of the kernel and is a rich source of dietary fiber and phytochemicals, such as polyphenols, and is also a very good source of minerals, especially calcium (Chethan and Malleshi, 2007). According to the US National Research Council (1996), finger millet grain is more nutritious than most cereal grains with respect to mineral, dietary fiber and amino acids. The proximate composition of finger millet grain is affected by both environment and genetics variation (Kavitha and Parimalavalli, 2014).

2.4.1 Carbohydrates and Dietary Fiber

Most of the carbohydrate in millets is starch, while soluble sugar, pentosans, cellulose, and hemicelluloses are low (Iren, 2004). According to Obilana and Manyasa (2002), carbohydrates make up 70-76% of the total weight of the finger millet grain and approximately 7.9% cellulose, 0.8% reducing sugars, 0.5% dextrins and 4.9% pentosans. The sugars found in finger millet grain include raffinose, sucrose, glucose, fructose and maltose (McDonough *et al.*, 2000). Sucrose and glucose constitute 33 and 12.5%, respectively, of the soluble sugars.

The total dietary fiber (22.0%) of finger millet grain is relatively higher than that of most cereal grains (e.g. 12.6, 4.6, 13.4, and 12.8% for wheat, rice, maize and sorghum, respectively) (Klopfenstein, 2000). Dietary fibers are categorized as water soluble or insoluble, and this reflects different physiochemical properties and abilities to produce biological effects (Yang *et al.*, 2012). Shobana *et al.* (2013) reported that, finger millet grain contained 15.7% insoluble dietary fiber

and 1.4% soluble dietary fiber, while Saleh *et al.* (2013) reported 22.0% total dietary fiber, 19.7% insoluble dietary fiber and 2.5% soluble dietary fiber.

Mathanghi and Sudha (2012) reported that,the principal potential health benefits of insoluble fibers relate to gastrointestinal transit and constipation. Fibers also have potential protective effects against colon cancer. Water soluble dietary fibers are considered to be important in preventive nutrition related to hyperlipoproteinemia and cardiovascular diseases. However, dietary fibers and some associated substances, such as phytate, have invitro mineral binding capacities and may thus alter mineral bioavailability.

2.4.2 Protein

The protein content of finger millet grain varies from 4.9 to 11.3% (McDonough *et al.,* 2000), while Shimelis *et al.* (2009) reported protein content of improved and local varieties of finger millets in Ethiopia varied from 6.26 to 10.5%. Brown and red seeded cultivars generally have protein levels in the lower range, whereas levels in the white seed cultivars and the wild subspecies Africana are at the higher end of the spectrum (10 to 14%) (Dida and Devas, 2006).

Protein content and composition varies due to genotypes, water availability, temperature, soil fertility and environmental conditions during grain development (Shimelis *et al.,* 2009). The mean protein content of 7.3% is similar to that of rice (7.9%) and lower or similar to that of other millets, sorghum and wheat (11.0, 9.6,9.0,7.9 and 12.6% pearl millet, fonio, sorghum and wheat, respectively (Obilana, 2003 and Klopfenstein, 2000).

Finger millet grain contains all essential amino acids e.g tryptophan, phenylalanine, methionine and aromatic acids, which are important in human

health and growth and deficient in most cereals grains (Shobana *et al.*,2013). Particularly, finger millet is high in methionine, ranging around 5% (US National Council, 1996). However, as with other cereals, lysine is limiting in finger millet grain, but among the millets pearl, finger millet usually have higher lysine content (McDonough *et al.*, 2000). The bioavailability of proteins may be adversely affected by antinutritional factors and which may be present in the finger millet grain, mainly trypsin inhibitors and phenolic compounds, (Imamura *et al.,* 2015).

2.4.3 Lipids

Lipids in food products, sorghum and millets can be grouped into glycolipid,s polar, nonpolar, and non-saponifiable lipids and are present as free, bounded or structural lipids. The most common and abundant are the non-polar lipids consisting of the triglycerides (fat/oil). The total lipid content of finger millet grain is estimated to be 5.2%, with palmitic, oleic and linoleic acids being the main constituents (McDonough *et al.,* 2000). The body metabolizes linoleic acid and alpha-linolenic acid into arachidonic acid and docosahexaenoic acid, respectively, which are essential to the normal development of the central nervous system (Glew *et al.,* 2008). The fat content of finger millet grain (1.3%) is relatively lower than that of sorghum and other species of millets, and similar to that of wheat (4.8, 2.8 and 1.1% pearl millet, sorghum and wheat, respectively) (Obilana, 2003). The low fat content of finger millet may be significant in that the grain may have superior storage properties due to a low tendency to become rancid.

2.4.4 Minerals

Minerals (micronutrients) are needed by human body in small amounts. Deficiency in minerals, however, can have a major impact on health such as anaemia and osteoporosis that commonly occur in both developed and developing countries (Norhaizan and Ain, 2009). Minerals can be divided into: macro elements such as; sodium, potassium, calcium, magnesium, chloride, phosphorus and sulphur which are essential for human beings in amounts > 50mg/day while trace elements such as iron, iodine, zinc, selenium, copper, manganese, chromium, and others are essential in concentrations of <50mg/day, and ultra-trace elements such as molybdenum, nickel, arsenic, vanadium etc are elements whose essentiality has been tested in animal experiments over several generations and deficiency symptoms have been found under extreme conditions (Belitz *et al.,* 2009). Finger seeds are exceptionally rich in calcium which is about 0.34%, 5-30 times more compared to other cereals. The phosphorus and iron contents are also high. Iron content is about 46 mg/kg (Shobana *et al.,* 2013).

Saleh *et al.* (2013) reported that, calcium content of finger millet is significantly higher than iron. The iron content of the finger millet cultivars are at least equal to that of some other cereal grains, such as wheat, rice and corn. Finger millet also has high level of potassium, magnesium, copper, sodium and phosphorus (Obilana and Manyasa, 2002). However, the bioavailability of some of the minerals (e.g. phosphorus and divalent metal ions) may decrease due to the

interaction with antinutritional factors, mainly phytic acid, oxalic acid and condensed tannins, which are present in finger millet grain.

2.4.5 Vitamins

Finger millet contains both water-soluble and liposoluble vitamins: thiamin, riboflavin, niacin and apparently vitamin C plus vitamin A,D,E and K (Obilana and Manyasa, 2002). The water-soluble B-vitamins are concentrated in the aleurone layer and germ, while the liposoluble vitamins are mainly located in the germ of the grains (Siwela *et al.,* 2009).

2.5 Antinutritional Factors

Bioavailability is a general term that refers to how well a nutrient can be absorbed and used by the body. It can be affected by many factors such as the presence of anti-nutrients, for example, phytates, oxalates, tannins and polyphenols in foods (Norhaizan and Ain, 2009). Food constituents with anti-nutrient properties may also have health beneficial properties, and the significance of each anti-nutritional factor has to be considered in the context of the specific diets and the specific nutritional problems in a population (Yang *et. al.*,2012).

The most important anti-nutritional constituent in diet in low-income countries in terms of negative and positive (the locals are ignorant on this) nutritional impact is phytate, primarily contributed from cereal staples and secondary from legumes and other plant foods. Others include polyphenol compounds which are present in different forms in fruits, vegetables, pulses and cereals. One of the

most widespread groups of polyphenols with anti-nutritional properties is soluble tannins (Michaelsen *et al.,* 2008).

2.5.1 Phytate (Phytic acid)

Phytic acid (myo-inositol hexaphosphate) are found in food high in fiber such as cereals (grains), legumes, oil seeds and nuts (Hidvegi and Lasztity, 2002). Phytate is a phosphorous containing compound that binds and hinder mineral absorption. The presence of phytate in foods has been associated with reduced mineral absorption due to the structure of phytate which has high density of negatively charged phosphate groups which form very stable complexes with mineral ions, trace elements, proteins, amino acids, and/or multivalent cations or minerals in food which have positively charged functional groups causing non availability for intestinal absorption (Afinah *et. al*., 2010). This interaction do not only have nutritional consequences, but also affects yield and quality of food ingredients such as starch, corn steep liquor or plant protein isolates (Wong *et al*., 2013).

The major concern about the presence of phytate in the human diet is its negative reaction on mineral uptake. Minerals of concern in this regard include zinc, iron, calcium, magnesium, manganese and copper (Kumar *et al.,* 2010). The formation of insoluble mineral phytate complexes at physiological pH value is the major reason for the poor mineral bioavailability, because these complexes are essentially non-absorbable from the human gastrointestinal tract. Furthermore, the human small intestine has only a very limited capability to hydrolyze phytate due to the lack of endogenous phytate degrading enzymes and

the limited microbial population in the upper part of the digestive tract (Badau *et al.,* 2013).

Degradation of phytate (myo-inositol hexaphosphate) to lower inositol occurs during food processing and in the gastrointestinal tract (Iqbal *et al.,* 2000). This degradation is of nutritional importance because the mineral binding strength decreases, due to lower inositol phosphates having less binding capacity and the solubility increase when phosphate groups are removed from the inositol ring, resulting in an increased bioavailability of essential dietary minerals. Saleh *et al.,* (2013) reported that, enzymatic hydrolysis generally occurs during biological processing and preparation of plant food/feed such as steeping, malting, hydrothermal processing, fermentation, and addition of phytase as well as during degradation in the gastrointestinal tract of some animals, for example rats. Non-enzymatic hydrolysis usually takes place when food/feed is treated with strong acid or high temperature and pressure.

Consumption of phytate, however, does not seem to have only negative impacts on human health. Dietary phytate was reported to prevent kidney stone formation and protect against atheriosclerosis and coronary heart diseases as well as against a variety of cancers and prevention of type II diabetes (Mathanghi and Sudha,2012). The level of phytate and its dephosporylation products in urine, plasma and other biological fluids are fluctuating with ingestion or deprivation of phytate in the human diet. Therefore, the reduction in phytate intake in developed compared to developing countries might be a factor responsible for the increase in diseases typical for western societies such as diabetes mellitus, renal diseases, cancer, atheriosclerosis and coronary heart diseases. It was suggested that phytate may exert the beneficial effects in the

gastrointestinal tract and other target tissues through its chelating ability (Johnsson *et al.,* 2015).

2.5.2 Phenolic Compounds

Plants produce a great variety of organic compounds that are not directly involved in primary metabolic processes of growth and development. The roles, these natural or secondary metabolites play in plants, have only recently come to be appreciated in an analytical context. Natural products appear to primarily function in defence against predators and pathogens and in providing reproductive advantage as attractants of pollinators and seed dispersers (Novus Research, 2011).

Alkaloids are synthesized principally from amino acids. These nitrogen-containing compounds protect plants from a variety of herbivorous animals. In a general rule, the terms phenolics and polyphenols refer to all secondary natural metabolites arising biogenetically from the shikimate-phenylpropanoids-flavonoids pathways, producing monomeric and polymeric phenols or polyphenols. Many plant phenolic compounds are polymerized into larger molecules such as the proanthocyanidins (condensed tannins) and lignins. Phenolic acid, condensed tannins, lignans, flavonoids, and some simple phenollic compounds are examples (Seuring *et al.,* 2015). In cereal grains, these compounds are located mainly in the pericarp, and can be concentrated by decorticating the grain (Scalbert, 2005; Dykes and Rooney, 2007 and Novus Research *et al.,* 2011).

Tannins are divided into two groups, hydrolysable tannins and condensed tannins (Ali *et al.,* 2009). Condensed tannins, consist of polymerized flavanol

units (Dykes and Rooney, 2007), and they contribute to astringency in plant foods and for their antinutritional effects, which seem to be mainly due to their interference with the digestion of protein. Tannins affect the growth of animals in three main ways; they have an astringent taste, which effects palatability and decreases feed consumption; they form complexes of reduced digestibility with proteins; and they act as inactivators of enzymes like, pectinase, amylase, lipase, proteolytic enzymes, β-galactosidase and those microbial enzymes involved in fermentation of cereal grains (Ali *et al.*, 2009). The occurrence of tannins in finger millet is a varietal property as in sorghum (Shobana *et al.*, 2013).

2.6 Alpha Amylase Inhibitors

Alpha amylase inhibitors are present in many cereals and legumes. Amylase is necessary to hydrolyze starch and is present in the saliva and in the pancreatic secretion. Alpha amylase inhibiters reduce starch digestion and energy availability through the inhibition of amylase. Therefore, significant alpha amylase inhibitor levels in the diet may prevent required starch digestion, with the result that undigested starch is metabolized in the large intestine with soluble fibers and turned into short chain fatty acids with lower energy efficiency which is beneficial for the control of blood glucose and important for the management of diabetes (WHO, 2015).

Current nutritional guidelines for the management of diabetes emphasize on low glycemic index diets. Whole grain foods are normally suggested to diabetics because of their complex carbohydrates and dietary fiber contents. The bran layer and cell wall components of the whole grain contain several bioactive

compounds such as polyphenols which offer health benefits. In addition to the dietary fiber, whole grain foods are rich in vitamins, minerals and other compounds that alone or in combination are likely to deliver significant health benefits. Lower incidence of complications of type II diabetes has been associated with whole grain consumption (Shobana et al.,2013). Moreover, whole grain consumption is known to improve the insulin sensitivity (Imamura *et al.,* 2015). In general, the beneficial effects of soluble fiber may be mediated through the slow absorption and digestion of carbohydrates that lead to a reduced demand for insulin. On the other hand, insoluble fiber shortens intestinal transit, thereby allowing less time for the sugars to be absorbed. Alpha amylase inhibitors are relatively resistant to boiling (Johnsson *et al.,* 2015).

2.7 Effect of Processing on the Nutrient Contents of Food

The reasons for processing food include preservation of foods for use in times of shortage; increase shelf life; removal of toxins, removal of anti-nutrients, and improvement in palatability, digestibility and availability of nutrients (Michaelsen *et al.,* 2008). Processing generally decrease the content of vitamins and mineral, however, some methods like germination and fermentation can increase the content of some nutrients, e.g. Vitamin B and C. Processing also decrease the content of antinutrients, and has a positive effect on the availability of vitamins and minerals (Seuring *et al.*, 2015).

2.7.1 Soaking

Both whole grain and flours can be soaked. Usually the process lasts for 1-2 days, but soaking for some hours may also have beneficial effects, like reduction of phytate content (Michaelsen *et al.,* 2008). Soaking may also wash out water-

soluble vitamins and minerals such as sodium, potassium, magnesium etc. The extent of the phytate reduction depends on the species, pH, length of time and conditions of soaking. Soaking improves the absorption of iron, zinc, and calcium in cereal-based foods prepared with a reduced phytate content. The content of other antinutrients such as saponins, trypsin inhibitors and some polyphenols and oxalates that inhibit iron and calcium absorption, respectively, may also be reduced during soaking (Hotz and Gibson, 2007).

Saleh *et al*. (2013) reported that in pigeon pea, the content of phytic acid reduced signficantly when soaked for longer period like 8h or more. The loss of phytic acid in the soaked pea may have been a function of leaching of phytate ions into the soaking water under the influence of concentration gradient which governs the rate of diffusion. Shobana *et al*. (2013) reported that soaking of pearl millet reduced the phytic acid content by 39.47 and 24.17% in two different varieties, while soaking of unrefined maize flour reduced phytate content by approximately 50% (Ali *et al*., 2009). Soaking also significantly decreased tannin content by 22.72% and 11.76% in two varieties of pearl millet. However, soaking has less effect on the reduction of polyphenol content compared to other processing methods. Saleh *et al.* (2013) also stated that, tannin content significantly decreased when the grains were soaked in either distilled water or NaOH for 8h, and the reduction was more pronounced when the grains were cooked after soaking in NaOH.

2.7.2 Germination

Germination induces the synthesis of hydrolytic enzymes such as starch degrading enzymes (amylases) and proteases. Germination has been claimed to

improve the nutritive quality of cereals. The enzymatic breakdown of starch to sugars (dextrin and maltose) reduces the water-binding capacity and consequently lowering the viscosity and bulk density of porridge and gruel made from cereals. Germination also improves protein quality and digestibility and the content of riboflavin, niacin, and vitamin C is increased and the content of antinutrients is reduced (Mbithi-Mwikya *et al.,* 2000 and Hotz and Gibson, 2007). The terms 'sprouting', malting', and 'germination' are used interchangeably to refer to the process of soaking grains in water until saturated and germinating them under controlled conditions. The term malting is more commonly used when grains, especially barley, are soaked and germinated for brewing purposes; however, sprouting has been reported to improve the nutritional quality of seeds by increasing the contents and availability of essential nutrients and lowering the levels of antinutrients (Shobana *et al.,* 2013).

Wong *et al*. (2013) stated that, sprouting finger millet resulted in lowered levels of the antinutreints assayed, namely tannins, phytate and trypsin inhibitors activity. These decreases were accompanied by an increase invitro protein digestibility (IVPD) and HCl extractability of minerals and trace elements. In raw ungerminated finger millet tannin content was 914±14.4mg/100g and on germination for 24, 48, and 72h it decreased by 20, 45, 62 and 72% respectively (Mbithi-Mwikya *et al.,* 2000). Similar changes in tannin have been reported in germination (Mathanghi and Sudha, 2012). The viscosity of 10% slurry of the millet was also lowered significantly during germination, hence greatly reducing its bulk density. It was observed that most of the nutritionally important changes, namely lowering of bulk density, antinutrient reduction and increase

invitro protein digestibility (IVPD), occurred to a significantly larger extent at 48h of germination (Liu *et al.,* 2012). Saleh *et al.* (2013) also reported that major biochemical changes were observed when germination for 24 h was followed by fermentation (6-18h) compared to germination alone.

Singh and Raghuvanshi (2012) stated that germination of finger millet for 96h reduced the phytate phosphorus from 72.6% to 42.3%. On germination, there was a marginal increase in thiamine content, but finger millet, pearl millet and foxtail millet germinated for 48 h contained 5, 8 and 6 mg ascorbic acid, respectively while the native millets did not contain measurable levels of it. Germination of finger, pearl and foxtail millets for 48 h enhanced the lysine content of their proteins and increases the tryptophan content; however, the threonine and the sulfur amino acid contents were not altered appreciably. The increase in lysine, tryptophan and ascorbic acid, and the decrease in phytate phosphorus form the important nutritional benefits of germination of millets. Shobana *et al*. (2013) reported that, finger millet also has potential for malting as it produces; high amounts of reducing sugar and high enzyme activity, like amylase. Slow degradation of cell wall components is also useful for the preparation of fiber-rich foods.

2.7.3 Fermentation

Fermentation is one of the oldest and most effective methods of producing and preserving foods (Badau *et al.,* 2013). Lactic acid bacteria are the most widespread of desirable microorganisms in food fermentation. Lactic acid bacteria convert the available carbohydrate to organic acid and lower the pH of the food. These acids contribute to the desired taste and flavor of food. The low

pH that is created also makes the food unfavourable for the proliferation of spoilage and pathogenic bacteria (Badau *et al.,* 2013).

Natural fermentation of sorghum improved its nutritive value by decreasing the tannin content, improving invitro protein digestibility and invitro starch digestibility (Hassan and Tinay, 1995), however, Elyas *et al*. (2002) stated that natural fermentation of pearl millet decreased polyphenols and phytic acid and caused no changes in tannin contents. Dhankher and Chauhan (1987) also reported that phytic acid and polyphenol content of Indian food made from fermented pearl millet decreased as the period of fermentation increased. Fermentation of cereals has been found to improve the contents of certain B vitamins (thiamine, riboflavin and niacin). For example, fermentation increased thiamine content in sorghum from 20 to 47µg/g, and riboflavin content in pearl millet from 0.19 to 0.36µg/g (Michaelsen *et al.,* 2008).

Fermentation can induce phytate hydrolysis via the action of microbial phytase enzymes and by activation of endogenous phytases, which hydrolyze phytate to lower inositol phosphates. Such hydrolysis is important because myo-inositol phosphates which has less than 5 phosphate groups do not have a negative effect on zinc absorption and those with less than 3 phosphate groups do not inhibit nonheme iron absorption (Sandberg *et al.,* 1999). The extent of the reduction in higher inositol phosphate levels during fermentation varies; sometimes 90% or more of phytate can be removed by fermentation of maize, soy beans, sorghum, cassava, cocoyam, and cowpeas (Saleh *et al.,* 2013). In cereals with a high tannin content (e.g bulrush millet and red sorghum), phytase activity is inhibited, making fermentation a less effective phytate reduction method for these cereals varieties. Low molecular weight organic acids (e.g.,

citric, malic, lactic acid) are also produced during fermentation and have a potential to enhance iron and zinc absorption via the formation of soluble ligands while simultaneously generating a low pH that optimizes the activity of endogenous phytase from cereal or legume flours (Shobana *et al.*, 2013).

2.7.4 Decortication

Dehulling and decortications are mechanical methods used to remove the outer layer of grains (Krishnan *et al.*, 2012). Finger millets are not decorticated by known processes because of its small size. The process for preparing the decorticated finger millet are steeping in water for 2-16 h, steaming at atmospheric pressure for 2-20min, drying to 8-16% moisture content, decortications in abrasive cereal mill, and aspiration of the seed coat and grinding the millet (Shobana and Malleshi , 2007).

Wong *et al. (*2013) reported that bulk density and soluble fiber of the decorticated millet was slightly higher than native millet, probably due to removal of the seed coat, and also due to the reduced porosity in the kernel. The increase in the soluble fiber content of the product has a special nutritional significance because of its physiological advantages in terms of hypoglycemic and hypocholesterolemic characteristics. The reduction in polyphenols and phytate phosphorus contents on decortications of millet was 74.7% and 39.8% respectively and this may provide nutritional advantages with respect to increased bio-availability of minerals and protein. Oghbaei and Prakash (2012) reported that, testa layer of the millet is highly pigmented and contributes to the bulk of polyphenols and tannin content of the millet, and hence, significant reduction in the polyphenol contents occurs on decorticating the millet.

Similarly, phytate phosphorus is located largely in the scutellum and to a smaller extent in the aleurone cells therefore, reduction in phytate phosphorus occurs on decortications of millet (Shobana and Malleshi, 2007). Reduction in some of these constituents has nutritional advantages since, these are considered as anti-nutritional factors and the reduction improves the bioavailability of minerals (Singh and Raghuvanshi, 2012).

Decortications of cereals also have limitation such as protein, fat, calcium and phosphorus contents of the decorticated millet were lower by 22%, 40%, 43% and 48% respectively than the native millet. The reduction in some of the nutrients could be mainly due to separation of the seed coat, as it has been reported that, the seed coat contains about 28% of protein, 49% calcium and 14% phosphorus (Shobana *et al.,* 2013).

2.7.5 Roasting

Roasting is a cooking method that uses dry heat where hot air envelops the food, cooking it evenly on all sides with temperatures of at least 150 °C (~300 °F) from an open flame, oven, or other heat source. Roasting can enhance flavor through caramelization and Maillard browning on the surface of the food. Roasting uses indirect, diffused heat (as in an oven), and is suitable for slower cooking of meat in a larger, whole piece. Roasted wheat is one of the best cereal grains to use for feed and organic wheat is commonly available (Ashley and Clifford 1999). Roasted wheat is a good source of starch for energy and moderate source of protein, the protein of wheat is highly digestible and generally of high quality, any variety of wheat can be fed to

birds, although some are slightly more digestible than others (Saleh *et al.*, 2013).

2.8 Utilization of Finger Millet

Various kinds of foods are made from finger millet of which include bread, cakes, cookies, porridges, flat breads, and gruels from processed and native grain by either blending with other cereals or not. However, when compared to other less common cereals like sorghum the utilization of finger millet to produce novel commercial products is very limited.

2.8.1 Bread Making Principles

The aim of the bread making process is quite simple; namely to convert flour and other ingredients into a light, aerated and palatable food. Bread is made by mixing flour, water, salt and yeast. Optional additives such as fat or oil, and sugar may be added as necessary (Kaur *et al.*, 2012). Wheat flour is a key ingredient in most bread production. However, to increase the utilization of less common cereals there is the need to blend with wheat. According to Banerjee *et al.* (2012) there are several functional differences between wheat and less common cereals like sorghum. Most importantly, the storage protein kafira does not produce visco-elastic dough, unlike the wheat gliadin/glutenin. This means that some other way has to be found to stabilize the dough foam, enabling it to expand as a result of carbon dioxide production during fermentation. In this context, also of importance are the facts that the gelatination temperature of starch is much higher than that of wheat and that the arabinoxylan non-starch

polysaccharides appear to be much more water insoluble than those of wheat. Therefore, different processing methods to modify the functionality of the biopolymers of these cereals to improve its bread making quality need to be explored.

Chandrasekara and Shahidi, (2012) reported that, malting of sorghum decreased the pasting temperature of sorghum flour to values approaching that of wheat. The use of malted boiled and dried sorghum in sorghum –wheat composite bread at a ratio of 30:70 improved bread quality in comparison to the unmalted sorghum and wheat composite. Crumb structure, water -holding and softness were improved and the rate of staling was decreased.

Chandrasekara *et al*. (2012) reported that, the addition of fermented and dried sorghum flour decreased dough pH from 5.8 to 4.9. The compositing of this flour at a ratio of 30:70 sorghum increased bread loaf volume by about 4% compared to the unfermented sorghum: wheat composite control. Fermented flour also improved crumb structure and slightly decreased in crumb firmness. Mixing wet fermented sorghum flour directly with wheat flour in the some ratio further increased loaf volume.

2.8.2 Biscuit Production

The term biscuit refers to all types of thin baked products that have been baked to low moisture content < 55%. Because of the low moisture content, biscuits have long shelf life provided that they are packed in a suitable packaging material usually polypropylene film lined with aluminum foil. Several ingredients are used in biscuit formulations which include wheat flour, sugar,

vegetable fat, milk powder, salt, lavening agents, flavors, and preservatives (Badau *et al.,* 2013).

To improve the nutritional quality of cakes with respect to the mineral contents and fiber contents, (Desai *et al*., 2010), attempted the supplementation of wheat with malted finger millet flour. Desai *et al*. (2010) further stated that, the cake samples prepared with combinations of refined wheat and 60% and 70% malted finger millet flour were richer in calcium, iron, phosphorus, and crude fiber than other samples, but the sensory scores for the same were low due to the loss in sponginess and increased intensity of brown color (Ana *et al*.,2001). The cake sample prepared with 50% malted flour had sensory scores that are the same as the control (100% wheat).

There is limited information on the characteristics of finger millet composite cookies, but Siwela *et al*. (2009) reported that cookies that are rich in fiber and minerals and are sensorially acceptable can be made by substituting, up to about 35%, wheat with a high-tannin finger millet. The supplementation of processed finger millet may increase due to decrease in tannin that gives astringency test to the product.

2.8.3 Snack Foods

The name of snack foods covers a wide range of food products. They are consumed as light meals or a partial replacement for a regular meal. They are convenient because they are quick and easy to eat (Johnsson *et al*., 2015). The term ’snack food’ does not only apply to some of the newer products such as potato crisps, but it also includes many traditional food items. Snack foods frequently receive criticism due to their high levels of salt, sugar, and fat. They

are seen to be nutritionally damaging when eaten regularly in place of a traditional food (FAO, 2010).

Snack foods, however, can be very nutritious when made from fruits, pulses, or cereals. It should also be pointed out that the consumption of snack foods does not necessarily lead to health problems such as obesity, but the cause is rather an unbalanced diet with excess fat, sugar, and salt. Therefore, if these food products are part of a wider diet, they can be an important source of fats and energy, particularly for the poorer sectors of society whose diet may be lacking in these nutrients (FAO, 2010).

There are a number of traditional and newer snack foods products for example “Dabo kolo” is one of Ethiopian traditional snack product (EARO, 2004). Among them the major types of snack foods are: Raw cut vegetable snacks, formed dough products from potato derivatives, formed dough products from maize derivatives, half-product or pellet snacks, directly expanded extrude snacks, popcorn and puffed wheat, and related processes, such as snack biscuits and breadsticks (EFIC, 2011).

2.8.4 Functional Foods

Functional foods are foods which provide health benefits beyond basic nutrition due to certain physiologically active components, which may or may not have been manipulated or modified to enhance their bioactivity. These foods may help prevent disease, reduce the risk of developing disease, or enhance health. Most health-conscious consumers have become aware of the health benefits associated with specific foods and are incorporating elements such as fiber, calcium, and soy into their diets (Barbara, 2011).

Clearly, most foods are functional in some way. According to European Food Information Council (EFIC,2011) as what makes a "functional food," however, is its potential ability to positively affect health. Functional foods range from fruits, vegetables, and whole grains, which are naturally high in phytochemicals, which are ingredients that are specifically added, removed, increased, or decreased to or from a product (Shetty *et al.,* 2005 and EFIC,2011). Examples of some functional foods are: yoghurts to optimal intestinal function and intestinal microbial balance, margarines to decrease cholesterol and risk of coronary heart disease, omega-3 fatty acids enriched eggs to control hypertension and lipids metabolism (EFIC,S 2011).

Finger millet has distinct quality such as being exceptionally rich in calcium containing about 0.34%, 5-30 times more than in most cereals (Upadhyaya *et al.,* 2006), and also has high levels of potassium, magnesium, copper, sodium and phosphorus content (Obilana and Manyasa, 2002). According to Dykes and Rooney (2007), sorghum and finger millet have all types of phenolic acids such as caffic, cinnamic, ferulic, and sinapic and total dietary fiber of finger millet grain is relatively higher (22.0 percent) than that of most of other cereal grains (e.g. 12.6, 4.6, 13.4, and 12.8% for wheat, rice, maize and sorghum, respectively) (Klopfenstein, 2000). Chethan and Malleshi (2007) reported millets contained 15.7% insoluble dietary fiber and 1.4% soluble dietary fiber, while Shobana and Malleshi (2007) reported that, 19.7% insoluble dietary fiber and 2.5% soluble dietary fiber.

2.9 Glycemic Index

The glycemic index (GI) provides a measure for classifying foods according to their potential to raise blood glucose levels (Wais, 2012). The effect that different foods have on blood sugar levels vary considerably. The glycemic index estimates how much each gramme of available carbohydrate (total carbohydrate minus fibre) in a food rises an individuals blood glucose level following consumption of the food, relative to consumption of pure glucose with glycemic index of 100.

A practical limitation of the glycemic index is that, it does not take into account the amount of carbohydrate actually consumed. A related measures of the glycemic load factors is by multiplying the glycemic index of the food in question by the carbohydrate content of the actual serving. Glycemic index charts often give only one value per food, but variations are possible due to variety, response, cooking methods, processing and the length of storage. (Glycemic Research Institute, 2012). The glycemic response is different from one person to another and even in the same person from day to day depending on blood glucose levels, insulin resistance, and other factors (Wais, 2012). Most of the values on the glycemic index do not show the impact on glucose levels after two hours. Some diabetic people may have elevated levels after four hours (Wais, 2012).

Foods with carbohydrates that breakdown quickly during digestion and release glucose rapidly into the blood stream tend to have a high GI. Foods with carbohydrate that breakdown more slowly, releasing glucose more gradually into the bloodstream, tend to have a low GI. The concept was developed by Dr.

David and colleagues in 1980 – 1981 at the University of Toronto in their research to find out which foods were best for people with diabetes. A lower glycocemic index suggests slower rates of digestion and absorption of the foods. Lower glycemic responses usually have long term blood glucose control and blood lipids. (Jenkins et. al., 1981, and Wolever *et al.,* 1987). The insulin index is also useful for providing a direct measure of the insulin response to a food. (Jain and Bal, 1997).

2.10 Sensory Evaluation

According to Onimawo *et al*. (2001), sensory evaluation analyses and measures humans responses to the composition of food and drink, e.g. appearance, touch, odour, texture, temperature and taste. In schools it provides an ideal opportunity for students to evaluate and give feedback on their dishes, test products and experimental designs. Evaluation of sensory quality can also be defined as "a scientific discipline used to evoke, measure, analyze and interpret reactions to those characteristics of foods and materials as they are perceived by the senses of sight, taste, touch and hearing."

The uses of sensory evaluation are to; compare similarities/differences in a range of dishes/products, evaluate a range of existing dishes/food products**,** analyse food samples for improvements, guage responses to a dish/product e.g. acceptable against unacceptable, explore specific characteristics of an ingredient or dish/food product, provide objective and subjective feedback data for informed decisions to be made. A typical testing kit includes:- serving spoons, teaspoon, small, plain, white cups, pots or plates, rubbish bags, cutlery and labels.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Materials

3.1.1 Finger Millet

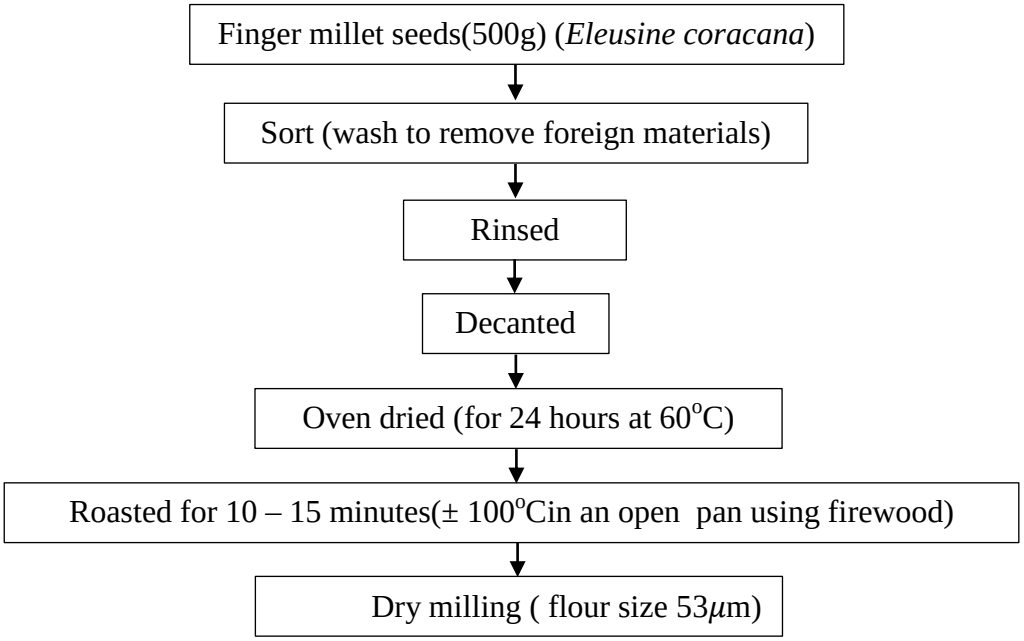
Finger millet commonly called *Tamba* in Hausa was purchased from the Central market, Kaduna and identified at the Herberium unit of the Department of Biological Sciences, Ahmadu Bello University, Zaria with voucher number 05321. The time of collection was twelve thirty (12:30) in the afternoon.

3.1.2 Chemical

Hydrochloric acid, boric acid, sodium hydroxide, potassium thiocyanate, petroleum ether, sulphuric acid, calcium chloride, potassium sulphate, copper sulphate, orthophosphoric acid, methanol acetone, ammonium hydroxide, sodium carbonate and potassium iodide were purchased from British Drug House (BDH) Ltd., England. Folin Cliocalteu reagent (2N) was diluted with equal volume of distilled water, Sodium carbonate, and Standard tannic acid solution (0.5mg/ml).

3.2. Processing of Finger Millet Seeds

3.2.1 Roasting



3.2.2 Germination

Finger millet was soaked in water for 8-12 h. The water was drained and the grains tied in a moist muslin cloth and left to sprout at room temperature for 72hrs (Badau *et al.*,2013). Each treatment was replicated 2 times. The germinated grains were laid out `on steel trays in thin layers of less than 2cm. the trays was then placed in a hot air oven and dried at 50^{0}C for 24h. The samples was milled to flour using a hammer mill and stored in an air tight polythene bags in a cool and dry place until use.

3.2.3 Fermentation

Production of fermented finger millet flour includes the following steps:

Cleaning and winnowing of finger millet by sorting out foreign materials and removal of immature seeds and washed to avoid unpleasant odour and removal of adherent particles. Finger millet was steppened in water for 48hours, drained

the water and rinsed off. It was spread on a cabinet drier for 24 hours at 60^{o}C, followed by dry milling and finally the flour.

3.2.4 Unprocessed Finger Millet

The grains were sorted, cleaned, washed, dried and pulverized using a plate mill to obtain whole flour (WF).

3.3 Methods

3.3.1 Determination of Functional Properties

3.3.1.1 Bulk density

Bulk density was determined following the method of Okaka *et al.* (1979), 50g flour sample was put into 100ml measuring cylinder until a constant volume was obtained. Bulk density (g/cm^3) was calculated as weight of flour (g) divided by flour volume (cm^3).

3.3.1.2 Water holding capacity

Water holding capacity of the raw and processed finger millet flours was determined by centrifuge method (Sosulki, 1962). The sample (1g) was placed in a 50ml centrifuge tube, distilled water (30ml) was added to the tube and the contents mixed well (30sec) using a glass rod. The tube was allowed to stand for 10 min; additional seven mixings was made with 10 min rest period following each mixing. The suspension was centrifuged at 2000g for 25minutes. The supernatant was decanted, the tubes drained and dried in the oven at 50^{0}C for 25minutes, cooled in a desiccator and weighed.

3.3.1.3 Swelling power

Swelling power and solubility was determined by centrifuge method (Sosulki, 1962). Each of the sample was placed in a 50ml centrifuge tube, distilled water (30ml) was added, mixed well and heated at 55^{0}C, 65^{0}C, 75^{0}C and 95^{0}C

respectively in a water bath with intermittent stirring for 30 minutes. Centrifuged at 3000g for 20 minutes and the supernatant was decanted and evaporated on a steam bath to obtain dissolved solids. The sediments flour was weighed to obtain the weights of the swollen flour particles

3.3.1.4 Solubility

One gramme of sample was dissolved in 20ml of distilled water in a screw capped glass. The mixture was incubated in water bath set at 95^0C for 30minutes with frequent stirring, then cooled to 20^0C. The mixture was centrifuged at 704 ×g (3000rpm) for 15minutes. The aquous supernantant (dissolved starch) was poured into a tared dish and dried at 100^0C for 3-4hours.

Calculations: The amount of dried solids recovered by evaporating the supernatant was expressed as gram of dried solids per gram of sample x 100, expressed as a percentage on weight basis.

Solubility = $weight\ of sample\ after\ drying\ \times\ 100$

3.3.1.5 Gelation capacity

Two (2)– twenty (20) percent (w/v) for samples suspensions were prepared in 5ml of distilled water in test tubes, the samples test tubes were heated in a boiling water bath for 1hr followed by rapid cooling under running cold tap water. The test tubes were placed in to a freezer for 2 hr at 4^oC. After cooling for 2hr at 4^oC, the test tubes were now inverted to determine the gelation concentration (Gelation Capacity).

Sample preparation

2%, 4%, 6%, 8%, 10%, 12%, 14%, 16%, 18% and 20%

i.e 2g of the sample in 100ml of H_2O

3.3.1.6 Gelatinization temperature

10% of sample suspension was prepared in a test tube and heated in a boiling water bath, with continuous stirring. After gelatinization was visually noticed, the temperature was now recorded after 20 seconds as gelatinization temperature.

Sample Preparation

Ten grams of sample in 100ml of H_2O

3.3.2 Determination of nutrient composition (proximate analysis, mineral elements, anti – nutrients composition, amino acids profile and dietary fiber)

3.3.2.1 Proximate analysis

The sample was analysed for moisture, ash, crude protein, fat, fiber and available carbohydrate according to the method recommended by Association of Official Analytical Chemists (AOAC, 2000).

3.3.2.1.1 Moisture Content:

The method employed for the determination of moisture content of the sample was that which is based on the measurement of the loss on weight due to drying at a temperature of 105^0C as described by AOAC (2000). Watch glasses were washed and dried in an oven at 105^0C, after which they were cooled and weighed empty. Two grams of each sample was weighed into their respective watch glasses. The watch glasses and their contents were dried in an air circulated oven at 105^0C to a constant weight. The watch glasses and their contents were cooled in desiccators and reweighed. The percentage moisture content of each sample was calculated using the expression.

$$\% \, Moisture = \frac{loss \, of \, weight \, on \, drying(g)}{initial \, sample \, weight} \times 100$$

3.3.2.1.2 Ash Content:

The term ash refers to the residue left after the combustion of the oven dried sample and is a measure of total mineral content. Determination of ash content was carried out according to the method described by AOAC (2000).

The crucible were p reheated in a muffle furnace at about 550^0C. Each crucible was cooled in a desiccator and weighed. Approximately 2g of each sample was weighed into the different crucibles. The crucibles and their contents were transferred into the muffle furnace at 550^0C and allowed to stay for 5 hours. The weights of the crucible contents was taken and recorded. Percentage ash was calculated using the expression below

$$\%Ash = \frac{weight \, of \, ash}{weight \, of \, original \, food} \times 100$$

3.3.2.1.3 Determination of Crude Protein :

Method (Pearson, 1986)

Exactly 2.0g of each sample was weighed into 100ml Kjedahl flask and a few anti bumping granules were added. One gram of the mixed catalyst ($CuSO_4$ and K_2SO_4 in the ratio 8:1 respectively) and 15ml of concentrated sulphuric acid were added. The flask was placed on a Kjedahl digestion rack and heated until a clear solution was obtained. At the end of the digestion, the flask was cooled and the sample was quantitatively transferred to a 100ml volumetric flask and made up to the mark with distilled water. Ten milliters of the digest was pipetted into semi micro nitrogen steel tube, and 10ml of 40% NaOH solution was added cautiously. The sample was steam distilled liberating ammonia into a 100ml conical flask containing 10ml of 4% boric acid using methyl blue indicator until

the colour changed from pink to green. Exactly 30ml of sample volume was collected. The content of the conical flask was then titrated with 0.1M HCl. The end point was indicated by a colour change from green to pink and the volume (v) of the acid for each distillate was noted. Percentage nitrogen per sample was calculated using the expression below:

$$\%\ Nitrogen = \frac{m \times v \times 14 \times 100 \times 100}{weight\ of\ sample \times 1000}$$

Where,

M = Molarity of HCl

14 = Atomic weight of Nitrogen.

100 = Total volume of digest.

100 = % conversion

10 = Volume of the digest taken

1000 = Conversion to litre

The crude protein was calculated as:

% protein = 6.25 x % nitrogen.

3.3.2.1.4 Determination of Lipid Content :

The lipid content was determined as in the method of AOAC (2000). Two round botton flasks were washed and few anti-bump granules were added to prevent bumping. Petroleum either of (40-60^{o}C) boiling point and volume (300ml) were poured into the flask. These were fitted into the Soxhlet extraction units. Extractor thimbles were weighed and 2g of samples were added. The thimbles were fixed into the soxhlet extraction unit and cold water circulation was also put on. The heating mantle was switched on and solvent refluxing was adjusted at a steady rate. Extraction was carried out for 8hours. The thimble was removed

and dried to constant weight in an oven at 70^0C and was weighted (W_2). The extractible lipid content of the sample was determined as follows;

$$\% \text{ Lipid} = \frac{Weight\ of\ Lipid\ extracted}{Weight\ of\ dried\ sample} \times 100$$

3.3.2.1.5 Determination of Crude Fiber:

The method described by AOAC (2000) was used. Two grams of finely ground sample was placed in a round bottom flask. 100ml of 0.25M H_2S0_4 was then added and the mixture was boiled under reflux for 30 minutes. The insoluble residue was washed several times with hot water until it was acid free (C_1). It was then transferred into a flask containing 100ml of 0.25M H_2S0_4 solution. The mixture was boiled again under reflux for 30 minutes and filtered under suction. The insoluble residue was washed with hot water until it was base free (C_2). It was then ashed in a furnace at 550^oC for 2 hours. The furnace was put off and allowed to cool down and the sample was removed, cooled and weighed (C_3). The crude fiber content was calculated as the loss of weight on ashing.

$$\% \ Crude\ fiber = \frac{C_2 - C_3}{W_1} \times 100$$

Where W_1 = Weight of the original sample (2g).

Determination of Insoluble Dietary Fiber

Wet and redistribute Celite bed in previously tared crucible, B(b), using ca 3ml H_2O. A suction was applied to crucible to draw Celite into even mat, enzyme digestate was filtered through crucible into filtration flask. The beaker was rinsed and the residue was washed twice with 10ml 70^OC H_20. The combine filtrate and water washings was transferred into pretared 600ml tall – form

beaker, and reserved for determination of soluble dietary fiber, using vacuum, the residue was washed 2 times each with 15ml portions of 78% ethanol, 95% ethanol, and acetone. (Note: Delay in washing IDF residues with 78% ethanol, 95% ethanol, and acetone may cause inflated IDF values.)

Determination of Soluble Dietary Fibre

Proceed as for insoluble dietary fibre determination through instruction to combine the filtrate and water washings in prepared 600mL tall-form beakers. The beakers were weighed with combined solution of filtrate and water washings, and estimate volumes.

four volumes of 95% ethanol preheated to 60^0 were added, portion of 60^0 ethanol was used to rinse filtering flask from IDF determination. Alternatively, the weight of combined solution of filtrate and water washing was adjusted to 80g by addition of H_2O, and addition of 320ml 60^0 95% ethanol and allowed to form precipitate at room temperature for 1h.

3.3.2.1.6 Determination of Carbohydrate Content:

The percentage carbohydrate was obtained by difference thus;

Percentage carbohydrate = 100 – (%ash + %crude fibre + %crude fat + %crude protein + %moisture).

3.3.2.2 Mineral Element Determination

Phosphorus (P), Iron (Fe), Calcium (Ca), Magnesium (Mg), Manganese (Mn), and Potassium (K) were determined by Atomic Absorption Spectrometry (AAS); while Sodium (Na) and Potassium (K) were determined by flame photometry according to the method of AOAC (2003).

Wet Digestion of Sample

For wet digestion of sample, exactly (1.0g) of the powdered sample was put to digestion tube. Twelve millilitres (12ml) of concentrated HNO_3 was added to the samples and the mixtures was kept overnight at room temperature. Then 4.0ml per chloric acid ($HCIO_4$) were added to the mixture and was kept in the fume hood for digestion. The temperature was increased gradually starting from 50^0C and increasing up to 250 - 300^0C. The digestion was completed in about 1hr 15min as indicated by the appearance of white fumes. The mixture was left to cool down and the contents of the tubes were transferred to 100ml volumetric flasks and the volume was made to 100ml with distilled water. The wet digested solution was transferred to plastic bottles labelled accurately and stored for mineral determination.

Procedure

Digested sample was analysed for mineral contents. The absorption measurement of the elements for the samples was read out. Different electrode lamps were used for each mineral. The equipment was ran for standard solutions of each of the mineral, before and during determination to check that it is working properly. The dilution factor for all minerals except Mg was 100, for determination of Mg, further dilution of the original solution was done using 0.5ml original solution and enough distilled water was added to it to make the volume up to 100ml. Also the determination of calcium (Ca), 1.0ml lithium oxide solution was added to the original solution to unmask Ca from Mg. The concentration of minerals was determined using the formula below:

$$C = \frac{Absorbency(ppm)\ x\ dry\ wet\ x\ D}{Weight\ of\ sampls} \times 100$$

Where:

C = Conc. of minerals

D = Dilution factor

Determination of Sodium (Na) and Potassium (K) were done by the method of flame photometry. The same wet digested sample solutions used in AAS were used for the determination of Na and K. Standard solutions of 20, 40, 60, 80 and 100mili equivalent/L were used both for Na and K. The calculation for the total mineral content involved the same procedure as given in Atomic Absorption Spectrophotometric (AAS) Method.

3.3.2.3 Anti-nutrients Determination

3.3.2.3.1 Determination of phytate

Phytate were determined using the method of Maga (1983). Each sample (2g) was weighed. Hundred ml of 2% concentrated hydrochloric acid was used to soak each sample into conical flask for 3h and filtered through a double layer of hardened filter paper. 50ml of each filtrate was placed in 250ml beaker and 107ml of distilled water was added in each case to give proper acidity. Ten ml of 0.3% ammonium thiocyanate solution was added into each solution as indicator. This was titrated with standard iron (III) chloride solution which contained 0.00495g iron per ml. The end point was slightly brownish yellow which persisted for 5min.

3.3.2.3.2 Determination of cyanide

The cyanide content was determined according to the method of AOAC, (2000). Exactly 2.0 g of sample was weighed into a flask and 100ml of distilled water was then added to it and allowed to hydrolyze for 1hr. Exactly 10ml of 2.5% NaOH was measured carefully and poured into the sample holder. The soxhlet

apparatus was set up and distilled into the sample holder containing the 2.5% NaOH until about 70ml was collected. It was then carefully transferred to a 100ml volumetric flask and the sample holder rinsed with distilled water successfully into the volumetric flask. It was also made up to 25ml mark of the distillate and was pipetted into a conical flask, 2ml of 6molar NH_4OH was added as well as 0.5ml of 10% KI solution, it was then titrated with 0.02M $AgNO_3$ to first turbid colour.

Note:1ml of 0.02M $AgNO_3$ is equal to 1.08g of cyanide.

3.3.2.3.3. Determination of alkaloid

The gravimetric method of Harbone (1980) was adopted. A given weight of each sample (5.0g) was weighed and dispensed into 50ml of 10% acetic acid solution in ethanol. The mixture was shaken thoroughly and allowed to stand for 24 hr before filtering. The filtrate was evaporated to one quarter (1/4) of its original volume. The concentrated NH_4OH was dropped wisely to precipitate the alkaloids. filtered off the precipitate with a weighed filter paper and washed with 1% NH_4OH solution. The filtering was done with a weighed filter paper. The precipitate was dried using filter paper in the oven at 60^0C for 30min and reweighed.

By weight difference, the weight of alkaloid was determined and expressed as a percentage of the sample weight analysed, given by the formula:

$$\%\ Alkaloids = \frac{w_2 - w_1}{w} \times 100$$

Where:

W= weight of sample

W_1 = weight of empty filter paper

W_2 = weight of filter paper plus precipitate

3.3.2.3.4 Determination of oxalates

Oxalate was determined using method of Oke (1969). The total oxalic acid of the powdered sample was determined by weighing 2g of sample into 250ml of conical flask. Distilled water (190ml) and 10ml of 6M HCl was then added. The mixture was incubated for 1hr on a boiling water bath, cooled, transferred into a 250ml volumetric flask, diluted to volume and filtered. Four drops of methyl red indicator was added, followed by concentrated ammonia till the solution turned faint yellow. It was then heated to 100^0C, allowed to cool and filtered to remove precipitate containing ferrous irons. The filtrate was then boiled and 10ml of 5% $CaCl_2$ added with constant stirring. It was allowed to stand overnight.

The mixture was filtered through Whatman No. 4 filter paper. The precipitate was then washed several times with distilled water and transferred to a beaker and 5ml of 25% sulphuric acid was added to dissolve the precipitate. The resultant solution was maintained at 80^0C and titrated against 0.5% potassium permanganate until the pink colour persists for approximately one minute. A blank was ran from the amount of potassium permanganate to be used, the oxalate content of the known sample was calculated using the equation below:
1ml potassium permanganate = 2.24mg oxalate

3.3.2.3.5 Determination of tannins

Tannins content was estimated according to the method described by international pharmacopeia and AOAC (2003)

Sample preparation

Three grams of the studied food products were dissolved with distilled deionsed water into 250ml volumetric flask during 4 hours at room temperature and then the samples were filtered.

Tannins assay

25ml of the infusion are measured into 1L conical flask, then 25ml of indigo solution and 750ml distilled deionsed water was added. Then 0.1N aqueous solution of $KMnO_4$ was used for titration until the blue coloured solution changes to green colour. Then few drops at time until solution becomes golden yellow are added. Standard solution of indigo carmine is prepared as following: Six grams Indigo carmine is dissolved in 500ml of distilled deionsed water by heating after cooling, 50ml of 95 – 97% H_2SO_4 was added. The solution was diluted to 1L and then filtered. The blank tests by titration of a mixture of 25ml indigo carmine solution and 750ml deionsed distilled water were carried out.

All samples were analysed in duplicates

Calculations

The tannins content (T,%) in the samples is calculated as follows:

$$T(\%) = \frac{(V-V_O) \text{ X } 0.004157 \text{ X } 250 \text{ X } 100}{g \text{ x } 25}$$

Where V is the volume of 0.1N aqueous solution of $KMnO_4$ for the titration of the samples

V_o – volume of 0.1N aqueous solution of $KMnO_4$ for the titration of blank sample, ml; 0.004157 – tannins equivalent in 1ml of 0.1N aqueous solution o $KMnO_4$;

g – mass of the sample taken for the analysis

3.3.2.3.6 Determination of saponin

The gravimetric method of AOAC (1984) employing the use of a soxhlet extractor and two different organic solvents was used. Dry ground sample (5g) was weighed into a thimble and transferred into the soxhlet extractor chamber fitted with a condenser and a flat bottom flask. Some quantity (200ml) of acetone, enough to cause a reflux was poured into the round bottom flask. The sample was completely extracted of its lipid and interfering pigments for 3 hours by heating the flask on a hot plate and the solvent distilled off. This was the first extraction, for the second extraction, a pre-weighed round bottom flask was fitted into the soxhlet apparatus (bearing the sample containing thimble) and methanol poured into the flask. The methanol was enough to cause a reflux. The saponin was then exhaustively extracted for 3hours by heating the flask on a hot plate after which the solvent was distilled off. The flask was re-weighed. The difference between the final and initial weights of the flask represented the weight of saponin extracted.

$$\% \text{ Saponin} = \frac{weight\ of\ Saponin}{weight\ of\ sample}\ x\ 100$$

3.3.2.4 Determination of Amino Acids Profile

The amino acid profle in the known sample was determined using methods described by Benitez (1989). The known sample was dried to constant weight,

defatted, hydrolysed, evaporated in a rotary evaporator and loaded into the applied Biosystems PTH Amino Acid Analyzer.

Defatting sample

The sample was defatted using chloroform/methanol mixture of ratio 2:1. About 4g of the sample was put in extraction thimble and extracted for 15 hrs in soxhlet extraction apparatus (AOAC, 2006).

Nitrogen Determination

A small amount (200mg) of ground sample was weighed, (No.1) and put in the Kjeldhal digestion flask. Concentrated sulphuric acid (10ml) was added. Catalyst mixture (0.5g) containing sodium sulphate (Na_2SO_4), copper sulphate ($CuSO_4$) and selenium oxide (SeO_2) in the ratio of 10:5:1 was added into the flask to facilitate digestion. Four pieces of anti-bumping granules were added.

The flask was then put in Kjeldhal digestion for 3 hours until the liquid turned light green. The digested sample was cooled and diluted with distilled water to 100ml in standard volumetric flask. Aliquot (10ml) of the diluted solution with 10ml of 45% sodium hydroxide was put into the Markham distillation apparatus and distilled into 10ml of 2% boric acid containing 4 drops of bromocresol green/methyl red indicator until about 70ml of distillate was collected.

The distillate was then titrated with standardize 0.01N hydrochloric acid to grey colored end point. The percentage Nitrogen in the original sample was calculated using the formula:

$$\text{Percentage Nitrogen} = \frac{(a-b)X\ 0.01\ X\ 14\ X\ V\ X\ 100}{W\ X\ C}$$

Where:

a = Titre value of the digested sample

b = Titre value of blank sample

v = Volume after dilution (100ml)

W = Weight of dried sample (mg)

C = Aliquot of the sample used (10ml)

14 = Nitrogen constant in mg.

Hydrolysis of the sample

The defatted sample was weighed into a glass ampoule and 7ml of 6N Hcl was added and oxygen was expelled by passing nitrogen into the ampoule (this is to avoid possible oxidation of some amino acids during hydrolysis e.g methionine and cystine). The glass ampoule was then scaled with Bunsen burner flame and put in an oven preset at $105^0C\pm 5^0C$ for 22 hours. The ampoule was allowed to cool before breaking open at the tip and the content was filtered to remove the humins. Tryptophan was destroyed by 6N HCl during hydrolysis. The filtrate was then evaporated to dryness using rotary evaporator. The residue was dissolved with 5ml to acetate buffer (pH 2.0) and stored in plastic specimen bottles, which were kept in the freezer.

Hydrolysis of tryptophan

The defatted sample was weighed into glass ampoule. 10ml of 4.2M NaOH was added and oxygen was expelled by passing nitrogen into the ampoule. The glass ampoule was then scaled with Bunsen burner flame and put in an oven preset at $105^0C\pm 5^0C$ for 22 hours. The ampoule was allowed to cool before breaking open at the tip and the content was filtered to remove the humins. The filtrate

was neutralized with 6N HCl and evaporated to dryness at 40^0C under vacuum in a rotary evaporator. The residue was dissolved with 5ml of acetate buffer (pH 7.0) and stored in plastic specimen bottles, which were kept in the freezer.

Loading of the hysrolysate into analyser

The amount loaded was 60 microlitre. This was dispensed into the cartridge of the analyzer. The analyser is designed to separate and analyse free acidic, neutral and basic amino acids of the hydrolysate.

Method of calculating Amino Acid Values from the Chromatogram Peaks

An integrator attached to the analyser calculates the peak area proporitional to the concentration of each of the amino acids.

3.3.2.5 Dietary Fiber Determination

Dietary fiber was determined by (AOAC, 2000) method. Samples were defatted and gelatinized in the presence of heat stable alpha amylase, and then enzymatically digested with protease and amyloglucosidase to remove digestible protein and starch. Four volumes of ethanol were added to precipitate soluble dietary fibre. Total residue was filtered off and washed with ethanol and acetone. The residue was weighed after drying. The remaining material was analysed for protein and ash content respectively. Subtracting the amounts measured for protein, ash and a blank control from the dry weight of the filtered residue will yield a value for total dietary fiber content.

Total dietry fiber= weight residue-protein-ash-blank/weight test portion.

Weight residue= average of duplicate

Weight test portion = average duplicate

3.3.3 Pilot Study on Commonly Consumed Products of Finger Millet

3.3.3.1 Study area

Kaduna North is a Local Government Area in Kaduna State, Nigeria with its coordinates at $10^0$20N$7^0$45'E. Headquarters at Doka. It has an area of 72km^2 and a population of 357,694 (2006 census). One hospitals namely Yusuf Dan-tsoho memorial hospital (YDMH) was conveniently selected for the study.

3.3.3.2 Study design

Cross sectional survey in four randomly selected wards of YDMH was adopted, using semi structured questionnaire administered to women of child bearing age.

3.3.3.3 Sample size

This was determined using the formula

$$n = z^2 p(1-p)$$

Where

n = Sample size

z = Confident level at 95% (standard value of 1.96)

p = Estimated prevalence of consumption (or just percentage)

l = Confident intervals (i.e. margin of error at 5%)

The sample size was 100 respondents which was randomly selected from the population of 300 respondents.

3.3.3.4 Standardized method of preparation of finger millet food products

Preparation of Tuwo:

Finger millet flour (200g) was mixed with 350ml of water to make a very thin paste and was constituted with hot boiling water on a stove. The mixture was allowed to boil for 20 minutes and flour was added and stirred continuously with

a wooden stick to form a mould. The mould was allowed to cook for 20 minutes on a medium high flame with the use of a wooden stick and the mixture (mould) was beaten to smooth dough like consistency with no lumps. The hot dough was then rested on low heat for10 minutes before rounding them on a wooden board into tennis sized balls with wooden spoon to scoop.

Preparation of Pap:

Finger millet flour (200g) was constituted with cold water (350ml) to a suitable consistency. It was reconstituted with hot boiling water at 100^{o}C to form gruel (Pap).

3.4 Glycemic Index Determination

Hospital: Yusuf Dantsoho Memorial Hospital (YDTMH) was selected for the study. It is the second largest hospital located in central part of Kaduna.

3.4.1 Subjects, Sample Size and Sampling

Diabetics and Control Subjects

The study involved all adult (>18years) diabetic patients attending Yusuf Dantsoho Memorial Hospital (YDMH). Twenty adults (10 males and 10 females) type II diabetic patients were the volunteers from the population of patients attending YDMH diabetic clinic and are non –insulin dependent according to the method of WHO (1999) and ADA (2007).

Inclusion Criteria

Subjects that volunteered to participate in the study, have no history of complications, non – smokers, no intake of nutritional supplements known to affect glucose metabolism, have no food allergy or pregnancy, no alcohol intake.

Exclusion criteria

Diabetic subjects (male and female) below the age of 18 years, BM I >25 kg/m^2, fasting blood glucose value >12mmol/L, smokers, alcoholics, on nutritional supplement, have history of complications, have food allergy ,type 1 diabetic subjects.

Control

Twenty apparently healthy control subjects were selected after matching for age and sex of the randomly selected subjects. The control subjects were volunteers and had no personal or family history of diabetes and were selected from staff of Yusuf Dantsoho Memorial Hospital and cleared as apparently healthy. Informed consent was obtained from the subjects and filled the inclusion criteria (appendix I). The nature of the study was explained using the language spoken by the subjects and were instructed not to change their physical activity pattern throughout the study period. This is in conformity with Fukagawa *et al.,* (1990) that change in activity might influence peripheral sensitivity to insulin and thus might have an effect on glycaemic index.

Drugs were stopped one week before the study commenced. Information obtained from the subjects using dietary history questionnaire, revealed that, the major regularly consumed foods before the study were beans, acha and wheat, and other carbohydrate foods. The quantities consumed were not controlled and only depend on how much they can eat and be satisfied.

Food macronutrient in Pap and Tuwo were calculated using food composition table by Enwere, (1998). The meal contained the following approximate macronutrients.

Carbohydrate	-	50grams (51.5%) of the total meal calories
Protein	-	16.01-20.6grams (19.1%) of the total meal calories
Fat	-	13.4 – 16.77grams (27.1%) of the total calories

Total calorie intake = 398.4 – 418.5 calorie.

The composition of carbohydrate, protein and fat (%) was within the recommended range as stated by World Health Organization (WHO, 1985, and WHO, 1990). Ingredients used were collected raw and in bulk to avoid differences in quality and quantity. Each portion was cooked separately to ensure that 50g of carbohydrate was maintained and contained in the cooked products.

Glucose solution (50g) was of pure glucose which was dissolved into 250ml of water to be taken orally. The participants (control and diabetic subjects) were instructed to have an overnight fast (at least 9 hours). Twenty (20) type II diabetic and 20 healthy subjects consumed the standardized meals prepared by the researcher. The proposal was approved by scientific research committee of the Ministry of Health and Human Services, Kaduna State (Appendix II).

The blood glucose levels of the subjects after overnight fasting were recorded following the finger – prick method (capillary blood) using a glucose sensor (Fine Test Auto-coding ^{TM} Premium) following internationally accepted protocol by a qualified technician. Soon after that the subjects were provided with the standard food (glucose solution) equivalent to 50g available carbohydrates and were advised to consume the same within 10 min. The subjects were allowed to drink adequate quantity of water during the test period. Subsequently, the postprandial blood glucose were measured at 30, 60, 90, 120 and 150 min. On three different occasions, the test foods were given to the

subjects with an interval of minimum of 3 days between each test. The blood glucose response curve was constructed and the incremental area under the blood glucose response curve (IAUC) with fasting blood glucose value as the baseline was measured (FAO/WHO, 1998). The IAUC reflects the total rise in blood sugar (glucose) levels after the ingestion of the test food. The GI was calculated by the formula below:

$$GI(\%) = \frac{IAUC\ for\ 50g\ equivalent\ available\ carbohydrate\ of\ the\ test\ food}{IAUC\ for\ 50g\ equivalent\ available\ carbohyddrate\ of\ glucose} \times 100$$

3.5 Sensory Evaluation

Sensory evaluation was carried out according to Indrani *et al.*, (2010). The acceptability of the products was carried out by 20 semi trained panelists.

The panelists were selected among the research scholars and lecturers in the Department of Nutrition and Dietetics, Kaduna Polytechnic. A 9 – point hedonic scale was used for sensory evaluation. All the above food products (Pap and Tuwo) were presented in small plates labelled with three digit random codes. Panelists were provided with drinking water to rinse their mouth between samples. The samples were presented in random order and panelists were asked to rate the assessment of color, taste/flavor, texture and overall acceptability on a 9 – point hedonic scale (1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like or dislike, 6 = like slightly, 7 = like moderately, 8= like very much, 9 = like extremely). A score of 5 or below was considered a limit of acceptability for all sensory attributes tested(Ana, 2007)

3.6 Statistical Analysis

Results were presented as mean ± standard deviation except if stated otherwise. Data was analysed by ANOVA (for processing methods), student t – test for glycaemic index, differences between means were separated by DMRT, Result with $P<0.05$ was considered significant, SPSS version 20 was used to carried out the statistical analysis.

CHAPTER FOUR

RESULTS

4.1 Functional Properties of Unprocessed and Processed (Roasted, Germinated and Fermented) Finger Millet Flour

Table 4.1 indicates that there is a significant difference ($P<0.05$) in the water absorption capacity, swelling capacity and solubility of unprocessed and processed (roasted, germinated and fermented) finger millet flour, while there is no significant difference ($p>0.05$) in the bulk density of flour as the result ranged from 0.76± 0.01 – 0.77± 0.01 g/cm^3.

The analysis revealed that the water absorption capacity 1.67± 0.06 ml/g, swelling capacity (939±3.00%) were highest in the fermented sample while solubility is significantly higher in germinated flour with the value 38.1± 1.30 g/100ml at an ambient temperature of 25 °C. The least gelation concentration of flour from unprocessed seeds (4.0%), roasted (4.0%), and fermented (4.0%) shows no significant ($p>0.05$) difference. The flour from germinated seeds showed lower (2.0%) gelation capacity. The gelatinization temperature of flour from unprocessed and processed (roated, germinated and fermented) finger nillet unprocessed seeds initial to final temperature ranged from 65^0 to 79 °C , 74^0 to 83 °C, 79^0 to 84 °C and 70^0 to 82 °C respectively. The peak pasting temperature of unprocessed (79 °C), roasted (83 °C), germinated (84 °C), and fermented (82 °C) respectively.

Table 4.1: Effect of Processing Methods on some Functional Properties of E. *coracana* Flour

Parameters	Un-processed	Roasted	Germinated	Fermented
Bulk Density (g/cm^3)	0.76±0.02^a	0.76±0.01^a	0.77±0.01^a	0.76±0.01^a
Water Absorption Capacity (ml/g)	1.40±0.10^a	1.40±0.17^a	1.53±0.06^b	1.67±0.06^b
Swelling Capacity (%)	711.67±5.51^c	687.33±11.02^b	263.67±12^a	939.00±3.00^d
Solubility (g/100ml)	5.30±0.20^a	6.53±0.12^a	38.10±1.30^c	9.57±0.25^b
Gelation capacity (%)	4.0±0.10^a	4.0±0.01^a	2.0±0.06^b	4.0±0.01^a
Gelatanization Temperature(^{o}C)	79±0.04^a	83±0.01^a	84±0.11^a	82±0.13^a

Values are Mean ± SD; Values with different superscript in the same row by processing methods are significantly different (P<0.05).

4.2 Nutrient Composition of Unprocessed and Processed Finger Millet flour and Food Products (Pap and Tuwo)

4.2.1 Proximate Composition

Table 4.2 indicates that, there is significant difference ($P<0.05$) in moisture content of flour from unprocessed and processed (roasted, germinated and fermented) finger millet seeds. The result also revealed that, flour from fermented finger millet seeds yielded significantly ($P<0.05$) higher moisture content (8.26±0.17), while there is no significant difference in the ash content of flour from unprocessed and processed (roasted, germinated and fermented) finger millet seeds. Likewise the fat content recorded no significant difference ($P>0.05$). The analysis revealed that flour from germinated and fermented seeds had higher (10.62±0.04 and 7.97±0.36%) protein content. Carbohydrate content of flour from unprocessed and processed (roasted, germinated and fermented) finger millet seeds had no significant difference ($P>0.05$) except for flour from germinated seeds that had the lowest value of 80.99±2.10% . Higher fiber content was shown in the flour from processed (germinated and roasted) finger seeds (4.63±0.14% and 4.90±0.12%). Table 4.3 food product (Pap) from roasted finger millet seeds had the lowest moisture content (84.99± 0.02%) and higher fiber content of 2.51± 0.11%. Pap from germinated seeds had higher (87.24±0.54%) carbohydrate content, followed by the sample from unprocessed seeds (86.89±1.21%), while there was no significant difference in the ash and fat content of Pap from unprocessed and processed finger millet seeds.

The result also revealed that tuwo (Table 4.4) from unprocessed (86.6±0.31%) and processed (roasted) seeds had the highest (86.99±1.41%) carbohydrate

content compared to food product (Tuwo) from germinated (85.64±1.45%) and fermented (86.22±1.32%) which are not significantly different (P>0.05) while Tuwo from germinated seeds had higher (3.67±0.06%) fiber content compared to sample from unprocessed, roasted and fermented seeds (3.19±0.03, 3.35±0.06, 2.90±0.05%) although, there was no significant difference (P>0.05) .

4.2.2 Effect of Processing Methods on Anti-nutrient Composition of Finger Millet

Anti-nutrients composition indicates that there is a significant reduction (P<0.05) of phytate, cynogenic glycosides, alkaloids, oxalate, tannins and saponins in some processed samples (roated and fermented) while saponin (flour) and phenol concentration increased in germinated finger millet flour and food products (Pap and Tuwo).

The result (Table 4.5) revealed that, flour from unprocessed sample had significantly higher concentrations of phytate, cynogenic glycosides, oxalate, alkaloids and tannins (483.72±0.29, 2.66±0.07, 36.14±0.39 mg/100g, 1.75±0.05 and 851.12±0.04 mg/100g), compared to the processed samples. The germinated sample had significantly (P<0.05) higher Saponin and Phenols (7.9±0.10% and 501.33±1.53 μ/g) respectively.

Table 4.6 revealed that food product (Pap), from unprocessed sample had higher content of phytate, cynogenic glycosides, oxalates, alkaloids, tannins and saponins (151.39±0.73, 0.72±0.02, 15.68±0.33 mg/100g, 0.71±0.01, 621.11±0.06 mg/100g and 2.09±0.08%) while germinated had higher content of phenols (82.60±1.00 μ/g). Likewise Table 4.7, food product (Tuwo) from unprocessed sample had higher content of phytate (292.73±0.88mg/100g),

cynogenic glycosides (1.76±0.04 g/100g)bb, alkaloid (0.94±0.01%), oxalate (20.35±0.0 mg/100g), tannins (431.23±0.02 mg/100g) and Saponin (2.60±0.02%) while germinated sample had the highest phenols content with the value of 63.63±1.89 μ/g. By implication, fermentation and germination as a processing method result in significant ($P<0.05$) reduction of phytate , cyanogenicglycosides,oxalate, and tannin.

Table 4.2: Effect of Processing Methods on Proximate Compositions of *E. Coracana* Flour

Parameters	Unprocessed	Roasted	Germinated	Fermented
Moisture (% wet weight)	8.19 ± 0.16^{b}	6.80 ± 0.19^{a}	7.21 ± 0.16^{a}	8.26 ± 0.17^{b}
Ash (% Dry matter)	1.60 ± 0.01^{a}	2.12 ± 0.04^{a}	2.34 ± 0.04^{a}	2.07 ± 0.04^{a}
Protein (% Dry matter)	6.96 ± 0.01^{b}	5.90 ± 0.07^{a}	10.62 ± 0.04^{d}	7.97 ± 0.36^{c}
Fat (% Dry matter)	1.20 ± 0.02^{a}	0.92 ± 0.02^{a}	1.15 ± 0.03^{a}	0.97 ± 0.04^{a}
Carbohydrate(%Dry matter)	86.32 ± 2.11^{a}	86.43 ± 0.31^{a}	80.99 ± 2.10^{b}	85.45 ± 0.54^{a}
Fiber (% Dry matter)	3.92 ± 0.10^{a}	4.63 ± 0.14^{b}	4.90 ± 0.12^{b}	3.54 ± 0.06^{a}

Values are Mean ± SD; Values with different superscripts in the row by processing methods are significantly different ($P<0.05$)

Table 4.3: Effect of Processing Methods on Proximate Compositions of *E. Coracana food product (*Pap)

Parameters (%)	Unprocessed	Roasted	Germinated	Fermented
Moisture (% wet weight)	90.48 ± 0.24^{b}	84.99 ± 0.02^{a}	90.36 ± 0.30^{b}	91.25 ± 0.12^{c}
Ash (% Dry matter)	3.14 ± 0.19^{a}	3.23 ± 0.05^{a}	3.05 ± 0.02^{a}	3.39 ± 0.05^{a}
Protein (% Dry matter)	7.01 ± 0.23^{a}	7.81 ± 0.09^{b}	6.82 ± 0.12^{a}	8.09 ± 0.06^{b}
Fat (% Dry matter)	0.77 ± 0.01^{a}	0.74 ± 0.06^{a}	0.81 ± 0.01^{a}	0.73 ± 0.02^{a}
Carbohydrate(% Dr matter)	86.89 ± 1.21^{b}	85.71 ± 0.32^{a}	87.24 ± 0.54^{b}	86.05 ± 1.10^{a}
Fiber(% Dry matter)	2.19 ± 0.10^{a}	2.51 ± 0.11^{b}	2.08 ± 0.08^{a}	1.74 ± 0.06^{a}

Values are Mean ± SD; Values with different superscripts in the row by processing methods are significantly different ($P<0.05$)

Table 4.4: Effect of Processing Methods on Proximate Compositions of *E. Coracana food product (* Tuwo)

Parameters (%)	Unprocessed	Roasted	Germinated	Fermented
Moisture(% wet weight)	83.69±0.03[a]	83.12±0.11[b]	82.72±0.15[b]	81.28±0.50[c]
Ash(% Dry matter)	1.95±0.04[a]	1.48±0.05[b]	1.68±0.10[a]	2.10±0.03[a]
Protein(% Dry matter)	7.37±0.12[a]	7.20±0.01[a]	8.07±0.16[b]	8.01±0.21[b]
Fat(% Dry matter)	0.85±0.01[a]	0.98±0.03[a]	0.94±0.08[a]	0.77±0.03[a]
Carbohydrate(% Dr matter)	86.64±0.31[a]	86.99±1.41[a]	85.64±1.45[b]	86.22±1.32[b]
Fiber(% Dry matter)	3.19±0.03[a]	3.35±0.06[a]	3.67±0.06[b]	2.90±0.05[a]

Values are Mean ± SD; Values with different superscripts in the row by processing methods are significantly different (P<0.05)

Table 4.5: Effect of Processing Methods on Anti – Nutrient Composition of *E. coracana* Flour

Anti Nutrients	Unprocessed	Roasted	Germinated	Fermented
Phytate (mg/100g)	483.72±0.29^{d}	383.81±0.14^{a}	434.36±0.94^{b}	451.28±1.19^{c}
Cyanogenic glycoside (mg/100g)	2.66±0.07^{b}	0.29±0.12^{a}	1.28±0.07^{c}	0.83±0.05^{c}
Alkaloids (%)	1.75±0.05^{a}	0.65±0.05^{b}	0.80±0.00^{b}	1.05±0.05^{b}
Oxalate((mg/100g)	36.14±0.39^{d}	17.72±0.61^{a}	29.90±0.46^{c}	25.76±0.45^{b}
Tannins (%)	851.12±0.04^{c}	231.23±0.03^{b}	220.93±0.03^{a}	220.76±0.01^{a}
Saponins (%)	6.00±0.25^{c}	4.10±0.10^{b}	7.90±0.10^{d}	3.25±0.25^{a}
Phenols (μ/g)	141.67±0.58^{a}	221.67±1.53^{b}	501.33±1.53^{d}	267.67±1.3^{c}

Values are Mean ± SD; Values with different superscripts in the rows by processing methods are significantly different (P<0.05).

Table 4.6: Effect of Processing Methods on Anti – Nutrient Composition of *E. coracana* Pap

Anti Nutrients	Unprocessed	Roasted	Germinated	Fermented
Phytate (mg/100g)	151.39±0.73^{d}	74.92±0.70^{b}	79.97±0.64^{c}	61.28±0.73^{a}
Cyanogenic glycoside (mg/100g)	0.72±0.02^{b}	0.40±0.01^{a}	0.56±0.01^{b}	0.24±0.01^{a}
Alkaloids (%)	0.71±0.01^{b}	0.49±0.01^{a}	0.64±0.01^{b}	0.55±0.01^{b}
Oxalate(mg/100g)	15.68±0.33^{d}	11.06±0.45^{b}	13.16±0.26^{c}	8.29±0.33^{a}
Tannins(%)	621.11±0.06^{d}	220.7±0.02^{c}	210.4±0.02^{a}	210.5±0.02^{b}
Saponins (%)	2.09±0.08^{c}	0.60±0.01^{b}	0.26±0.01^{a}	0.32±0.01^{a}
Phenols (μ/g)	41.50±0.00^{a}	44.83±0.76^{b}	82.60±1.00^{d}	52.90±1.00^{c}

Values are Mean ± SD; Values with different superscripts in the row by processing methods are significantly different (P<0.05).

Table 4.7: Effect of Processing Methods on Anti – Nutrient Composition of *E. coracana* Tuwo

Anti Nutrients	Unprocessed	Roasted	Germinated	Fermented
Phytate (mg/100g)	292.73±0.88^{d}	125.66±0.65^{b}	138.21±2.12^{c}	99.56±1.05^{a}
Cyanogenic glycoside (mg/100g)	1.76±0.04^{b}	0.90±0.02^{a}	1.28±0.04^{a}	0.59±0.04^{a}
Alkaloids (%)	0.94±0.01^{b}	0.42±0.02^{a}	0.82±0.02^{b}	0.34±0.02^{a}
Oxalate(mg/100g)	20.35±0.00^{d}	15.96±0.35^{c}	13.35±0.15^{b}	7.89±0.34^{a}
Tannins (%)	431.23±0.02^{c}	210.69±0.01^{b}	210.53±0.03^{b}	202.4±0.03^{a}
Saponins (%)	2.60±0.02^{b}	0.48±0.02^{a}	0.32±0.01^{a}	0.22±0.02^{a}
Phenols (μ/g)	41.33±0.29^{c}	35.57±0.81^{b}	63.63±1.89^{d}	24.37±0.29^{a}

Values are Mean ± SD; Values with different superscripts in the row by processing methods are significantly different (P<0.05).

4.2.3 Effect of Processing Methods on the Mineral Composition of *E. Coracana* Flour

Table 4.8 revealed the concentration of mineral elements in the flour samples. Flour from unprocessed seeds had higher content of iron (24.00±4.60 mg/100), phosphorous (16.10±1.20 mg/100g), calcium (16.00±2.10 g/100g), magnesium (12.10±1.20 mg/100g) and manganese (6.00±0.20) compared to the flour from processed seeds except for roasted that had higher (12.00±2.50 mg/100g) potassium. As for the food product (Pap), table 4.9 shows that pap from unprocessed seeds had the value of 12.00±1.20 mg/100g for iron content compared to pap from processed seeds (roasted; 11.00±1.80 and fermented; 11.00±1.60 mg/100g) which has no significant difference ($P<0.05$) except for germinated sample that had higher content of iron (14.00±2.60 mg/100g) and calcium (13.00±1.20 mg/100g) with the lowest content of manganese (2.00±1.60 mg/100g) compared to unprocessed (8.00±1.20 mg/100g), roasted (6.00±1.10 mg/100g) and fermented (5.00±1.60 mg/100g). There was no significant difference ($P>0.05$) in phosphorus content of pap from roasted and fermented seeds (8.00±1.70 and 8.00±1.60 mg/100g) likewise with respect to the unprocessed and germinated (6.00±2.60 and 6.00±2.60 mg/100g) samples. The result also revealed that magnesium content of pap from roasted (8.00±1.30 mg/100g) and germinated (8.00±1.60 mg/100g) seeds shows no significant difference ($P>0.05$) . The result in table 4.10 revealed that Tuwo from processed seeds (roasted and fermented) had higher iron content (11.00±2.10 mg/100g and 11.00±1.80 mg/100g) and had no significant difference ($P>0.05$). Likewise, the unprocessed (10.00±1.60 mg/100g) and germinated (10.00±1.60 mg/100g) samples. Tuwo from germinated seeds had higher phosphorus (9.00±1.60 mg/100g), magnesium (9.00±1.60 mg/100g), and manganese (8.00±1.10 mg/100g) content and no significant difference($P<0.05$) with the unprocessed (8.00±1.10 mg/100g) sample. There is no significant difference ($P<0.05$) in the potassium content tuwo from unprocessed (10.00±2.16 mg/100g) and fermented

(10.00±2.60 mg/100g) samples with the roasted sample having higher (11.00±2.60 mg/100g) content.

Table 4.8: Effect of Processing Methods on the Mineral Composition of *E. coracana* Flour

Minerals (mg/100g)	Unprocessed	Roasted	Germinated	Fermented
Phosphorous	16.10 ± 1.20^{d}	14.00 ± 2.60^{c}	11.00 ± 1.60^{b}	8.00 ± 2.60^{a}
Iron	24.00 ± 4.60^{d}	18.00 ± 2.80^{c}	16.00 ± 1.70^{b}	14.00 ± 2.60^{a}
Magnesium	12.10 ± 1.20^{c}	$11.60.2.10^{c}$	10.00 ± 2.60^{b}	8.00 ± 1.60^{a}
Potassium	8.00 ± 1.20^{a}	12.00 ± 2.50^{d}	11.00 ± 1.60^{c}	10.00 ± 2.70^{b}
Calcium	16.00 ± 2.10^{c}	14.00 ± 1.60^{b}	14.00 ± 1.10^{b}	13.00 ± 1.20^{a}
Manganese	6.00 ± 0.20^{d}	4.00 ± 1.60^{c}	3.00 ± 1.10^{b}	2.00 ± 1.60^{a}

Values are Mean ± SD; Values with different superscripts in the row by processing methods are significantly different ($P<0.05$) .

Table 4.9: Effect of Processing Methods on the Mineral Composition of *E. coracana* food product *(*Pap)

Minerals (mg/100g)	Unprocessed	Roasted	Germinated	Fermented
Phosphorous	6.00 ± 2.60^{b}	8.00 ± 1.70^{a}	6.00 ± 2.60^{b}	8.00 ± 1.60^{a}
Iron	12.00 ± 1.60^{b}	11.00 ± 1.80^{a}	14.00 ± 2.60^{c}	11.00 ± 1.60^{a}
Magnesium	6.00 ± 1.20^{b}	8.00 ± 1.30^{c}	8.00 ± 1.60^{c}	5.00 ± 1.70^{a}
Potassium	11.00 ± 1.70^{b}	10.00 ± 1.60^{a}	10.00 ± 2.70^{a}	10.00 ± 1.60^{a}
Calcium	12.00 ± 1.60^{b}	12.00 ± 1.20^{b}	13.00 ± 1.20^{c}	10.00 ± 1.10^{a}
Manganese	8.00 ± 1.20^{d}	6.00 ± 1.10^{c}	2.00 ± 1.60^{a}	5.00 ± 1.60^{b}

Values are Mean ± SD; Values with different superscripts in the row by processing methods are significantly different ($P<0.05$) .

Table 4.10: Effect of Processing Methods on the Mineral Composition of *E. coracana* food product *(*Tuwo)

Minerals (mg/100g)	Unprocessed	Roasted	Germinated	Fermented
Phosphorous	6.00 ± 1.60^{a}	8.00 ± 2.60^{b}	9.00 ± 1.60^{c}	8.00 ± 2.60^{b}
Iron	10.00 ± 1.60^{a}	11.00 ± 2.10^{b}	10.00 ± 1.60^{a}	11.00 ± 1.80^{b}
Magnesium	6.00 ± 1.60^{a}	8.00 ± 1.60^{b}	9.00 ± 1.50^{c}	6.00 ± 1.60^{a}
Potassium	10.00 ± 2.16^{b}	11.00 ± 2.60^{c}	9.00 ± 3.60^{a}	10.00 ± 2.60^{b}
Calcium	6.00 ± 2.60^{d}	5.00 ± 1.30^{c}	4.00 ± 1.40^{b}	3.00 ± 1.10^{a}
Manganese	8.00 ± 1.10^{c}	7.00 ± 1.10^{b}	8.00 ± 1.10^{c}	6.00 ± 1.20^{a}

Values are Mean ± SD; Values with different superscripts in the row by processing methods are significantly different ($P<0.05$) .

4.2.4 Effect of Processing Methods on Dietary Fibre of *E. coracana* Flour and Food Products (Pap and Tuwo)

Table 4.11 shows that, the total dietary fiber of flour from unprocessed seeds is significantly (P<0.05) higher (19.80±0.50 g/100g) than flour from germinated (15.40±0.40 g/100g), roasted (14.70±0.10) and fermented (11.40±0.50).

Pap from unprocessed seeds had higher (16.50±0.50 g/100g) total dietary fiber content compared to the processed samples of which the pap from fermented seeds had the lowest (10.40±0.05 g/100g) value. The result also revealed that, Tuwo from unprocessed seeds had significantly (P<0.05) higher (18.70±0.50 g/100g) content of total dietary fiber compared to the samples from processed seeds. Insoluble dietary fiber of flour from unprocessed seeds was significantly (P<0.05) higher (18.10±0.04 g/100g) compared to samples from processed seeds. Likewise pap from unprocessed seeds had higher (15.00±0.30 g/100g) content of insoluble dietary fiber. The fermented sample had the lowest (9.00±0.02 g/100g) value. The insoluble dietary fiber content was significantly (P<0.05) higher in Tuwo from unprocessed seeds (17.10±0.40 g/100g) compared to the samples from processed seeds.

The result (table 4.11) also revealed that, the flour from germinated seeds had higher (2.80±0.10 g/100g) soluble dietary fiber content compared to unprocessed sample (1.70±1.00 g/100g) and the fermented having the lowest value (1.20±0.40 g/100g). In food product, Pap from germinated had higher (1.80±0.20 g/100g) soluble dietary fiber content compared to samples from unprocessed seeds (1.50±0.10 g/100g), fermented (1.40±0.03 g/100g) and the roasted having the lowest (1.10±0.10 g/100g) content. Furthermore, Tuwo from

roasted seeds had higher (2.10±0.30 g/100g) soluble dietary fiber and the lowest is shown in the fermented sample (1.11±0.30 g/100g).

Table 4.11: Effect of Processing Methods on Dietary Fibre of *E. coracana* flour and food products*(Pap and Tuwo)*

Treatment	Total Dietary Fibre (g/100g)			Insoluble Dietary Fibre (g/100g)			Soluble Dietary Fibre (g/100g)		
	Flour	**Pap**	**Tuwo**	**Flour**	**Pap**	**Tuwo**	**Flour**	**Pap**	**Tuwo**
Unprocessed	19.80±0.50^{a}	16.50±0.50^{a}	18.70±0.50^{a}	18.10±0.04^{a}	15.00±0.30^{a}	17.10±0.40^{a}	1.70±1.00^{a}	1.50±0.10^{a}	1.60±0.20^{a}
Roasted	14.70±0.10^{b}	13.20±1.10^{b}	14.20±1.00^{b}	13.10±0.40^{b}	12.10±0.90^{b}	12.10±0.90^{b}	1.60±0.20^{a}	1.10±0.10^{b}	2.10±0.30^{a}
Germinated	15.40±0.40^{b}	11.70±0.50^{c}	11.80±0.40^{c}	12.60±0.30^{b}	9.90±0.30^{c}	10.00±0.30^{c}	2.80±0.10^{b}	1.80±0.20^{a}	1.80±0.10^{a}
Fermented	11.40±0.50^{c}	10.40±0.05^{d}	11.21±0.50^{d}	10.20±0.10^{c}	9.00±0.02^{d}	10.10±0.20^{c}	1.20±0.40^{c}	1.40±0.03^{b}	1.11±0.30^{b}

Values are Mean ± SD; Values with different superscripts in the same colum are significantly different (P<0.05).

4.2.5 Effect of Processing Methods on Amino Acids Composition of E. *Coracana* Flour and Food Products (Pap and Tuwo)

The result obtained from amino acid profile (Table 4.12) shows that, flour from germinated seeds had higher content of leucine (98.00g/100g), while fermented and germinated sample show similar value for histidine content (2.23 g/100g). The flour from unprocessed seeds had higher content of lysine (5.00 g/100g), valine (5.84 g/100) while the fermented seeds (flour) had higher content of isoleucine (4.35 g/100g), phenylalanine (5.14 g/100g), Tryptophan (1.99 g/100g), Arginine (4.99 g/100g). Reduction of glutamic acid (5.45 g/100g) was shown in the fermented (flour) compared to 17.11g/100g shown in the flour from unprocessed seeds.

The result also revealed that, food product (pap) from fermented seeds had higher content of leucine (4.19 g/100g), phenylalanine (4.79 g/100g), tryptophan (1.89 g/100g), valine (5.69 g/100g), methionine (2.32 g/100g) and histidine (2.17g/100g) compared to the lowest content of leucine (7.18 g/100g), lysine (3.42g/100g), isoleucine (3.34g/100g), tryptophan (1.57 g/100g), valine (4.35 g/100g), methionine (2.00g/100g) and histidine (1.95 g/100g) shown in pap from unprocessed seeds.

The result also shows that, tuwo from germinated seeds had significantly ($P<0.05$) higher leucine (10.39 g//100g), isoleucine (4.58 g/100g), phenylalanine (5.58 g/100g), tryptophan (2.15 g/100g), valine (6.20 g/100g) content. Higher content of methionine is found in tuwo from germinated seeds flour (2.40 g/100g) while the lowest is in the roasted (1.79 g/100g) sample. Tuwo from fermented seeds had higher content of Alanine (8.38 g/100g) while glysine

content is higher in the fermented sample (4.34 g//100g). Tuwo from roasted seeds had the lowest content of histidine (1.85 g/100g), methionine (1.79 g/100g), valine (3.59 g/100g), tryptophan (1.41 g/100g), phenylalanine (3.37 g/100g), isoleucine (3.01 g/100g), lycine (3.10 g/100g) and leucine (6.83 g/100g).

4.3 Glycemic Response

Twenty (20) type II diabetic and twenty (20) control subjects participated in the study. The age ranged from 35-65years with the control having the same age range.

The mean blood glucose response to pap from unprocessed seeds in the diabetic subjects (table 4.13) was lower (9.31±1.53mmol/L) at 120 minutes compared to sample from germinated seeds showing the highest peak value of 13.28±1.21mmol/L, fermented 13.08±1.27mmol/L and roasted (9.62±0.79mmol/L). The IAUC for pap from unprocessed seeds had the lowest value of 0.02±0.63mmol/L at 90 minutes followed by the roasted sample (0.49±0.91mmol/L) compared to the higher value shown in germinated and fermented (4.61±0.50 and 5.54±1.85mmol/L) samples.

The same trend was observed in the normal (healthy) subjects fed with pap (Table 4.14). The pap from unprocessed seeds had the lowest blood glucose response (4.22±0.3mmol/L) at 120 minutes followed by the roasted (4.51±0.4mmol/L) and the germinated sample (pap) had the highest value, although, glucose solution (STD food) had the highest (8.18±1.9mmol/L)peak of blood glucose response compared to the germinated (7.02±0.9mmol/L).

Table 4.15 shows the result for blood glucose response of type II diabetic subject fed with Tuwo. The highest blood glucose response was observed in type II diabetic subjects fed with Tuwo from germinated (14.31±1.22mmol/L) seeds at 120minutes while the unprocessed samples show the lowest value of 8.21±2.04mmol/L. The IAUC shows that, tuwo from unprocessed seeds had the lowest value of 1.34±0.72mmol/L at 120 min followed by roasted sample (2.03±0.19mmol/L).

Table 4.16 shows the blood glucose response of normal samples fed with tuwo. The result revealed that, sample from germinated seeds had the higher (6.53±1.5mmol/L) blood glucose response at 120minutes compared to the lowest value shown in unprocessed (4.22±1.1mmol/L) samples. The glucose solution (STD food) had the highest peak value of 7.81±1.9 at 120 minutes. The IAUC also shows that glucose solution (STD Food) had highest peak value (2.82±0.3) at 120munites by fermented and germinated samples (1.70±1.6and 1.62±0.3mmol/L) compared to the lowest value shown in tuwo from unprocessed and roasted seeds (0.32±0.5 and 1.01±0.9mmol/L).

Table 4.12: Effect of Processing Methods on Amino Acid Composition of E. *coracana* Flour and Food Products

Amino acid (g/100g)	UNPROCESSED			ROASTED			GERMINATED			F ERMENTED		
	Flour	Pap	Tuwo	Flour	Pap	Tuwo	Flour	Pap	Tuwo	Flour	Pap	Tuwo
Leucine	9.80	7.18	8.69	9.69	8.49	6.83	9.19	9.07	10.39	9.86	9.48	9.98
Lysine	3.87	3.42	3.71	3.84	3.52	3.20	3.71	3.71	4.29	3.89	3.81	4.40
Isoleucine	4.25	3.34	3.80	4.22	3.60	3.01	3.99	3.89	4.58	4.35	4.19	4.19
Phenylalanine	5.0	3.81	4.25	4.88	4.08	3.37	4.70	4.43	5.58	5.14	4.79	5.50
Tryptophan	1.91	1.57	1.73	1.89	1.68	1.41	1.84	1.73	2.15	1.99	1.89	2.13
Valine	5.84	4.35	5.43	5.73	4.41	3.59	5.70	5.61	6.20	5.79	5.67	5.93
Methionine	2.35	2.00	2.24	2.35	2.19	1.79	2.35	2.29	2.40	2.40	2.32	2.29
Proline	5.38	3.96	4.97	5.28	4.26	3.65	5.28	4.87	5.78	5.38	5.38	5.58
Arginine	4.90	4.99	4.47	4.73	5.16	4.90	4.56	4.38	5.76	4.99	4.64	5.67
Tyrosine	3.09	2.75	3.09	3.09	3.09	2.75	3.09	3.09	3.61	3.09	3.27	3.44
Histidine	2.17	1.95	2.20	2.20	2.04	1.85	2.23	2.04	2.43	2.23	2.17	2.39
Cystine	2.18	1.69	1.93	2.18	1.81	1.45	2.05	1.93	2.30	2.18	2.06	2.30
Alanine	7.81	6.03	6.90	7.66	6.41	5.16	7.54	7.58	8.27	7.81	7.73	8.38
Glutamic acid	17.11	17.18	15.14	16.96	14.99	15.44	15.89	15.89	16.96	5.45	16.65	15.59
Glycine	3.80	3.25	3.80	3.66	2.99	2.99	3.46	3.39	4.34	3.89	3.56	4.30

Table 4.13: Blood Glucose Responses and Increment to Pap From Veriaous Processing Methods in Diabetic Subjects

	DIABETIC SUBJECTS							
	Unprocessed		Roasted		Germinated		Fermented	
Time (Min)	Blood glucose (mmol/L)	Incremental glucose (mmol/L)	Blood glucose (mmol/L)	Incremental glucose (mmol/L)	Blood glucose (mmol/L)	Incremental glucose (mmol/L)	Blood glucose (mmol/L)	Incremental glucose (mmol/L)
0	9.23±1.14		9.81±1.72		9.59±1.69		8.52±0.48	
30	12.51±1.12	3.28±1.21[b]	12.86±1.22	3.05±0.63[b]	12.51±1.18	2.92±0.82[b]	11.59±1.74	3.08±1.31[b]
60	11.05±0.65	1.82±1.34[b]	11.51±1.48	1.70±0.46[b]	14.01±1.38	4.42±0.41[c]	14.21±1.42	5.70±0.23[d]
90	10.25±1.31	1.02±0.63[a]	10.30±1.36	0.49±0.91[a]	14.20±1.57	4.61±0.50[b]	14.05±1.83	5.54±1.85[c]
120	9.31±1.53	0.08±1.18[a]	9.62±0.79	0.19±0.84[b]	13.28±1.21	3.69±0.81[c]	13.08±1.27	4.56±0.61[d]
150	8.04±1.33	0.19±0.42[a]	8.40±0.28	0.41±0.35[a]	12.09±0.93	2.50±0;35[b]	11.08±1.55	2.59±1.66[b]

Values in (mmol/L) are means ± SD. Values in the same row with same superscripts are not significantly different ($p \leq 0.05$). blood glucose concentration at time 0minute corresponds to fasting blood sugar (FBS). Incremental means increment in blood glucose concentration over fasting blood glucose.

Table 4.14: Blood Glucose Responses and Incremental to Glucose and Pap from Various Processing Methods In Healthy Subjects

HEALTHY SUBJECTS FED WITH PAP										
	GLUCOSE SOLUTION						PAP (MEAL)			
Time (Min)	Blood glucose solution	Incremental glucose (mmol/L)	Unprossed glucose (mmol/L)	Incremental glucose (mmol/L)	Roasted glucose (mmol/L)	Incremental glucose (mmol/L)	Germinated glucose (mmol/L)	Incremental glucose (mmol/L)	Fermented glucose (mmol/L)	Incremental glucose (mmol/L)
0	5.08±1.4		4.54±1.8		3.85±0.4		5.01±2.0		4.71±0.2	
30	9.33±0.7	4.25±0.6^{b}	7.77±1.5	3.23±0.8^{a}	7.83±0.7	3.98±0.9^{b}	8.69±1.3	3.68±0.9^{b}	8.38±0.9	3.67±1.5^{b}
60	10.8±0.2	5.72±0.3^{d}	6.56±0.3	2.02±0.6^{a}	7.57±0.8	3.72±0.5^{b}	10.32±1.9	5.31±0.6^{c}	10.05±0.4	5.34±0.9^{c}
90	9.48±2.1	4.40±0.8^{a}	5.22±0.2	0.68±0.4^{b}	5.81±0.6	1.96±0.9^{c}	9.41±0.0	4.40±1.9^{a}	9.21±1.9	4.50±0.8^{d}
120	8.18±1.9	3.10±0.5^{cd}	4.22±0.3	0.32±0.9^{a}	4.51±0.4	0.66±0.4^{b}	7.02±0.9	2.01±1.6^{c}	6.23±1.2	1.52±1.7^{c}
150	7.63±0.7	2.55±0.2^{c}	3.01±1.3	0.53±0.2^{b}	3.63±0.9	0.22±0.1^{a}	5.11±0.6	0.10±0.8^{a}	4.51±0.8	0.20±0.8^{a}

Values in (mmol/L) are means ± SD. Values in the same row with same superscripts are not significantly different ($p \leq 0.05$). blood glucose concentration at time 0minutes corresponds to fasting blood sugar (FBS). Incremental means increment in blood glucose concentration over fasting blood glucose.

Table 4.15: Blood Glucose Responses and Increment to Tuwo from Veriaous Processing Methods in Diabetic Subject

DIABETIC SUBJECTS								
Time (Min)	Unprocessed Blood glucose (mmol/L)	Incremental glucose (mmol/L)	Roasted Blood glucose (mmol/L)	Incremental glucose (mmol/L)	Germinated Blood glucose (mmol/L)	Incremental glucose (mmol/L)	Fermented Blood glucose (mmol/L)	Incremental glucose (mmol/L)
0	6.87±1.20		10.01±1.71		9.63±1.83		8.85±1.67	
30	10.21±1.51	3.34±0.44[a]	12.42±1.36	2.41±0.53[b]	13.51±1.73	3.88±0.42[c]	11.55±2.02	2.70±0.66 [a]
60	12.01±1.48	5.14±1.68[a]	14.23±1.11	4.22±0.16[b]	15.32±1.48	5.67±0.85[c]	13.70±1.65	4.85±1.17 [a]
90	11..08±1.82	4.21±1.05[a]	13.41±1.83	3.40±0.41[b]	15.01±1.54	5.38±0.51[c]	15.56±2.01	6.71±0.59[d]
120	8.21±2.04	1.34±0.72[a]	12.04±1.24	2.03±0.19[b]	14.31±1.22	4.68±0.17[c]	14.27±1.19	5.42±0.41[d]
150	7.31±1.42	0.53±0.58[a]	8.19±0.38	1.82±0.58[b]	13.05±1.19	3.42±0.73[c]	12.05±1.41	3.20±0.57 [c]

Values in (mmol/L) are means ± SD. Values in the same row with same superscripts are not significantly different ($p \leq 0.05$). blood glucose concentration at time 0minute corresponds to fasting blood sugar (FBS). Incremental means increment in blood glucose concentration over fasting blood glucose.

Table 4.16: Blood Glucose Responses and Incremental to Glucose and Tuwo from Various Processing Methods In Healthy Subjects

HEALTHY SUBJECTS FED WITH TUWO										
GLUCOSE SOLUTION										
Time (Min)	Blood glucose solution	Incremental glucose (mmol/L)	Unprocessed glucose (mmol/L)	Incremental glucose (mmol/L)	Roasted glucose (mmol/L)	Incremental glucose (mmol/L)	Germinated glucose (mmol/L)	Incremental glucose (mmol/L)	Fermented glucose (mmol/L)	Incremental glucose (mmol/L)
0	4.95±0.7		4.54±0.2		5.12±0.5		4.91±0.7		3.92±1.9	
30	8.59±0.9	3.63±1.3^{b}	7.77±1.9	3.23±0.9^{a}	8.49±0.7	3.37±1.9^{a}	8.52±1.6	3.61±0.6^{b}	7.25±1.3	3.33±1.4^{a}
60	9.83±1.7	4.88±0.9^{c}	7.11±0.6	2.57±0.9^{b}	7.11±0.7	1.99±1.3^{a}	10.38±1.0	5.47±0.4^{c}	9.22±1.5	5.30±2.4^{c}
90	8.42±1.2	3.47±0.8^{c}	5.62±1.3	1.08±0.2^{a}	6.65±0.2	1.53±0.1^{b}	9.02±1.7	4.11±0.8^{d}	7.53±1.9	3.61±1.9^{d}
120	7.81±1.9	2.82±0.3^{d}	4.22±1.1	0.32±0.5^{a}	6.13±0.8	1.01±0.9^{b}	6.53±1.5	1.62±0.3^{c}	5.62±1.3	1.70±1.6^{c}
150	7.08±0.9	2.13±1.9^{b}	2.01±0.8	0.53±0.8^{a}	3.43±0.6	0.69±0.4^{a}	5.92±1.8	1.01±1.6^{a}	5.01±0.3	1.09±2.2^{a}

Values in (mmol/L) are means ± SD. Values in the same row with same superscripts are not significantly different ($p \leq 0.05$). blood glucose concentration at time 0min corresponds to fasting blood sugar (FBS). Incremental means increment in blood glucose concentration over fasting blood glucose

4.3.1 Glycemic indices

Germination and fermentation increased the glycaemic index (GI) value for Pap and Tuwo compared to samples from unprocessed and roasted finger millet seeds in normal subjects. The values for Pap were, 28.51±10.11% (unprocessed), 32.44±14.05% (roasted), 40.56±12.10% (germinated), and 35.71±14.10% (fermented).

The glycaemic index (GI) value for Tuwo from unprocessed and processed (roasted, germinated and fermented) finger millet seeds in the normal subjects were 28.59±14.21% (unprocessed), 32.74±8.10% (roasted), 51.04±11.20% (germinated) and 40.24±13.12% (fermented).

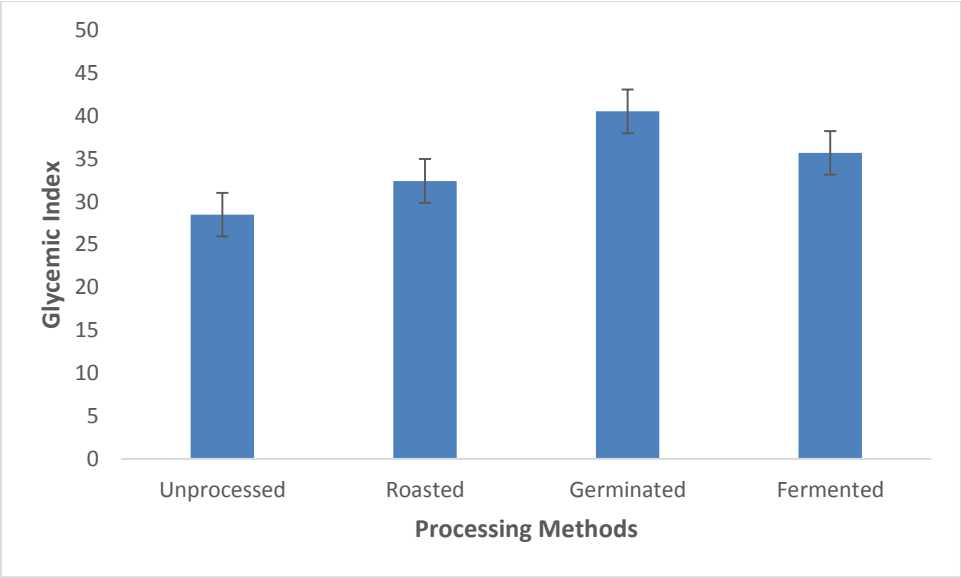


Fig. 4.1: Glycemic Index of apparently healthy subjects given differently processed Pap

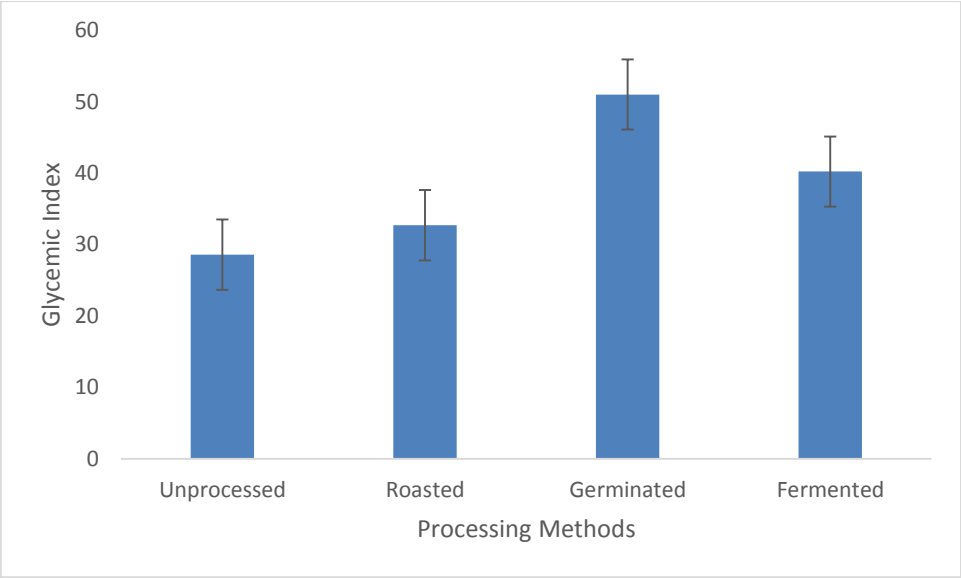


Fig. 4.2: Glycemic Index of apparently healthy subjects given differently processed Tuwo

4.4 Pilot Study

Pilot study was carried out to identify commonly consumed food product from finger millet (Table 4.17). The result indicate that the consumption of pap from finger millet is significantly ($P<0.05$) higher (59%) compared to Tuwo (41%) from finger millet.

4.5 Sensory Evaluation

Table 4.18 shows the result of sensory evaluation carried out on Pap and Tuwo prepared from unprocessed and processed (roasted, germinated and fermented) finger millet seeds. The result shows that, food products from roasted finger millet seeds, performed better in terms of general acceptability, taste, color, aroma/flavour and texture compared to other food products from unprocessed and processed (fermented) finger millet seeds.

Table 4.17: Commonly Consumed Finger Millet Food Products

Form of Consumption	**%**
Pap	59
Tuwo	41

Table 4.18: Acceptability of Food Product (pap) from Finger Millet as determined by the 9 Point Hedonic Scale

	Unprocessed	Roasted	Germinated	Fermented
Taste	4.00 ± 0.30^{a}	8.00 ± 0.50^{d}	7.20 ± 0.40^{c}	5.60 ± 1.30^{b}
Color	4.00 ± 0.30^{a}	7.20 ± 0.40^{c}	8.00 ± 0.40^{d}	6.00 ± 1.30^{b}
Texture	4.00 ± 0.50^{a}	8.00 ± 1.40^{d}	7.20 ± 0.42^{c}	6.00 ± 1.40^{b}
Aroma / Flavor	4.00 ± 0.30^{a}	8.00 ± 0.42^{d}	7.20 ± 0.42^{c}	6.00 ± 1.40^{a}
General acceptability	4.00 ± 0.30^{a}	8.50 ± 1.40^{a}	7.80 ± 0.40^{c}	6.00 ± 1.30^{d}

Values are Mean ± SD; Values with different superscripts in the row by processing methods are significantly different ($P<0.05$).

Table 4.19: Acceptability of Food Product (tuwo) from Finger Millet as Determined by the 9 Point Hedonic scale

	Unprocessed	Roasted	Germinated	Fermented
Taste	4.10 ± 0.50^{a}	7.10 ± 0.30^{c}	7.00 ± 1.40^{c}	5.40 ± 1.20^{b}
Color	3.40 ± 0.50^{a}	8.00 ± 0.30^{d}	7.00 ± 0.30^{c}	5.10 ± 1.20^{b}
Texture	4.30 ± 1.40^{a}	8.80 ± 0.32^{d}	3.00 ± 1.20^{c}	5.20 ± 1.60^{b}
Aroma/Flavor	4.30 ± 1.40^{a}	8.80 ± 0.32^{d}	7.00 ± 1.20^{c}	5.20 ± 1.60^{b}
General Acceptability	7.20 ± 0.31^{bc}	7.00 ± 1.40^{c}	3.00 ± 1.30^{b}	5.40 ± 1.26^{b}

Values are Mean ± SD; Values with different superscripts across the rows by processing methods are significantly different ($P<0.05$).

CHAPTER FIVE

5.0 Discussion

Functional properties of flour of the finger millet indicated that, processing increased water absorption capacity, swelling capacity (fermentation), solubility power and gelatinization temperature (germination) of flour as shown in table 4.1 compared to other samples (roasted and unprocessed). Mathanghi and Sudha (2012), stated that this might be due to enzymatic breakdown of starch to sugar during germination and softing of seeds occurs during fermention and germination making the milling easier with smaller particles than unprocessed grains.

The increased solubility according to Shobana *et al.*,(2013) could be due to increase in the amount of soluble sugar present in the germinated and fermented flour. The flour from unprocessed seeds had bulk density of 0.76 ± 0.02 g/cm^3 which was not significantly ($P > 0.05$) higher than that of roasted, germinated and fermented flour. Lower concentration of the flour was required to form a gel as observed in the analysis. The result revealed no significant difference with the gelation capacity of flour from unprocessed and processed finger millet seeds, although, the germinated had the lowest gelation capacity. Malik *et al.*, (2002), stated that, pearl millet showed significantly lower mean gelation capacity.

The gelatinization of flour from unprocessed seeds occurs at a lower temperature compared to flour from processed seeds. Functional properties of flour play important role in the production of foods according to Shobana *et*

al.(2013). The ability of flour to absorb water for example depends on the availability of hydrophilic groups which bind water molecules.

The moisture content of flour from roasted and germinated seeds were lower than the fermented and unprocessed samples as shown in table 4.2. This might be the reason for its prolonged shelf life as stated by Banerjee *et al.* (2012).

There is no significant difference ($P>0.05$) in ash content of flour from unprocessed and processed (roasted, germinated and fermented) finger millet seeds. Similar trend was also observed in food products (Table 4.3) and (Table 4.4). Similarly the fat content. The values for the proximate composition of flour from unprocessed and processed (roasted, germinated and fermented) finger millet seeds were in line with the values of some earlier studies that have been reported in literature (Shobana *et al.*, 2013).

The carbohydrate content of germinated flour is significantly lower compared to the food products (pap and tuwo) which has higher values is in conformity with the study of Malik *et al.* (2002), reported that, higher water absorption capacity and hygroscopicity of flour derived from germinated grains maybe due to high protein content and the presence of more hydrophilic carbohydrates which result to excess flour been required to produce food products.

The lower fiber content in fermented samples as shown in table 4.2, 4.3 and 4.4 (flour, pap and tuwo) compared to other samples might be as a result of partial solubilization of cellulose and hemicellulosic type of material by microbial enzymes according to Shobana *et al.*(2013). Increase in protein content of germinated and fermented finger millet seeds respectively including improved amino acid quality is in conformity with the study of Saleh *et al.* (2013), that

fermentation and germination improves nutritional quality of millets compared to other cereals.

The reduction of some anti-nutrients (phytate, alkaloids, oxalate, cynogenic glycosides and saponins) in flour, pap and tuwo following various processing methods as shown in Tables 4.5, 4.6 and 4.7 are consistent with the report of Saleh *et al*. (2013) that, microbial production of phytase and linamarase is possible reason for the reduction of phytate and cynogenic glycoside respectively. Similar changes in tannins have also been reported.

The results from (Table 4.5, 4.6 and 4.7) clearly revealed increased in phenol content of flour and food products (Pap and tuwo) from germinated seeds than unprocessed and some processed samples (roasted and fermented). However flour from germinated seeds had the highest content of phenol while the flour and food products (Pap and tuwo) from unprocessed sample had the highest phytate content. Mathanghi and Sudha (2012) reported that finger millet contains high variety of phenolic compounds (present in cereals bran) and the most common polyphenols are phenol and tannins which were also present in all the food products following various processing methods.

Polyphenols are reported to possess higher antioxidant capacity, inhibits amylases and slowing carbohydrate digestibility, thereby controlling blood sugar level and prevents the risk for diabetes (Banerjee *et al.*,2012). Chandrasekara and Shahidi (2012) also reported that, processing of peal millet grains resulted in a significant increase in phenols and phytate. This conformed to the result obtained that, there was significant increase in the antinutrients content of food products (pap and tuwo) compared with the flour sample.

Whole finger millet seeds were used in this study which resulted to low reduction in the minerals composition of flour, pap and tuwo (Tables 4.8, 4.9 and 4.10) from unprocessed and processed finger millet seeds as dehulling and milling according to Oghbaei and Prakash (2013), is a critical process affecting the concentrations of inorganic elements in cereals, grains, and food products prepared from them.

There was no significant reduction of total dietary fiber (TDF) recorded in the unprocessed flour and food products (pap and tuwo). Similarly flour and food products from processed seeds (roasted, germinated and fermented). This is supported by Pushparaj and Urooji (2011), who reported that, processing had no effect on total dietary fiber and insoluble dietary fiber (IDF) content. Similarly finger millet products (indian meal) a significant increase in total dietary fiber and insoluble dietary fiber was observed accordinng to Shobana *et al.*(2013).

The increased content of amino acids in processed (germination and fermentation) flour and food products (pap and tuwo) from finger millet seeds (Table 4.12) is in conformity with the study of Singh and Raghuvanshi (2012),that germination and fermentation for 48h improved the lysine, tryptophan, phenylalanine,methionine and histidine content of pearl, foxtail and finger millets.

The lower (less than 55%) (Figures 4.1 and 4.2) glycemic index and blood glucose response values (Tables 4.13, 4.14, 4.15 and 4.16) observed in all food products from flour made from unprocessed finger millet seeds could be based on the nature of the millet starch and its molecular organization including the influence of it polyphenols, phytate, and dietary fiber contents (Saleh *et al*.,

2013). Dietary quality, especially the use of wholegrain is the most emphasized important aspect for overall maximization of human health and preventing the risk factors for chronic diseases such as diabetes and related conditions (Singh and Raghuvanshi, 2012).

Pilot study result (Table 4.12) indicated that, commonly comsumed food products from finger millet were tuwo and pap amongs both diabetic and non diabetic. Although most people have no knowledge of the grain and the health benefits. Finger millet (Tamba) is known as the most superior in nutritional and health characteristics compared to other cereals (Saleh *et al*.,2013). The grain is under utilized due to lack of popularity, however its utilization in the preparation of finger millet products using various processing techniques would be a successful approaches for improving human health especially for diabetes prevention, control and management as shown in this research work.

The least acceptability (Tables 4.18 and 4.19) of food products from flour made from unprocessed seeds in terms of flavour/aroma, texture, general acceptability and especially color is in conformity with the study by Tizazu *et al*. (2010) stated that, vision plays a major role in sensory analysis and the appearance of food can have a major effect on its acceptability.

CHAPTER SIX

6.0 Summary, Conclusion and Recommendations

6.1 Summary

i. Processing had varied effects on the functional properties of finger millet flour. Fermentation significantly ($P<0.05$) increased swelling and water absorption capacity, germination increased solubility power.

ii. There was no significant difference ($P>0.05$) in the moisture content of pap from unprocessed, germinated and fermented finger millet seeds. Likewise, tuwo from unprocessed and processed seeds (roasted, germinated and fermented).

iii. Germination decreased the carbohydrate content of flour significantly, while there was no significant ($P>0.05$) difference between the carbonhydrate content of flour from unprocessed, roasted and fermented seeds. The carbohydrate content of the products (pap and tuwo) did not differ significantly ($P>0.05$).

iv. There was no significant difference ($P>0.05$) in the fiber content of flour and tuwo from unprocessed seeds.

v. Processing methods reduced significantly ($P<0.05$) phytate, tannins, cyanogenic, glycosides, saponins and oxalate content of food products (Pap and Tuwo) from fermented seeds, likewise flour from roasted seeds.

vi. Processing methods also had varied effects on the mineral composition of flours. Flours from unprocessed seeds had higher content of iron, phosphorus, calcium, magnesium and manganese compared to the

processed flour samples except for roasted samples that had higher potassium content.

vii. Food product (pap) from germinated seeds had higher content of iron and calcium compared to fermented, roasted and unprocessed samples , while the potassium content of samples from processed seeds had no significant ($P<0.05$) difference. Pap from unprocessed seeds had higher content of potassium and manganese, there was no significant difference ($P>0.05$) between calcium content of pap from unprocessed and roasted samples. Tuwo from germinated seeds had higher content of phosphorous and magnesium. There was no significant difference in the iron content of tuwo from unprocessed and germinated seeds. Likewise, tuwo from roasted seeds had higher potassium contents.

viii. Fermented seeds products (flour, pap and tuwo) are low in soluble dietary fiber and high in insoluble dietary fiber.

ix. Germination and roasting improved sensory attibutes of food products and processing increased the glucemic index and blood glucose response of food products.

6.2 Conclusion

Processing had no effect in bulk density of flour, fermentation improved water absorption and swelling capacity, while germination improved solubility of flour, low gelation capacity and higher gelatinization temperature.

Proximate composition results revealed that germination decreased carbohydrate content of flour and improved the protein content of both flour

and food products. Processing (germination and fermentation) improved the mineral element concentration such as iron, potassium, calcium, magnesium and manganese. Processing improved the amount of phenylalanine in products (Pap and Tuwo) from fermented and germinated finger millets seeds. The unprocessed food products had higher total dietary fiber. Germination and fermentation increased the glycemic index of food products, while the products from unprocessed seeds had lower (<55%) glycaemic response and glycaemic index than the poducts from processed seeds. Food products from roasted seeds had medium glycaemic index (56-69%), the most acceptable with improved sensory attributes.

6.3 Recommendations

- Pap and tuwo made from unprocessed flour of finger millet had lower glycemic indices than pap and tuwo made from processed flour, therefore, pap and tuwo made from unprocessed finger millet flour is a recommended food for diabetic management.
- There should be further studies on the possible development of a functional foods from finger millets.
- Further studies on microbial analysis, the storage and package of finger millet flour and food products should be carried out.

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APPENDIX I

DEPARTMENT OF BIOCHEMISTRY, FACULTY OF SCIENCE AHMADU BELLO UNIVERSITY, SAMARU- ZARIA.

INFORMED CONSENT FORM (ICF)

The informed consent form is for pregnant mothers attending antenatal clinic in Yusuf dan tsoho memorial hospital in Kaduna state. I am inviting you to participate in this research work titled "Effect of processing on the functional properties, nutrients composition, glycemic index and sensory attributes of finger millet (eleusine coracana) food products'.

Researcher : Aliyu Maimunatu Ladidi
Supervisor(s) : Prof. D.A Ameh and Dr. O.A Owolabi
Institution : Department of biochemistry Ahmadu Bello Zaria.
Name of sponsor : Self
Name of proposal : MSc. Nutrition.

This informed consent form has two part:

- Information sheet (to share information about the research with you)
- Certificate of Consent (for signatures if you agree to take part)

PART 1: INFORMATION SHEET

Introduction

I am Aliyu Maimunatu Ladidi an MSc. Student of department of biochemistry, faculty of life science Ahmadu Bello University, Zaria, carrying out a research work under the supervision of Prof. D.A Ameh and Dr. O.A Owolabi. We are doing a research work on "effect of processing on functional properties, nutrients composition, glycemic index and sensory attributes of finger millet (eleusine coracana) food products". I am going to give you information and invite you to be part of this research. You do not have to decide today whether or not you will participate in the research. Before you decide, you can talk to anyone you feel comfortable with about the research.

Purpose of research

The purpose of this research is to find the effect of processing on functional properties, nutrients composition, glycemic index and sensory attributes of finger millet (eleusine coracana) food products.

Participant selection

We are inviting all healthy subjects and diabetic patients (18-65) to participate in the research work on the Effect of processing on the functional properties, nutrients composition, glycemic index and sensory attributes of finger millet (eleusine coracana) food products.

Do you know why we are asking you to take part in this study? YES..... NO.....
Do you understand what this study is all about? YES..... NO.....

Voluntary participation

Your participation in this research is entirely voluntary, it is your choice whether to participate or not. Whether you choose to participate or not. All the services you receive at this hospital will continue and nothing will change. If you choose not to participate in this research project you will be offered the treatment that is routinely offered in this diabetic clinic. You may change your mind later and stop participating even if you agreed earlier.

If you decide not to take part in this research study. Do you know what your options are? YES... NO...

Do you know that you do not have to take part in this study, if yes do not wish to? YES.. NO...

Do you have any questions? YES... NO.....

Procedures and protocol

When you have agreed to participate in this research, we will need you fill this questionnaire and we will take your blood sample before and after consumption of the food products using glucometer to measure your blood glucose level.

Description of the process

During the research a routine one visit will be made every diabetic clinic and small amount of blood sample will be taken and it will be used to test for the level of blood glucose/glycemic index. Sensory evaluation will be carried out among healthy subjects using food products of finger millet.

Duration

The research will take place over three to four months. During that time, it is necessary for you to be regularly be attending your antenatal clinic days.

- *How many times are we asking you to come to the hospital to participate in the research?.....*
- *Can you tell me the number of time we will take your blood sample?.....*
- *Do you have any questions?.....*
- *Do you want me to go through the procedures again?.....*

Risk

There is a risk that you may share some personal information or confidential information by chance, or that you may feel uncomfortable talking about some topics. However information you provided will be kept strictly confidential. You can choose not to answer any question or take part in the research if you feel the question(s) are too personal or if talking about them makes you uncomfortable.

Benefits

If you participate in this research, you will have the following benefit:

- You will have the opportunity of having tests that others not participating in the study will not have.
- There may not be any benefit to the society at this stage of the research, but future generations are likely to benefit.
- Apart from these few benefits listed above, your participation is likely to help us to the research questions.

Reimbursements

You will not be provided with any special incentive or travel allowance for you to take part in the research. But we advise that your visit to the hospital will have to be on your normal antenatal days.

- Can you tell me if you have understood correctly the benefit that you will have if take part in the study.....
- Do you know that the study will not pay your travel costs? .....
- Do you have any other questions? .....

Confidentiality

The information that we collect from this research project will be kept confidential. Any information about you will have a number on it instead of your name which only the investigator will know your number.

Right to refuse or to withdraw

Whether you chose to participate or not. All the services you receive at this hospital will continue and nothing will change. If you choose not to participate in this research project you will be offered the treatment that is routinely offered in this antenatal clinic. You may change your mind later and stop participating even if you agreed earlier.

Who to contact

If you have any questions you may ask them later, even after the study has stated. If you wish to ask questions later you may contact the following:
ALIYU MAIMUTU LADIDI: 08080636351

This proposal has been reviewed and approved by scientific ethical committee (SEC) of the ministry of health which is a committee whose task is to make sure that research participants are protected from harm.

If you decide not to take part in this research study do you know what your options are? YES..... NO.....
Do you know that you do not have to take part in these study, if yes do not wish to? YES..... NO.....
Do you have any questions? YES..... NO.....

PART II: CERTIFICATEOF CONSENT

I have read the foregoing information, or it has been read and translated to me in language that I understand. I have also talked it over with my Doctor and also my family to my satisfaction. I have had the opportunity to ask question about it and any question that I have been answered to my satisfaction. I understand that my participation is voluntary. I know enough about the purpose, methods, risk and benefits of the research study to judge that I want to take part in it. I understand that I may freely stop being part of this study at any time. I have received a copy of this consent form and additional sheet to keep for myself. I therefore consent voluntarily to participate in this research.

Name of participant: .....
Signature of participant: .....
Date: .....

Statement by witness

I have witnessed the accurate reading of the consent form to the potential participant, and the individual has had the opportunity to ask questions. I confirm that the individual has given consent freely.

Name of witness: .....and **thumb print of proposal**

Signature of witness: .....

Date: .....

Statement by the researcher/person taking consent

I have accurately read out the information sheet to the potential participant, and to the best of my ability make sure that the participant understands that the following will be done:

1. Blood sample will be taken

1 confirms that sufficient information, including about risks and benefits, to make an informed decisions have been fully explained to the participants. The participant was given an opportunity to ask question about the study, and all the questions asked by participant have been answered correctly and to the best of my ability. I confirm that the individual has not been coerced into giving consent, and the consent has been given freely and voluntarily.

A copy of this ICF has been provided to the participant.

Name of researcher/person taking the consent: .....

Signature of researcher/person taking the consent: .....

Date: .....
Day/month/year

APPENDIX II: Ethical Clearance Letter

MINISTRY OF HEALTH AND HUMAN SERVICES
KADUNA STATE, NIGERIA

MOH/ADM/744/VOL.1/373

4th February.2016

The Medical Director
Yusuf Dan Tsoho
Memorial Hospital - Tudun Wada
Kaduna

RECEIVED
DATE 9/3/16
Yusuf Dan Tsoho Memorial Hospital T/Wada Kaduna

NOTICE OF APPROVAL AFTER FULL COMMITTEE REVIEW

EFFECTS OF PROCESSING METHODS ON NUTRIENT COMPOSITION AND GLYCAEMIC INDEX OF FINGER MILLET PRODUCTS (ELEUCINE CORACANA) FOOD

Name of Principal Investigator:	ALIYU MAIMUNATU LADIDI
Address of Principal Investigator:	Faculty Of Science, Dept of Biochemistry,A.B.U,Zaria.
Date of receipt of Application	13th JAN, 2016
Date of Ethical Approval	28th JAN, 2016

This is to inform you that the Research described in the submitted Protocol, the Consent forms, advertisements and other participant information materials have been reviewed and given full approval by the Health Research Ethics Committee (HREC).

If there is delay in starting the research or any change, inform the HREC so that the dates of approval can be adjusted accordingly.

However, Researcher is kindly requested to submit a copy of his/her findings to the State Ministry of Health, please.

DR. BUTAWA NUHU N
SECRETARY
FOR: CHAIRMAN

4/2/16

A

B
HOD Lab

Ref to HOD Lab
9/3/16

Independence Way, P.M.B 2014, Kaduna, Kaduna State-Nigeria
Tel: +234 (0) 818 407 8693 | Website: www.kdsg.gov.ng | Email: health@kdsg.gov.ng

APPENDIX III

QUESTIONNAIRE ON THE KNOWLEDGE OF COMMON FOOD PRODUCTS FROM FINGER MILLET (TAMBA)

Instruction:

Complete the form by answering the below question. All the information given are treated as confidential and will be used for academic purpose only.

SECTION A

Demographic Data

1. Country of Origin:_____
2. Location: Urban ☐ Rural ☐
3. Sex: Male ☐ Female ☐
4. Age: 18 -24 ☐ 25-35 ☐ 36-45 ☐ 46 above ☐
5. Marital Status: Married ☐ Single ☐ Divorce ☐ Widow/Widower
6. Number of Children: Nil ☐ One ☐ Two ☐ Three Four above
7. Occupation: Student ☐ Civil servant ☐ Trader ☐
8. Education Status: Primary ☐ Secondary ☐ Tertiary

SECTION B

Knowledge of Finger Millet

9. List five types of cereals you know

   i. ii. iii. iv. v.

10. How often do you eat each of the cereals as food?

    Daily ☐ 3 times a week ☐ Once of month ☐ As the need arise ☐

11. How many types of millet do you know from below

Finger millet ☐ Proso millet ☐ Pearl millet ☐

12. How frequent do you eat each of the millet

Daily ☐ 3 Times a week ☐ when the need arise ☐

13. Of what Purpose?

Food alone ☐ Health purpose ☐ any other purpose ☐

14. If used for health purpose which of the following

i. Prevention of illness ☐

ii. Management of illness ☐

iii. Maintenance of healthy body ☐

15. Do you have specific illness that you eat finger millet for?

Yes ☐ No ☐

16. If yes, for.

i. Treatment of Diabetes ☐

ii. Management of diabetes ☐

iii. Management of Hypertension ☐

iv. Prevention of hypertension ☐

v. Prevention of cancer ☐

vi Weight management and control ☐

vii. Reduction of cholesterol level ☐

viii. Prevention of constipation ☐

ix. All of the above ☐

SECTION C

Knowledge of the nutritional properties of finger millet

17. How many Food prepared with finger millet do you know?

None ☐ One ☐ Two ☐ Three ☐ More

18. Specify from the list below your commonly consumed products from finger millet

Pap ☐ Bread ☐ Tunwo ☐ Bean cake ☐ Cake ☐ Infant weaning meal ☐

19. Do you know the nutritional properties of finger millet?

Yes ☐ No ☐

20. List two nutritional properties, if yes.

i.

ii.

21. Do you know the composition of finger millet?

Yes ☐ No ☐

If yes, List them: _____