UNIVERSITY FOR DEVELOPMENT STUDIES

EFFECTS OF *Citrullus vulgaris* ("NIRI") AS AN EXTENDER IN BEEF SAUSAGE

EDWARD AYINBILA ADUA

THESIS SUBMITTED TO THE DEPARTMENT OF ANIMAL SCIENCE, FACULTY OF AGRICULTURE, UNIVERSITY FOR DEVELOPMENT STUDIES IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF PHILOSOPHY DEGREE IN ANIMAL SCIENCE

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BY

EDWARD AYINBILA ADUA (B. Sc. Agricultural Technology)

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DECEMBER, 2018

DECLARATION

STUDENT

I hereby declare that this dissertation/thesis is the result of my own original work and that no part of it has been presented for another degree in this university or elsewhere:

Candidate's Signature: ……………………. Date :……………………………

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SUPERVISORS'

I hereby declare that the preparation and presentation of this dissertation/thesis was supervised in accordance with the guidelines on supervision of dissertation/thesis laid down by the University for Development Studies.

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Dr. Anthony A. Agbolosu

ABSTRACT

This study was conducted to determine the nutritional composition of “niri” (*Citrullus vulgaris*) seeds and its effect as an extender in beef sausages. The nutritional composition of whole “niri” seed, its purees (raw and roasted) and Chaffs (raw and chaffs) were determined using standard procedures. The purees and chaffs were used as extenders at 0, 5, 15 and 25 % inclusion levels in beef sausages. Sensory analyses were conducted using the British Standard procedures on days 1, 7 and 14 after production using a fifteen member trained panel. Nutritional, physico-chemical and peroxide analyses were also conducted using standard procedures. The results were analysed using two-way ANOVA of Genstat Discovery edition 4. The results revealed a high protein and oil contents in whole “niri” seeds. There were no significant differences ($p < 0.05$) in the sensory parameters of sausages extended with “niri” purees except for colour. The colour of raw “niri” puree extended beef sausages were similar (intermediate) but that of roasted purees decreased (dark to very dark) with increasing inclusion level. Proximate results showed no significance ($p > 0.05$) in ash and carbohydrate contents of puree extended samples. Significant differences ($p < 0.05$) were recorded in fat, moisture, protein and mineral contents. High inclusion levels of purees resulted in high pH of sausages. Peroxide values of all extended sausages were above acceptable limits with raw puree products recording exceedingly high values in each week than the roasted (puree and chaff) samples. Sausages that were extended with “niri” chaffs recorded no significant differences ($p > 0.05$) for all sensory parameters except colour during the evaluation period. Colour scores of roasted chaff products were very dark while raw chaff products were dark. There was significant difference ($p < 0.05$) in all nutritional parameters of chaffs extended sausages. High ash, carbohydrates, fat and all minerals except zinc were

recorded in 25 % roasted chaff products. High pH values were also reported in 5 and 15 % roasted chaff products and 25 % raw chaff products at a significance of 5%. Low formulation costs were obtained at high inclusion levels of "niri".

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DEDICATION

I dedicate this work to my father Gbandaana David Adua of blessed memory. I am forever indebted to him for giving me education, the greatest asset in life. May God grant him a peaceful rest in His heavenly Kingdom.

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CHAPTER ONE

1.0 INTRODUCTION

Meat refers to the flesh of animals eaten as food (Lawrie and Leward, 2006). It plays a major role in human diet and has a key link to people's way of life, economic and health status (Dario *et al.,* 2016). Meat is sourced from many domestic species based on cultural and religious beliefs, accessibility and convenience (Paredi *et al.*, 2013). Warriss (2010) identified pigs, poultry, sheep and cattle as the main meat producing animals in the world.

Nutritionally, meat is a source of lipids, vitamins and complete proteins with high biological quality and minerals (Wyness, 2013; Verbeke *et al*., 2010). The growth and development of our bodies is therefore highly influenced by meat due to the presence of essential amino acids (Warriss, 2010). Consumption of meat in developing economies will improve their health status and go a long way to increasing their productivity.

Raw meats are highly susceptible to microbiological contaminants during processing and heat treatment is usually not enough to completely remove these microbes in the industries (Trindade *et al.*, 2010).This, coupled with a growing desire by people to improve their lives makes them spend much time outside home working leaving little time for food preparation (Amir *et al.,* 2015). These challenges call for the processing of convenient or ready-to- eat meat products to meet these demands.

Teye (2007) defined meat processing as the processes that involve ingredients' addition to meat to produce specific products through the conversion of fresh meat by mechanical actions. Examples of processed meat products include but not limited to sausages, meatballs, frankfurter, burgers, bacon and meat loaf (FAO, 1991). Meat processing leads to the preservation or extension of shelf life, improvement of tenderness and flavour of meat and its products (FAO, 2007) and value addition to DFD and PSE meats (Adzitey, 2011; Adzitey and Huda, 2011; Adzitey and Huda, 2012). Meat processing also offers jobs to processors and persons that are directly or indirectly linked to the industry.

The most appetizing and common processed meat product is sausage (Ehr *et al*., 2016). Major components of sausage include boneless meat, fat, water, spices with or without additives and preservatives stuffed into casings (Ismed, 2016).

The expensive nature of boneless meat leads to an increased cost of production (Teye *et al*., 2012). The products then finally become very expensive (Wiriyacharee, 1992) limiting their consumption to only the rich and wealthy in society (Adjekum, 1997). This practice if not checked, will compromise the health of the poor majority and increase the nation's expenditure on health care, increase malnutrition and consequently decrease productivity. There is the need therefore to find ways of reducing formulation cost of meat products to reduce cost while maintaining the high biological value of meat products to make them affordable to a majority of the population. Teye *et al*., (2012) proposed the use of extenders as a means to reducing the formulation cost of meat products.

Extenders or fillers according to FAO (1991) are protein additives (plant or animal extracts) used to increase yield and water holding ability of meat products. Extenders improve protein and lower formulation costs. Common examples are flours of cereals and legumes, soy proteins, starch and milk proteins.

Cowpea flour was used up to 10% inclusion as an extender and gave positive outcomes in sensory and yield of meat balls, comminuted pork and beef frankfurter-type sausages and coarse smoked beef and pork sausages (Teye *et al.*, 2006; Teye *et al.*, 2009; Zakaria, 2003; Serdaroglu *et al*., 2004).

These gave an indication that locally available materials can be used as extenders in meat products formulation. One such local feed resource is “Niri” or brown-seeded-melon (*Citrullus vulgaris*). It is an annual vine crop usually intercropped with cereals in the three regions of Northern Ghana. The seeds are used to prepare stews and soups. It is an important resource in traditional homes as it is used to prepare special meals for important personalities like in-laws and sick persons for quick recovery. A traditional Frafra funeral is also incomplete without “Niri” soup. Despite all these uses, its potential as an extender in meat products has not been exploited.

This study therefore seeks to determine the effects of “niri” as extender in beef sausages.

The specific objectives of the study were to determine;

- The proximate and mineral composition of “niri” seeds and its processed materials.
- The organoleptic/sensory characteristics of “niri” beef sausages.
- The proximate and mineral composition of the “niri” beef sausages.
- The pH values of the “niri” beef sausages.
- The peroxide values of the “niri” beef sausages.
- The formulation costs of “niri” beef sausages.

CHAPTER TWO

2.0. LITERATURE REVIEW

2.1. Meat

Food Standards of Australia and New Zealand (FSANZ, 2002) Code defines meat as the part or entire carcass of a slaughtered goat, pig, poultry, cattle, sheep, buffalo, camel, deer, hare or rabbit other than their wild state, but does not include eggs or feotuses. This does not narrow meat to only skeletal muscles nor does it restrict the species of meat to the traditional domestic animals. The definition includes offals exclusive of bones and their contents. This gives people an array of meat to choose from according to their income and availability to enrich their diets.

Meat could be grouped into "red" or "white" depending on the source. Red meat is described as meat from cattle, goat and sheep (Williams, 2007). The most sort after meat in Africa, Europe, North and South America is beef (Warriss, 2010). White meat on the other hand describes meat from poultry and pork.

2.1.1. Physical composition of meat

According to FAO (Heinz and Hautzinger, 2007), muscles are attached to skeletons by tendons. A muscle consists of many muscle fibre bundles which are macroscopic containing 30 to 80 muscle fibres or muscle cells (Heinz and Hautzinger, 2007). Muscle cells are a few centimetres long and 0.01 to 0.1 mm wide (Heinz and Hautzinger, 2007). Breed and type of animal and the age are determinants of the size and diameter of muscle cells. Blood vessels, fat (intramuscular) and connective tissues are located between muscle cells. Sarcolemma (cell membrane) envelops each muscle cell. Sarcoplasma (a soft protein structure) is made of numerous filaments called myofibrils. The myofibril is therefore the basic unit of the muscle.

2.1.2. Chemical composition of meat

Generally, meat consists of water, mineral, protein, fat and small amount of carbohydrate. Briggs and Schweigert (1990) identified a muscle to contain about 75 %, 20 %, 3 % and 2 % water, protein, fat and soluble substances respectively. This is supported by Warriss (2010) who stated that a muscle tissue contains around 75% water, 20% protein and 5% of fat, a very small amount of carbohydrate, nucleotides, dipeptides and amino acids. The most valuable of these components is protein.

2.1.3. Nutritional composition of red meat

Williams (2007) stated that red meat provides proteins of high biological value and valuable micronutrients including omega-3 polyunsaturated fatty acids that a person needs for a good healthy life. Biological value describes the ease with which proteins can easily be incorporated into body tissues for growth and maintenance of body cells. This makes red meat an important source of protein to most people especially children, pregnant and lactating mothers including people in the active working age group. Though nutritional composition varies depending on; plane of nutrition, season, meat cut and breed, lean red meat is generally low in fat, moderate cholesterol, essential vitamins, minerals and protein. Cooking red meat will result in a protein content of between 28-36g/100g than the 20-25g/100g of raw red meat, due to decrease water content during cooking making nutrients more concentrated in cooked products (Williams, 2007).

Table 2. 1: Nutrient composition Beef and Mutton (per 100g) of lean

Parameter	Beef	Mutton
Moisture(g)	73.1	73.2
Protein(g)	23.2	21.5
Fat(g)	2.8	4
Energy(kJ	498	514
Cholesterol(mg)	50	66
VitaminB6(mg)	0.52	0.8
Vitamin B12(µg)	2.5	2.8

Source: **Williams *et al*., (2002); Sinclair *et al*., (1999); Sadler *et al*., (1993)**

Table 2.1. Show that beef is a good source of protein. It also has a relatively low amount of fat and cholesterol than mutton and appreciable amounts of energy, vitamins B_6 and vitamin B_{12}. Low cholesterol in beef means beef will pose less danger to cardiovascular health than mutton. The high amount of energy in mutton than beef is due to the high quantity of fat which is richer in energy than protein.

Nutritional composition of different beef products are illustrated in Table 2.2. The table indicates that processing leads to a reduction in protein content due to the addition of fat into sausages during processing. This is probably due to the desire to increase yield and sensory attributes of sausages.

Table 2. 2: Nutrient composition of different beef products/100g

Product	Moisture	Protein	Fat	Ash	Calories
Beef (lean)	75	22.3	1.8	1.2	116
Beef carcass	54.7	16.5	28	0.8	3.23
Raw cooked sausage finely comminuted, no extender	57.4	13.3	22.8	3.7	277

Source: **Heinz and Hautzinger, 2007**

2.1.3.1. Proteins

The human body is basically made of proteins and worn out tissues are replaced from proteins that we eat in our diets in order to retain a balance. Animal protein is made up of 65% and 30% of skeletal muscle and connective tissues (elastin and collagen) respectively (Heinz and Hautzinger, 2007). Keratins (nails and hairs) and blood constitute the remaining 5% (Heinz and Hautzinger, 2007). Proteins from animals are highly digestible (94%) compared to 86% and 78% respectively for whole wheat and beans (Bhutta, 1999). There are about twenty known essential amino acids and meat provides all these essential amino acids (Williams, 2007). Protein quality is evaluated by Protein Digestibility Corrected Amino Acid Score (PDCAAS) method and has 1.0 as maximum possible score (Williams, 2007). Beef therefore have an approximate score of 0.9, compared to 0.5-0.7 for a majority of plant foods (Schaafsma, 2000). Soy proteins for instance has a biological value of 0.65 (Heinz and Hautzinger, 2007) making beef superior to other types of red meats. Paddon-Jones and Leidy (2014) reported that red meat enhances vitality of food because it has high quality protein and elevated bioavailable iron. The high quality protein will lead to adults regaining weight, infants gaining weight, avoidance of weight gain and support of weight loss in overweight persons (Westerterp *et al*., 2009; Brehm and D′Alessio, 2008; Halton and Hu, 2004), ease fat mass (Keller, 2011) and guard against decreases in lean body pile (Wycherley *et al*. 2012; Kushner and Doerfler, 2008; Bopp *et al*., 2008; Weigle *et al.*, 2005). Middle age persons are encouraged to ingest more high quality protein so as to preserve the value of life connected with sufficient muscle mass (Dario *et al*., 2016) through the consumption of meat.

However, when persons are discouraged from eating red meat, the consequences are enormous. These include; skeletal muscle mass degeneration (sarcopenia) in older adults and replacement of skeletal muscles with fat or sarcopenic obesity (Paddon-Jones and Leidy, 2014; Paddon-Jones and Rasmussen, 2009; Paddon-Jones *et al*., 2008).

2.1.3.2. Fats/Lipids

The key contribution of fat to human diet is energy or calories (Heinz and Hautzinger, 2007) providing about 2.25 times more than carbohydrate and protein per unit (Shahiri and Mazaheri, 2014). Exterior fat ("body fat") is to a great extent softer than the interior fat surrounding organs because of high concentration of unsaturated fat in the external organs. Linoleic, arachidonic and linolenic acids are the nutritionally and physiologically vital unsaturated fatty acids which are constituents of mitochondria, metabolic sites and cell walls (Heinz and Hautzinger, 2007). These fatty acids cannot be synthesized by our bodies and have to be provided in our foods (Heinz and Hautzinger, 2007). Relatively good sources of these fatty acids are meat and meat products though some cereals and seeds provide about 20 times more linoleic acids (Heinz and Hautzinger, 2007).

On sensory, fat contributes to aroma or odour, taste, mouth feel and flavour (Moghazy, 1999). This is supported by Mona *et al*. (2011) who stated that high fat levels contribute to desirable ground meat patty qualities like juiciness and mouth feel. This suggest that fat is indispensible in human diet.

2.1.3.3. Mineral composition of red meat

Minerals are defined as inorganic substances in all body tissues and fluids which are for the preservation of specific physicochemical processes essential to life (Soetan *et al.*, 2010). They play essential roles in many body activities except energy (Eruvbetine, 2003) and every living tissue needs minerals for normal life processes (Ozcan, 2003).

Eruvbetine (2003) classified minerals broadly into major (macro) or minor (trace or micro) elements and ultra trace elements. Macro-minerals are; calcium, magnesium, chloride, sodium and phosphorus, the micro-elements are; selenium, copper, potassium, zinc, cobalt, iodine, manganese, chromium, molybdenum, fluoride, iron and sulfur while the ultra trace minerals includes boron, arsenic, silicon and nickel. Major minerals are needed in greater amounts (more than 100mg/dl) and minor minerals are needed in small quantities less than 100mg/dl) by the body (Murray *et al.*, 2000). The biggest public health concern in most developing countries is micronutrient deficiencies with pregnant women and infants (Batra and Seth, 2002). These classes of people are most affected because they need these micronutrients for growth, development and maintenance of normal physiological function. This calls for the consumption of food ingredients that contain reasonable amounts of these micronutrients for a healthy living.

Williams (2007) stated that the richest source of iron and zinc is beef and lamb and a quarter of adult daily requirement is obtained from a 100 g serving of these red meats. Mineral compositions of red meats are shown in Table 2.3.

Table 2. 3: Mineral composition of red meats (per 100g) lean

Mineral	Beef	Lamb	Mutton
Sodium (mg)	51	69	71
Potassium (mg)	363	344	365
Calcium (mg)	4.5	7.2	6.6
Iron (mg)	1.8	2	3.3
Zinc (mg)	4.6	4.5	3.9
Magnesium (mg)	25	28	28
Copper (mg)	0.12	0.12	0.22
Selenium (µg)	17	14	<10

Source: Williams *et al*., (2002); Sinclair *et al*., (1999); Sadler *et al*. 1993

2.1.3.3.1. Calcium

The most abundant inorganic element in the body is calcium accounting for about 2% of adult body weight, equivalent to 1200g (Ilich and Kerstetter, 2000). The skeleton and teeth constitutes about 99% of body calcium where it provides rigidity while body fluids and soft tissues account for the remaining 1% (Ilich and Kerstetter, 2000). Calcium is a component in bones and teeth, muscle and nerve regulation, blood and milk clotting, muscle contraction and transmission of nerve impulses. Other functions are activation of enzymes like adenosine triphosphatase (ATPase), lipase and succinic dehydrogenase. It is therefore evident that the role of calcium in human nutrition and by extension survival is indispensable.

Recognition of these important functions of calcium has led the FAO/WHO (2002) to jointly recommend that, men between the ages of 19 and 65 years and women over 19 years, up to menopause should consume 1000 mg of calcium/day while men above 65 years and postmenopausal women should consume 1300 mg of calcium/day for normal body functions to take place unhindered.

The use of calcium without replacement at the rate at which the body needs leads to deficiency which hinders normal body function and conformation. Calcium deficiencies lead to inadequate calcium phosphate calcification of bones in growing children causing rickets. It causes osteoporosis as a result of decalcification of bones due to a metabolic disorder which leads to fractures (Murray *et al.*, 2000). Rickets (bow-legs) in children causes poor bone structure and bad posture which prevents children from taking part in physical activities like sporting leading to low self –esteem. Excess calcium in the body leads to cardiac and respiratory failure. They are however, removed by the kidney (Soetan *et al.*, 2010).

2.1.3.3.2. Iron

This mineral element being an indispensable component of blood haemoglobin is present in all parts of the body. According to the Scientific Advisory Committee on Nutrition (SACN, 2010), food iron exists in two distinct forms: haem and non-haem iron. The haem iron is originated almost completely from food of animal source while non-haem iron exists in animal and plant tissues. Cereals, nuts, vegetables, fish, eggs and meat are the richest sources of non-haem iron (California Nutrition and Physical Activity Guidelines for Adolescents [CNPAGA], 2013). Beef is estimated to contain a haem iron content of 64 (Valenzuela *et al.*, 2009) to 78% (Lombardi-Boccia *et al.*, 2002) of total iron and other red meats containing 52 to 83% of total iron(Lombardi Boccia *et al.*, 2002). Iron is a raw material for the synthesis of haemoglobin which carries oxygen in blood. Every cell therefore needs iron in order for respiration to take place. Iron in meat is well absorbed and it is said to be facilitated by the high meat protein content (Williams, 2007).

Institute of Medicine (2001) recommends 8, 11 and 8 mg/day of iron for males within ages of 9-13, 14-18 and 19-30 years respectively. Females require 8, 15 and 18 mg/day of iron for persons within the ages of 9-13, 14-18 and 19-30 years respectively. All pregnant women require a daily iron intake of 27 mg for a healthy mother and embryo. Lactating mothers on the other hand require 10 and 9 mg/day respectively for the ages 14-18 and 19-30 years. Increase blood volume and body mass during adolescence makes iron an important mineral for normal growth and development to take place. Adolescent girls need more iron to produce more blood to replenish the blood that they lose through menstruation.

Iron deficiency leads to anaemia and weakened immune system making a person susceptible to diseases. The consequences of iron deficiency include; tiredness, susceptibility to infection, reduced intellectual performance and increased exposure to lead poisoning in early stages and irritability, paleness, decreased cardiovascular endurance, anorexia, rapid tachycardia, swelling of the heart (cardiomegaly) and nutrient deficiencies in later stages (Institute of Medicine, 2001). Low birth weight, pre-term birth and prenatal mortality are common reproductive consequences of iron deficiency (Kaiser and Allen 2008). A common symptom of iron deficiency in pregnant women and other people is the increased desire by such persons to eat non-edibles like dirt and clay (Institute of Medicine, 2001).

2.1.3.3.3. Potassium

Potassium is a chief component in every living cell and an indispensable nutrient needed in large quantities by humans, animals and plants (Hamdallah, 2004). It is the seventh most abundant mineral within the earth's crust and the third largest mineral in the human body (Bhaskarachary, 2011). Potassium is the key cation in intercellular fluids while sodium is the key cation in intracellular fluids (Bhaskarachary, 2011). Being an essential mineral means it has to be provided in the diet. Humans acquire a bulk of their potassium directly from plants or indirectly from animal products in their food (Bhaskarachary, 2011). According to Kinabo (2015), beef contains 230 mg/g and 122 mg/g for fish but lower than groundnut (705mg/g), cowpea (278 mg/g) and finger millet (408 mg/g).

Pohl *et al*. (2013) stated that potassium is important for the normal functioning of all parts of the human body. It is also vital to heart performance and helps in smooth muscle and skeletal contraction, making it essential for undisturbed functioning of digestive system and muscular performance.

Table 2.4 illustrates the recommended daily potassium requirements for all ages and some categories of people.

Table 2. 4: Dietary recommendation for potassium

Age Group	0-6 Months	7-12 months	1-3 years	4-8 years	9-13 years	14-18 years	> 18 years	Pregnancy (14-50 years)	Lactation (14-50 years)
Adequate Intake (mg/day)	400	700	3,000	3,800	4,500	4,700	4,700	4,700	5,100

Source: Institute of Medicine (1997)

2.1.3.3.4. Magnesium

Recent studies have shown that, among the numerous most ignored inorganic elements in the human body is magnesium (Faryadi, 2012). Researchers have discovered magnesium as a vital electrolyte in all living organisms and ranks fourth in terms of mineral abundance in the body and a cofactor of over 300 enzymes (Gröber *et al*., 2015). About 60% of total body magnesium is stored in bones while 40% is situated in extra- and intracellular tissues (Gröber *et al*., 2015). According to Jahnen-Dechent and Ketteler (2012), an adult weighing 70 kg with 20% (w/w) fat will contain approximately 24 g (~1000 - 1120 mmol) of magnesium. Green vegetables, nuts, seeds and unrefined cereals are rich sources of magnesium while meat, legumes, fruits and fish contain intermediate levels (Gröber *et al*., 2015). The Institute of Medicine (IOM) (1997) of the United States of America recommended that children between the ages of 1-3 and 4-8 years should consume 80 and 130 mg/day of magnesium respectively. Older males are expected to take a daily allowance of 240 mg/day for 9-13 years and as high as 420 mg/day for persons 31 years and above. The recommended daily allowance for females ranges from 240, 360 and 320 mg/day respectively for 9-13, 14-18 and 31 years and above.

2.1.3.3.5. Zinc

Zinc is one of the essential minerals found in all body fluids, organs and tissues and represents approximately 1.5–2.0 g or around 0.003% of total adult human weight (Deshpande *et al*., 2013). According to Prasad (2003), about two billion people in the third world countries are zinc deficient. It is estimated that about 800,000 infant mortalities globally are due to zinc deficiency related diarrheoa and infections (Hambidge and Krebs, 2007). Brown *et al*. (2002) undertook a study in developing countries and confirmed that, zinc deficiency was commonly observed to be responsible for growth retardation. Zinc is commonly found in meat, kidney, liver, chicken, fish, cereals and vegetables (Deshpande *et al*., 2013). Though zinc is found in many foods, the deficiency problem among children in developing countries is due to the low consumption of foods like red meat, liver, poultry, crabs, oysters and fish which are rich and readily absorbable sources of zinc (Deshpande *et* *al*., 2013). Another factor favouring zinc deficiency is the current dietary habits that discourage the consumption of red meats which are high in zinc and iron in favour of dairy, fish and poultry products (Nriagu, 2007).

According to WHO (1996), the recommended physiological zinc requirement for adult males is 1.4 mg/day and 1.0 mg/day for females. There is high requirement for males due to the essential role zinc plays in the male reproductive system. There is high zinc concentration in male reproductive organs and the semen is exceedingly high in zinc than the rest of the body tissues and fluids (Nriagu, 2007). The high concentration of zinc in growing spermatozoa helps in oxygen intake by the spermatozoa, acrosin activity and chromatin stabilisation. Clinically, zinc deficiency adversely affects spermatozoa development and maturation, growth and steroidogenesis of testicles (Nriagu, 2007). Deshpande *et al*., (2013) reported that, zinc deficiency in persons with sickle cell disease is 60-70% in adults and 44% in infants.

2.2.0. Meat processing

Raw meat is highly inclined to microbiological contamination during and after slaughter of animals (Trindade *et al*., 2010). This vulnerability reduces shelf life of raw meat making it unavailable at certain times or compels producers to sell meat below average in order to dispose products on time. Producers at certain times are compelled to sell meat at high prices to make it for the spoiled ones. These limit the economic and physical access to meat affecting Food Security. These setbacks coupled with the growing desire for ready-to-eat foods calls for the need to process raw meat.

Meat processing is defined as the process of converting the flesh and edible parts of meat by employing physical and biochemical technologies into value added products (Teye, 2010). This will open doors for the marketing of farm animals and motivate farmers to increase livestock production. The preservation or extension of shelf life, tenderness and flavour improvement (FAO, 2007) and the provision to consumers with a range of textures and flavours with efficient utilisation of less attractive meat trims and cuts (El-sayed, 2013) are benefits of meat processing. This will increase the intake of meat and meat products which are excellent sources of protein and minerals to balance the deficiencies in plant based food sources (FAO, 1992), reducing malnutrition and improving health status of consumers. Researchers have discovered that meat could be processed into products like; burgers, sausages, frankfurter, meatballs, bacon and meat loaf (FAO, 1991; Adzitey *et al*., 2014).

2.2.1. Sausages

The most popular and common ready-to-eat processed meat products across the globe are sausages. Sausage making came to being through continuous effort by man to preserve meat. Sausage is derived from a Latin word *salsus* which means salted (Ehr *et al*., 2016). It is the most enticing and extensively used processed meat product (Ehr *et al*., 2016). The desire by man to improve the sensory characteristics of the product led to the present form and types available on the markets. Sausage according to Essien (2003) are meat products made from ground or comminuted red meat, white meat or their combination with water, binders, spices and stuffed into casings and then cured, smoked or cooked. A sausage can also be defined as a ground or chopped meat mixed with salt, seasonings and other ingredients, stuffed into a container or casing of particular shape and size (UGA Extension Bulletin, 2014).

The availability of distinct styles of sausage is as a result of the availability of local materials, spices, casings and ethnic group through a series of development and refinement of sausage production and preparation methods (UGA Extension Bulletin, 2014). Most common sausages look cylindrical, measuring 10-15 cm long with semi-circular ends. A wide range of sausages can be created by varying the meat source and seasonings, ingredients and/or through the method of preparation (UGA Extension Bulletin, 2014).

A comprehensive review about developments in sausage production and practices by Badpa and Ahmad (2014) identified and categorized sausages into; Fermented sausage, Emulsion-type sausages, Cooked sausages, Smoked precooked and Fresh sausages.

2.2.1.1. Fresh sausages

These are made from fresh meats which are not cured, smoked, fermented or cooked and are coarsely comminuted. These sausages ought to be refrigerated preceding eating. They are uncooked and sold as that and it is the consumer who cooks them before eating (Badpa and Ahmad, 2014).

2.2.1.2. Fermented sausages

These are fermented, cured or uncured sausages usually smoked but not heat processed (Badpa and Ahmad, 2014). Fermentation is among the oldest methods of meat preservation and is employed in sausage production to prolong the shelf life of products. This is due to the production of lactic acid in the fermentation process (Essien, 2003). These sausages are sub-divided into semi-dry (Summer sausage or cervelat, Lebanon bologna) and dry sausages (Salami, Pepperoni and Genoa) (Essien, 2003).

2.2.1.3. Smoked precooked sausages

Smoked sausages are precooked, cured and unfermented products. The heat leads to extended shelf life because of the partial decrease of the moisture level and is normally cooked before consumption (Badpa and Ahmad, 2014). Smoke gives the sausages the distinctive smoke flavour which is attained through addition of synthetic (liquid) or natural smoke during processing (Essien, 2003).

2.2.1.4. Cooked sausages

These are ready-to-eat sausages, mainly made from earlier cooked fresh or specially cured raw materials and cooked before stuffing, with or without smoking. Examples of these sausages are cooked or baked specialties such as liver sausage, cheese and meat loaf (Badpa and Ahmad, 2014).

2.2.1.5. Emulsion-type sausages

Emulsion-type sausages consist of ready-to-serve products. They are finely comminuted and well mixed cured meats, water, fatty tissue and seasonings generally smoked and minimally cooked. These sausages are called "scalded" as they are only scalded (pasteurized) and partially cooked (Badpa and Ahmad, 2014). Bologna, frankfurters, bruhwurst, kochwrst, bruhwurst and liver sausage are examples of emulsion-type sausages and they are finer than fresh sausages (Essien, 2003).

2.2.2. Sausage composition

Sausage is an assemblage of appropriate ingredients in their right quantities under a structured design and a guided process (Badpa and Ahmad, 2014). The quality of products reflects the grade of raw materials used. Raw materials in sausage making include; lean meat, fat, ice cubes, nitrite, phosphate, sugar, ascorbates, salt and spices. Quality sausage is dependent on the quality of meat used and the process. The selection of meat is therefore paramount in achieving quality meat products. Meat is the baseline for all sausage formulas and all additional ingredients used in the production are based on weight not percentage of meat (Badpa and Ahmad, 2014). Ismed (2016) stated that meat should not constitute less than 75% of any sausage product. This is to ensure that meat products provide the essential nutrients (protein and minerals) that raw meat supplies to consumers. According to Essien (2003), a new European Union meat definition stipulates that fat should not exceed 25 % of all other mammalian products, 30 % of pork and 15 % for birds and rabbits. Connective tissues should also be restricted to 25 % for all other mammals and 10 % for birds and rabbits.

2.2.2.1. Role of spices in sausages

Spices are used for preservation and flavouring of meat products and are esoteric in nature (Srinivasan, 2005). Gadekar *et al.*, (2009) defined spices and condiments as products of plants that are usually used for seasoning and flavouring which enhances flavour of foods and beverages. Common spices in sausage making are; nutmeg, black, white and red pepers, sage, chilli peppers and adobo. These may be added in coarsely ground form, powdered or in whole seeds form. Spices and herbs have additional functional properties against inflammation, cancer and oxidation (Badpa and Ahmad, 2014) hence their addition to sausages. These functionalities make producers employ cheap and easy to use inorganic substances at levels that pose health risk to consumers. Consumers are therefore concerned about the health risk associated with these meat products as a result of the chemical or inorganic substances used in their processing. This concern is negatively affecting the meat processing industry as consumers worldwide now prefer organic food products. This has led researchers into exploring natural substances to address this concern. Teye *et al*. (2014), studied the potential of sweet basil (*Ocimum basilicum*) leaf extract as a Spice in Hamburger and concluded that the addition had no significant effect on sensory attributes of hamburgers. This study was informed by Abu (2012) who came to the conclusion that sweet basil leaf paste had increased protein content of meat products. Al-Jalay *et al*. (1987) reported that cloves have the strongest antioxidant ability followed by rose petals, cinnamon, nutmeg and other spices. Garlic juice reduced the peroxide value, microbiological count, TBARS (thiobarbituric acid reactive substance) value and the residual nitrite level of emulsion sausage for the period of cold storage at 1 % and 3 % (Park and Kim, 2009). This is as a result of the presence of allicin in garlic which has antimicrobial capacity against gram-positive and gram-negative bacteria (Badpa and Ahmad, 2014). Colour and freshness of pork sausages were also improved by the addition of rosemary extract (Sebranek *et al*., 2005). Black pepper (*Piper nigrum*) is reported to be the king of spices and has been one of the most essential and oldest spice in the world with the distinctive pungent aroma attributable to a blend of compounds (Srinivasan, 2007).

2.2.2.2. Role of salt in sausages

Xiong (2012) defined salt as any product that results from the substitution of some or all hydrogen atoms of an acid by a metal ion(s). Salts are therefore ionic compounds made of cations and anions. Salts are electrically neutral in aqueous solutions and are dissociable in the aqueous phase of meat products making them reactive with proteins and muscle constituents. Commonly used salt worldwide is Sodium Chloride (NaCl). Salts are technically present in all sausages and are included at an amount of 1% to 2% (w/w) of entire sausage batter mass (Ehr *et al*., 2016).

Salt is added to sausage for flavour enhancement and increase meat dehydration (lower amount of water available) thereby changing the osmotic pressure resulting in inhibition of bacterial growth. Salt in solution binds some amount of the water leading to a reduction in the level of water available for the microorganisms (Tim, 2002).This will subsequently prevent spoilage leading to preservation and extension of shelf-life (Xiong, 2012). Salt helps in the binding of products by extracting the needed meat myofibrilar proteins and also emulsifies fat (Meat Board, 1991). Salt addition to raw lean meat products increases their cooking yield and water-holding capacity (Tim, 2002).

Excess dietary sodium is currently reported to be associated to hypertension and increased cardiovascular diseases (Xiong, 2012; Gadekar *et al*., 2009), a major public health concern. Research has established that consuming more than 6 g NaCl/day/person is linked to blood pressure as age increases (Gadekar *et al*., 2009). It is therefore recommended that the full amount of dietary salt intake should not exceed 5 - 6 g/day (Ruusunen and Puolanne, 2005). This calls for the need to partly substitute NaCl with non-sodium salts in meat products. This concern led to Gordon and Barbut (1992) comparing four chloride salts; Potassium Chloride

(KCl), Lithium Chloride (LiCl), Magnesium Chloride ($MgCl_2$) and Calcium Chloride ($CaCl_2$) as possible partial replacers for NaCl in reduced-sodium meat emulsion products. The study revealed a similar protein extraction pattern between NaCl, KCl, and LiCl (1.5%) treatments. $CaCl_2$ and $MgCl_2$ were however less capable to stabilise fat and bind water.

2.2.2.3. Role of phosphates

Salts of phosphoric acid and sodium or potassium phosphates are the common types of phosphates in the meat industry (Long *et al*., 2011). Phosphates can be classified as monophoshates (containing one phosphorus atom $(PO_4)^3$, diphosphates (two phosphorus atoms $(P_2O_7)^{4-}$), tripolyphosphates (three phosphorus atoms $(P_3O_{10})^{5-}$) and polyphosphates (greater than three atoms of phosphorus $(P_nO_{3n+1})^{(n+2)-}$) (Hourant, 2004).

Phosphorus is present in DNA, enzymes, RNA and forms a matrix with calcium and magnesium in bones (Long *et al*., 2011). The Institute of Medicine's Standing Committee on the Scientific Evaluation of Dietary Reference Intakes (1997), recommended dietary intakes (RDIs) stipulates that depending on age and/or some peculiar problem, phosphorus intake among age groups should be; 0- 6 months needs 100 mg/day, 7 - 12 months requires 275 mg/day, 1-3 years needs 460 mg/day and 4-8 years needs 500 mg/day. Others are; 9- 18 years, 1,250 mg/day, adults more than 19 years, 700 mg/day, expectant mothers or breastfeeding women 14 to 18 years, 1,250 mg/day and women above18 years, 700 mg/day. The use of phosphates is strictly prohibited in fresh meat but could be added according to specification in meat products, meat preparations and minced meat (Regulation EC No 853/2004, 2004). A 5g/kg phosphorus peroxide (P_2O_5) alone or in a mixture is the maximum permissible limit of phosphates in minced meats and meat products by the European legislation (Directive No.95/2/EC, Rev. 2006).

Phosphates play essential roles on physical, chemical and sensory properties of meat and meat products. Combinations of monophosphates (monosodium phosphates, disodium phosphates and trisodium phosphates) are outstanding buffers; except diphosphates chain (Lampila and Godber, 2002). Buffering characteristics helps meat maintain and secure its fresh colour by altering the pH of meat post slaughter (Lampila and Godber, 2002).

Long *et al*., (2011) in a review, revealed that, phosphates are to some extent bacteriostatic as it reduces the growth rate of some gram-positive types of bacteria. Phosphates cannot solely be used as direct preservatives. They only exhibit this bateriostatic property when used with acidulants or in amalgamation with food ingredients like nisin, sodium chloride, nitrites and erythorbate. Phosphates can restrain gram-positive bacteria like *Leuconostoc carnosum, Listeria* monocytogenes, *Staphylococcus aureus, Bacillus spp*. and *Corynebacterium glutamicum*. They however have minimal effect on gram-negative bacteria like *Salmonella Typhimurium*, *Salmonella Enteritidis* and *Escherichia coli* (Buòková *et al*., 2008).

Phosphate flavour is considered as unpleasant. A phosphate concentration of 0.3 to 0.5% could result in unacceptable bitter taste of products (Ranken, 2000) as phosphate flavour is typically unpleasant (Long *et al*., 2011). Sensory properties must therefore be considered in choosing a suitable phosphate mixture.

2.2.2.4. Role of nitrates/nitrites in sausages

The attractive red or pinkish colour of cooked meats is as a result of nitrate (NO^{-}_3) and nitrite (NO^{-}_2) addition in the meat-curing practice (Xiong, 2012). Nitrites have in recent times replaced nitrates in meat cures because the latter has to be reduced by reducing compounds or organisms to nitrite before curing reactions proceed but nitrites proceeds directly. Nitrate use is now limited to few products like dry sausages and country-cured hams (Xiong, 2012). Sodium nitrite is now the most commonly used curing agent in meat products (Gadekar *et al*., 2009).

Nitrite addition to meat and meat products is highly restricted to a maximum limit of 200 ppm/kg of product (Gadekar *et al*., 2009). The restriction is because of the formation of carcinogenic nitrosamines by nitrites in cooked-meat or intestines of humans by reacting with secondary amines. Nitrosamines are known to be carcinogenic and their formation is highly facilitated by high temperatures (Xiong, 2012). As a result, less nitrites is recommended for products that are cooked at high temperatures (≤ 120 ppm/kg nitrite in bacon) than products that are cooked at relatively low temperatures like ham (≤ 200 ppm/kg) (Xiong, 2012). Cancer should therefore not be a major concern to the average meat consumers as the quantity of nitrite eaten is relatively low. According to Mills (2004), the deadly oral intake for humans is 22–23 mg nitrite/kg body weight. This dispels the erroneous impressing that people have concerning processed meat products.

Nitrite is a multifunctional ingredient in meat processing. The pinkish colour of cured meat products is as a result of the binding of nitric oxide (NO), transformed from NO^{-}_2 by reduction to a heme iron (Fe^{+}_2) to form nitrosylmyoglobin which appears pinkish red (Xiong, 2012). This reaction sequences in the colour formation possibly play an important function in the strong anti-oxidant property in cured meat by nitrite. This is because the mechanisms for the antioxidant property comprise reactions of nitrite with heme proteins, metals and nitroso- and nitrosyl-compounds which are antioxidants (Pegg and Shahidi, 2000). Nitrites posses strong inhibitory properties against anaerobic bacteria most especially *Clostridium botulinum* and controls other micro organisms like *Listeria monocytogenes* (Sebranek and Bacus, 2007). The distinguishing cured meat flavour is a product of nitrite addition (Xiong, 2012; Gadekar, 2009). Nitrite is the only known compound that can simultaneously perform all these functions in cured meats (Xiong, 2012).

2.2.2.5. Ice/water

Product temperature could increase quite quickly during chopping and ice or ice water addition avoids this (Essien, 2003). Ice and ice water is therefore added to keep the sausage cold and to hydrate the product. Cold temperature delays the growth of microbes and enhances a better texture of the final product (Ehr *et al*., 2016). According to Pearson and Gillet (1996), water helps in dissolving salt which facilitates its uniform distribution in the meat. Improvement of sausage texture and tenderness are noticeably affected by added water (Pearson and Gillet, 1996). Water in the recipes solubilises proteins during comminution (Essien, 2003). Ice and water are also added to increase yield of sausages (Pearson and Gillet, 1996) and easy stuffing, mixing and processing but should not exceed 3 % (UGA Extension Bulletin, 2014). Unmelted ice as a result of excessive addition of ice could remain after chopping and could be detrimental to quality resulting in fatty tissue damage causing elevated fat losses, uneven fat distribution and poor emulsion binding properties (Essien, 2003).

2.2.3. Sausage casing

Casings in general provide sausages shape, extend product shelf life through moisture conservation and oxygen resistance and minimisation of product weight loss throughout cooking (Essien, 2003). Casings are basically used in sausage production to achieve their main importance of portioning (Essien, 2003). There are two main types of casings: natural and artificial or synthetic casings.

Natural casings are made from the gastro-intestinal tract of hogs and beef cattle (Essien, 2003). Ehr *et al.* (2016) classified hog casings into; bladders, bungs, smalls, middles and stomachs. Bungs and middles are normally used for stuffing liver sausages. Middles are exclusively used for making dry sausage. Fresh sausages, chorizos, frankfurters, bockwurst and polish sausages are stuffed using smalls (small intestine). Head cheese is normally stuffed into stomachs. Bladders are used to stuff minced luncheon meats. Small hog casings are doubtlessly the most commonly used and easier to find. Almost the whole beef alimentary canal can be used to prepare casings like beef rounds which are used for stuffing holsteiner, mettwurst and ring bologna (Ehr *et al*., 2016). Pork breakfast sausage and frankfurter are stuffed with sheep intestines (Ehr *et al*., 2016). Sewed-casings are frequently used by commercial sausage makers. Sewed casings are made by stitching two natural casings that are slit, matched up, and stitched together (Ehr *et al*., 2016). This practice increases their consistency and vigor.

Natural casings are mainly made of collagen which has the distinctive trait of variable permeability (Ehr *et al*., 2016). Natural casings tend to soften by moisture and heat making them more permeable. This permits smoke infiltration and does not add to any undesirable flavours (Ehr *et al*., 2016). Natural casings have a characteristic "curve shape" after stuffing and cooking (Essien, 2003). Natural casings could be stored for long if salted or kept in 80-100 % brine and refrigerated below 4.5°C (Essien, 2003).

Artificial casings are are manufactured from plastics, cellulose and collagen and do not need refrigeration (Essien, 2003). These casings are patronised by commercial producers and come in different colours. For instance some producers use red casings for bologna, transparent casings for salami and white for stuffing liverwurst (Ehr *et al*., 2016). Artificial casings are uniform in diameter, have high tensile strength, longer storage and cost effective in commercial manufacturing (Ehr *et al*., 2016).

2.3. Physical properties of sausages

2.3.1. pH

It is the negative logarithm of hydrogen ion concentration of a product which is measured on logarithmic scale (0-14). It tells how acidic or alkaline a product is. The survival of microorganisms is highly influenced by pH of the medium. Generally bacteria, yeast and filamentous fungi multiply at a faster rate at 6.0-8.0, 4.5-6.5 and 3.5-6.8 respectively. Lactobacilli and acetic acids however have optimal pH of 5.0 and 6.0 respectively with meat recording 5.6 – 6.2 (Dilbaghi and Sharma, 2007). According to FAO (2007), pH contributes to the longevity of meat and meat products thus lower values are not favourable to pathogenic bacterial growth. pH plays an essential function during emulsification of patties and is closely associated with the physicochemical and functional properties of emulsions (Zoba and Kurt, 2006). The characteristic flavour and taste of meat is achieved when pH drops to 5.8 – 5.6 (FAO. 2007). Meats with higher pH have high water binding abilities than those with low pH (FAO, 2007). Water binding ability has an impact on the meat physical structure as well as its light reflecting characteristics (Ismed, 2016).

2.3.2. Peroxide value (PV)

Oxidation is a hygrogenation process that involves the carbon atom adjacent the double bond in oils and fats. Oxidation is a non-microbiological process that occurs during storage of raw materials, processing, thermal treatment and through to storage of finished products resulting in quality decline of meat and meat products even at refrigerated storage (Sayed *et al*., 2014). Oxidation ultimately produces rancidity in oil which produces off flavours (Miller, 2010). Oxidation induces modifications of muscle lipids and proteins which affects the sensory and nutritional qualities of meat and meat products resulting in financial losses and health problems (Isani *et al*., 2008; Karpiriska *et al*., 2001).

Lipid oxidation causes the formation of prooxidants capable of reacting with oxymyoglobin to form metmyoglobin causing colour change in meat and meat products (Frankel, 1998). Grinding exposes lipid membranes in minced meat and meat products to metal oxidation catalysts which speed up the rate of oxidation (Devatkal *et al*., 2010). The process involves a series of complex reactions that breakdown products into stages, starting with primary oxidation products (peroxides, dienes, free fatty acids), then secondary products (carbonyls, aldehydes, trienes) and finally tertiary products (Devatkal *et al*., 2010).

The PV test is an excellent way to measure the amount of primary oxidation products in fresh food products. Products may have significantly high peroxide values but odourless if secondary oxidation has not set in (Miller, 2010). Products will be rancid even with low PVs if oxidation is advanced as a result of decomposition of primary oxidation products (Miller, 2010). PV is therefore not a perfect measure of oil quality.

Light, oxygen availability, temperature, moisture and presence of metal catalyst like copper and iron as well as the amount of polyunsaturated fatty acid present in products determine the rate of oxidation progress (Miller, 2010).

Sausages by their nature of production are prone to oxidation even under refrigerated conditions. These tendencies according to Eastman (2010) are as a result of:

- Grinding which increases meat surface area and contact to oxygen.
- Association between lipids and heme pigments in meat calatalyses their oxidation.
- Under freezer conditions, oxidation is catalysed by high levels of salt in the sausages.

The most important measures for preventing rancidity are the utilization of antioxidants and restriction of contact with oxygen throughout storage by vacuum-packaging (Tang *et al*., 2001). These additives are put into unprocessed and processed meats to avert oxidative rancidity, advance the stability of colour and slow down the advancement of off-flavours (Nam and Ahn, 2003).

2.4. Extenders in meat processing

Meat extenders are non-meat ingredients with significant protein content used in the meat industry with the prime intention of creating meat products at low cost (FAO, 2007). Non-meat ingredients are incorporated into meat products to enhance the value and decrease the cost of products (Badpa and Ahmad, 2014). These ingredients come from a wide range of sources like eggs, dairy, plants, microbial and probiotics (Xiong, 2012; Yadav *et al*., 2013). From a health perspective, excessive eating of meat products is not recommended to particular population groups due to their large fat content (Muguerza *et al*., 2004; Cengiz and Gokoglu 2005). The fat of meat has cholesterol and a greater amount of saturated fatty acids than polyunsaturated fatty acids (PUFAs) (Muguerza *et al*., 2004). High ratios of n-3 PUFAs exercise suppressive properties on the pathogenesis of several diseases like cardiovascular disease (CVD), inflammatory, cancer and autoimmune diseases (Simopoulos, 2002).

Among the n-3 PUFAs, α linolenic acid (ALNA, C18:3) can be found in large amounts in plant products (Jimenez-Colmenero 2007) but little in animal products (Badpa and Ahmad, 2014) hence the need for extension of meat products with plant materials.

Highly extended meat products were traditionally less demanded because their sensory properties could not completely be comparable to full-meat products (FAO, 2007). This is because the general characteristics of meat and meat products such as mouth feel, appearance and texture are reliant on protein functionality and these properties cannot be generated by any other food protein (Xiong, 2004). Advancements have however been made in recent times to improve the sensory attributes of extended meat products through the use of improved balanced spice combinations or other appropriate additives of vegetative source like flavouring herbs (leeks, parsley, rosemary, oregano) or bulbs (onion and garlic), roots and tubers (ginger, raddish) (FAO, 2007). This will make the low-cost market more competitive and may lead to further development of extenders. Some non – meat additives have the prospects of increasing the roughage content (dietary fibre enrichment) of extended meat products through the use of wheat, cotton seed, bamboo, chicory and red beet (FAO, 2007).

Besides the nutritive value and sensory satisfactoriness of meat products, economics is a very vital criterion that decides the marketability of any product (Malav *et al*., 2013). The production of more competitive, inexpensive and popular meat products is achieved by cautious selection and reformulation of ingredients from plant sources (Huang *et al*., 2005). Meat extenders can be obtained in the form of flakes (>2 mm), minced (>2 mm) and chunks (15-20 mm) capable of absorbing 2.5 to 5 times water relative to their initial weight (Riaz, 2004). These nonmeat proteins are frequently utilised as substitute to gelling substances in processed meat products to improve the feel and yield of products by enhancing water-binding properties (Pietrasik *et al*., 2007). Extended products will be dry if hydration is done with too little water (Asgar *et al*., 2010).

A review by Badpa and Ahmad (2014) on "developments in sausage production and practices" concluded that non-meat ingredients can reduce cost, improved value attributes and consumer satisfaction of meat products.

2.4.1. Proximate properties of extended meat products

Proximate composition is vital in determining the value of raw materials and it is frequently used as the foundation for establishing the nutritional quality and in general, acceptance of a product by consumers (Moses *et al*., 2012).

Meat is a major source of high biological value proteins, mineral and some essential vitamins. The quest to reduce cost and improve functional properties of meat products should not undermine the nutritional status of meat products but maintained if unable to increase the nutrient content.

There was significant ($p < 0.01$) increase in protein content from 17.89 % to 23.67 % of 10 % cowpea extended burgers and significant ($p < 0.01$) fat reduction from 6.73 % to 1.67 % in the 10 % extended cowpea burgers (Teye *et al*., 2012). A study by Ergezer *et al*. (2014) revealed a significant reduction of fat and non – significant protein content of low fat meat balls incorporated with potato puree and bread crumbs. Amir *et al*., (2015) reported a fat content of 11.46 % and 11.6 % in chickpea and lentil flour respectively and high protein contents of chickpea extended Momtaze hamburgers. Hegazy (2011) found that substituting fenugreek at 3%, 6%, 9%, and 12% in place of soy flour in beef hamburgers considerably increased the fat values of the samples, compared with the control. The protein values of the controls were significantly lesser than that of other burgers owing to the high protein value of legume flour (Amir *et al*., 2015). Ranathunga *et al*. (2015) studied the effects of wheat flour, mung bean flour, cowpea flour, rice flour and maize flour as extenders on physical, chemical and sensory characteristics of sausages. The results showed a significant difference ($p < 0.05$) in all proximate characteristics with cowpea recording the highest (13.0) and maize flour the lowest (11.0) in protein content. Fat was high (37.2) in mung bean flour and lowest (33.0) in maize flour. Kassem and Emara (2010) concluded that carrots and peas can partly replace fat and meat in the formulation of beef burger patties to reverse the negative consumer perception about fast foods.

2.4.2. Physicochemical properties of extended sausages

Physicochemical properties play an essential function in the physical behaviour of food and ingredients during processing and storage hence its evaluation (Enwere and Ngoddy, 1986).

According to Ergezer *et al*. (2014), addition of potato puree and bread crumbs improved the cooking properties and inhibited lipid peroxidation of meatballs. Increasing cowpea content in hamburgers decreased cooking loss and lipid peroxidation values of products (Teye *et al*., 2012). Cowpea flour can therefore be used to improve yields of hamburgers with increase shelf life (Teye *et al*., 2012). Ranathunga *et al*. (2015) recorded a cooking yield of 91.2, 88.0, 88.8, 88.4 and 87.8 % in wheat, mung bean, cowpea flours, rice and maize flours respectively in extended sausages.

2.4.3. Sensory properties of extended sausages

Sensory evaluation is a scientific discipline that measures and analyses human responses to the composition of food and drinks by appearance, taste, touch, texture, odour and temperature. In schools, this provides a perfect chance for students to appraise and give feedback on their dishes, test products and experimental designs (Lawless and Heyumann, 2010). Sensory evaluation is used to: compare similarities or differences in a variety of dishes or products, appraise a range of on hand dishes or food samples, analyse food samples for modification, explore precise characteristics of an ingredient, dish or food product, verify whether a finished dish or food product meets its original specification and to provide an objective and subjective feedback data to facilitate informed decisions to be made (Lawless and Heyumann, 2010). Sensory results of maize was significantly higher ($p < 0.05$) than other extenders (wheat, mung bean, rice and cowpea flours) in an experiment to determine the effects of these flours on physical, chemical and sensory characteristics of sausages (Ranathunga *et al*., 2015).

Teye *et al*. (2012) reported that the addition of cowpea has no unpleasant sensory qualities of beef and ham burgers. Chickpea and lentil flours at 4 % in hamburgers were similar in sensory characteristics as controls and could therefore be used in extending hamburgers (Amir *et al*., 2015). Potato purees and bread crumbs were similar in sensory scores except texture in meatballs. Potato purees meatballs were softer in texture than breadcrumb products (Ergezer *et al*., 2014).

2.5 . Formulation cost of "niri" extended beef products

Modernity has drifted consumers' satisfaction for traditional meat products (Malav *et al*., 2013) to more nourishing and set-to-eat products. This is as a result of life style changes and swift urbanization (Deogadi *et al*., 2008). High cost therefore limits the average income earner, regular usage of these products in their diets (Malav *et al*., 2013) due to expensive nature of lean meat (Teye *et al*., 2012). The main reason for the high cost of animal proteins is possibly due to the over 65% feed cost in the entire production cost (Olomu, 2011).

The use of extenders and fillers in processing meat products could lead to about 10 to 30 percent reduction in the cost of meat products (Heinz and Hautzinger, 2007). This will make processed meat products reasonably priced and afford consumers the ability to regularly purchase them (Decker & Park, 2010) through the use of plant proteins (Odiase *et* al., 2013).

2.6. "Niri"

2.6.1 Botany of "niri"

"Niri" (*Citrullus vulgaris*) belongs to the *Cucurbitaceae* or cucurbit family. They are generally referred to as the melon, gourd, pumpkin or cucumber (Penuel *et al*., 2013). *Citrullus vulgaris* is grown extensively in the tropics and in temperate regions where heat is a requirement (Achinewhu, 1984). Sawaya (1986) stated that the farming of "niri" is less cumbersome.

It is a trailing herbaceous and yearly vine with a woody rootstock (Ajuru and Okoli, 2013) with a plant population density of 20,000-40,000 plants per hectare (Achinewhu, 1984) and has a succulent and greenish colour stem.

2.6.2. Nutritional properties of "niri"

Several researches carried on many varieties of *C. vulgaris* seeds, suggest high protein value making the seed a good source of protein (Penuel *et al*., 2013). Work done by Penuel *et al*., (2013) reported 5.05, 49.00, 36.58, 4.83, 4.00 and 0.59 % of moisture, fat, crude protein, ash, crude fibre and carbohydrates respectively in raw undefatted "guna" ("niri") seeds in Nigeria. These results were similar to previous research report of a protein content of 32 %, 49.59 %, moisture 2.75 %, ash 3.53 % and a carbohydrate content of 9.17 % by Ogundele *et al*., (2012). Akinyele and Oloruntoba (2013) also reported a proximate composition of 37.76, 26.85, 4.44 and 3.38 % for crude protein, fat, moisture and ash contents respectively of unfermented *C. vulgaris*.

Mineral results of raw undefatted *C. vulgaris* as reported by Penuel *et al*. (2012) were 81.00 mg/100 g for magnesium, 136.00 mg/100 g for iron, 33.00 mg/100 g for calcium and 207 mg/100 g for sodium. These results indicate that *C. vulgaris* is comparable to other plant food sources.

2.6.3. Utilization of "niri"

The seeds are usually shelled, ground and used to thicken soup and stews. In Akwa Ibom State of Nigeria, the seeds are ground and mixed with pepper (*Capsicum annum*), salted, baked and eaten. These cakes and soups are usually delicacies during traditional marriages and festivals (Ajuru and Okoli, 2013).

CHAPTER THREE

3.0. MATERIALS AND METHODS

3.1. Study Site

Test materials and sausage samples were prepared at UDS Meats Unit while pH determinations of test samples were carried out at the Spanish Laboratory of the University for Development Studies. Proximate and mineral analyses were respectively carried out at the Food Analysis Laboratory – Food Science and Technology Department and the Central Laboratory of Kwame Nkrumah University of Science and Technology, Kumasi.

3.2. Experimental design

Completely randomized design was used to assign treatments (raw puree, roasted puree, raw chaff and roasted chaff) to minced meat. The research composed of three different experiments. The first aspect involved the determination of nutritional composition of "niri" (the test material), the second was a comparison between raw and roasted "niri" puree products and the third was a comparison between raw and roasted "niri" chaff products. Experiments two and three were each evaluated against a control (without "niri"). Each treatment was incorporated with "niri" at 0, 5, 15 and 25 % per kilogram of beef. Raw and roasted products were to determine if there are differences in flavour and whether processing affects the nutritional and eating qualities of the products. The chaffs (by-product) were used to determine if their use as dietary fibre will affect nutritional and eating qualities of beef sausages.

3.3. "Niri" purees preparation

3.3.1. Raw puree preparation

Four bowls of "niri" weighing approximately 6.8 kg were bought from the Aboabu market in Tamale Metropolis. Seeds were totally immersed in a bucket of clean water, washed and allowed to stand for ten minutes. All floating materials and seeds were removed off and the remainder rewashed and sun dried. The sun dried material was then winnowed and further hand sorted to remove all foreign materials.

The pure seeds were then milled using simple corn mill. The milled material was mashed with tap water. A kilogram of the milled material was first mashed in 1.5 litres of clean water and sieved using a cheese cloth and the filtrate collected in a bucket. The chaff was mashed for the second and third time with 0.75 litres each of clean water.

Filtrate was collected into transparent containers with lids and kept in a chiller for 24 hours to settle. The settled filtrate was then decanted and drained off to obtain puree. The puree was then kept in a freezer at – 18°C awaiting samples preparation.

3.3.2. Roasted puree preparation

Seven kilograms of "niri" seeds were bought, washed, winnowed and hand sorted. A kilogram each was evenly spread on a 50×35 cm^2 steel tray and placed into an electric oven (Turbofan Blue seal, UK). Seeds were roasted at a temperature of 220°C for 30 minutes. They were intermittently stirred at 10 minutes interval within the roasting period. Roasted seeds were evenly spread on a clean kitchen floor for 3 hours to cool. They were then collected for milling using simple corn mill.

Each kilogram of milled seeds was first mashed manually with hands in 1.5 litres of pipe borne water and sieved using a cheese cloth and the filtrate collected into a bucket. The chaff was mashed with the hands for the second and third times with 0.75 litres each of pipe borne water.

Filtrate was collected into transparent containers with lids and kept in a chiller for 24 hours to settle. The settled filtrate was then decanted and drained off to obtain puree. The puree was then stored in a freezer at – 18°C for samples preparation.

3.4. "Niri" chaffs preparation

Raw and roasted chaffs were collected separately onto 50×35 cm^2 trays and oven dried at 60°C for 8 hours in an electric oven (Turbofan Blue seal, UK), cooled for 6 hours at 26°C and blended using kitchen blender (Philips) for 8 minutes. Samples were then collected, cooled, sealed and stored in a freezer for samples preparation.

3.5. Sausage formulation

Raw and roasted purees, raw and roasted chaffs and minced beef were formulated on per kilogram basis. Purees and chaffs replaced minced beef at 0, 5, 15 and 25 % per kilogram. Spices and ice cubes were added equally to each treatment. Spices were weighed using a digital scale (Tanita, 900 C). The formulations are shown in Tables 3.1 and 3.2.

Table 3. 1: Sausage formulation with purees on kg basis

Ingredient	0 % Niri	5 % RaP	15 % RaP	25 % RaP	5 % RoP	15% RoP	25 % RoP
Beef	1	0.950	0.850	0.750	0.950	0.850	0.750
Raw puree	0	0.050	0.150	0.250	0	0	0
Roasted puree	0	0	0	0	0.050	0.150	0.250
Ice cubes	0.070	0.070	0.070	0.070	0.070	0.070	0.070
Curing salt	0.015	0.015	0.015	0.015	0.015	0.015	0.015
Adobo	0.002	0.002	0.002	0.002	0.002	0.002	0.002
White Pepper	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Black Pepper	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Chilli Pepper	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Phosphate	0.005	0.005	0.005	0.005	0.005	0.005	0.005

RaP = Raw puree **RoP = Roasted Puree**

Table 3. 2: Sausage formulation with chaff on kg basis

Ingredient	0 % Niri	5 % RaC	15 % RaC	25% RaC	5 % RoC	15% RoC	25% RoC
Beef	1	0.950	0.850	0.750	0.950	0.850	0.750
Raw chaff	0	0.050	0.150	0.250	0	0	0
Roasted chaff	0	0	0	0	0.050	0.150	0.250
Ice cubes	0.070	0.070	0.070	0.070	0.070	0.070	0.070
Curing salt	0.015	0.015	0.015	0.015	0.015	0.015	0.015
Adobo	0.002	0.002	0.002	0.002	0.002	0.002	0.002
White Pepper	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Black Pepper	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Chilli Pepper	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Phosphate	0.005	0.005	0.005	0.005	0.005	0.005	0.005

RaC = Roasted Chaff RoC = Roasted Chaff

3.6. Sausage preparation

Twenty – six kilograms (26 kg) of boneless beef was purchased from UDS Meats Unit. The meat was trimmed of all visible fat and connective tissues and minced through a 3 mm sieve plate using an electric mincer (Talleres Ramon,Spain). The minced beef was weighed according to each treatment formular using digital scale (Javendar).

The minced beef and spices were thoroughly comminuted using 3 – knife, 30 – litre capacity bowl chopper (Talleres Ramon, Spain). Seventy (70) grams of ice cube was crushed and added to the minced meat to maintain comminution temperature at 16°C. Comminution was done till the desired consistency was attained.

The comminuted paste was transferred into a hydraulic stuffer (Talleres Ramon, Spain) and manually linked to about 10 cm long.

Sausages were then smoked for two hours, scalded to a core temperature of 70°C and cooled for 30 minutes in chilled water.

Products were then bagged into transparent polythene bags and vacuum sealed using an electronic vacuum sealer (Busch, Ramon Spain), labeled and refrigerated in a freezer prior to sensory and laboratory analysis.

3.7. Sensory analysis

Samples were removed from the freezer, and were allowed to thaw for 4 hours at 26°C. Thawed samples were warmed at a temperature of 70°C for fifteen minutes, sliced to about 2 cm^3 and wrapped with aluminium foil to keep them warm and packed into transparent containers with lids prior to analysis.

Sliced bread and sachet water were provided to taste panelist after each treatment to serve as neutralisers before the next treatment was administered.

Twenty students were randomly selected and screened to fifteen. The qualified students were then trained according to the British Standard Institution (BSI, 1993) guidelines to constitute the taste panel. Panelists independently evaluated each treatment in a well lit room using a five-point hedonic scale as shown in Table 3.3.

Table 3. 3: Sensory Analysis Outline

Parameter	Scale				
	1	**2**	**3**	**4**	**5**
Colour	Very dark	Dark	Intermediate	Pale	Very pale
Aroma	Very offensive	Offensive	Intermediate	Pleasant	Very pleasant
Flavour intensity	Very weak	Weak	Intermediate	Strong	Very strong
Flavour liking	Dislike very much	Dislike	Intermediate	Like	Like very much
Texture	Very course	Course	Intermediate	Smooth	Very smooth
Tenderness	Very tough	Tough	Intermediate	Tender	Very tender
Juiciness	Very dry	Dry	Intermediate	Juicy	Very juicy
Taste	Very bitter	Bitter	Intermediate	Sweet	Very sweet
Overall liking	Dislike very much	Dislike	Intermediate	Like	Liked very much

3.8.0. Proximate analysis

Samples from each experiment in both experiments were taken for proximate analysis. Analyses were carried out in triplicates and all reagents used were of analytical grade and conducted according to Association of Analytical Chemist (AOAC, 2005) procedures.

3.8.1. Determination of moisture content

Five (5) grams of sample was added to dried and weighed petri dish. The petri dish with sample was placed into a thermostatically controlled oven at 105°C for 5 hours. The dish was removed, placed in a desiccator, cooled to 26°C and weighed. The determination was in triplicates and averages found.

Calculations:

Moisture content (weight/weight) = (weight of petri dish+wet sample) - (weight of petri dish+dried sample)

% moisture (wet/wet) = weight of H_2O in sample/weight of sample ×100 %.

3.8.2. Ash content

Five (5) grams of sample was weighed into a pre-dried crucible. Crucibles were placed into a cool muffle furnace. The furnace was ignited for 2 hours at about 600°C. The muffle furnace was turned off and waited until the temperature dropped to at least 250°C or lower. Safety tongs were used to quickly transfer crucibles to a desiccator with a porcelain plate and desiccant. The desiccator was closed and crucibles allowed to cool prior to weighing.

Calculations:

Weight of Ash = (weight of crucible+ ash) – weight of empty crucible

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

3.8.3. Fat content by soxhlet extraction methods

About 5.0 g of sample was weighed onto a folded filter paper. A small piece of cotton wool was placed into the thimble to prevent loss of the sample. One hundred and fifty (150) ml of petroleum ether B.P was added to the round bottom flask on the assembled apparatus. The condenser was connected to the soxhlet extractor and reflux for 6 hours at 40 - 60° C on the heating mantle. After extraction, the thimble was removed and solvent recovered by distillation. The flask and fat/oil was heated in an oven at 103°C to evaporate the solvent. The flask and contents was cooled to 26°C in a dessicator. The flask was weighed to determine the weight of fat/oil collected.

Weight of fat (wet basis) = (weight of flask + oil) – weight of flask

% fat (wet basis) = (wt of flask + oil) – wt. of flask / weight of sample × 100 %

3.8.4. Protein determination

An amount of 2 g of sample, half of selenium – based catalyst tablets and a few anti-bumping agents were put into the digestion flask. 25 ml of concentrated H_2SO_4 was added and the flask well shook so that the entire sample was thoroughly wet. The flask was placed on a digestion burner and heated slowly until boiling ceased and the resulting solution was clear. Contents were cooled to room temperature and the digested sample solution transferred into a 100 ml volumetric flask and made up to the mark with distilled water.

Distilled water was boiled in a steam generator of the distillation apparatus with the connections arranged to circulate through the condenser for at least 10 minutes to flush the apparatus before use. Whenever the tip of the condenser was beneath the surface of the distillate, the receiving flask was lowered and heating continued for 30 seconds in order to carry away all liquid in the condenser. Twenty-five (25) ml of 2% boric acid was pipetted into a 250 ml conical flask and 2 drops of mixed indicator added. The conical flask and its contents were placed under the condenser in such a position that the tip of the condenser was completely immersed in the solution. 10 ml of the digested sample solution was measured into the decomposition flask of the Kjedahl unit, fixed and excess of 40% NaOH (about 15-20 ml) was added to it. The ammonia that was produced was distilled into the collection flask with the condenser tip immersed in the receiving flask till a volume of about 150 – 200 ml was collected. The apparatus was flushed after distilling each sample and after all distillations were completed. Steam was passed only after 5 ml of distillate was obtained.

The distillate was titrated with 0.1N HCL solution. The acid was added until the solution was colourless. The nitrogen content was determined in triplicates and a blank determination ran using the same amount of all reagents used for the samples. The blank corrected for all traces of nitrogen in the reagents and was included in the digestion as well as the distillation.

Calculations:

% total nitrogen = $(Va-Vb) \times NA \times 0.01401 / (W \times 10) \times 100$ %

Where;

Va- volume in ml of standard acid used in titration

Vb- volume in ml of standard acid used as blank

NA- normality of acid

W- Weight of sample taken

3.8.5. Carbohydrate determination

This was calculated by difference from the sum of all the crude percentages from 100 %.

Therefore, Carbohydrate (%) =100 % - (% moisture +% fat +% protein +% ash).

3.9.0. Mineral analysis

3.9.1. Procedure for digestion of samples

3.9.1.1. Preparation of reagents

The following chemicals were used in the preparation of the reagents; Concentrated Nitric acid, Perchloric acid and Sulphuric acid, all of Analar grade. Other chemicals were $KMnO_4$ and double distilled water.

HNO_3 –$HClO_4$ acid mixture was prepared by mixing equal volumes (50 ml of conc. HNO_3 to 50 ml of $HClO_4$) of concentrated nitric and perchloric acids together. 10% Nitric acid bath was prepared on volume by volume basis by adding 100 ml of concentrated Nitric acid to 900 ml of double distilled water and was thoroughly mixed. 0.5% $KMnO_4$ solution was prepared by measuring 5g of potassium permanganate into 1L of distilled water on weight by volume basis.

3.9.1.2. Washing of glasswares

Glasswares like digestion tubes and small PET bottles for storing the digest were soaked into detergent solution overnight and washed. The washed glasswares were rinsed with running water and soaked in 10 % nitric acid bath for 24 hours, removed and washed under running water. A 0.5% $KMnO_4$ was then used to rinse them. The $KMnO_4$ was then washed off using double distilled water till all permanganates were washed off. The glasswares were then dried in an oven.

3.9.2. Digestion procedure

A 1 gram each of homogenized sausage samples were precisely weighed into well labeled digestion tubes. 1.0 ml of double distilled water was added and swirled to mix up contents well. About 4.0 ml of HNO_3 – $HClO_4$ (1:1) mixture was added, followed by 5.0 ml of concentrated H_2SO_4 acid and the mixture was swirled to ensure uniform mixing and then heated gradually to a temperature of 200° C (±5°C) until the solution became clear. The solution was allowed to cool to room temperature, topped up to the 50 ml mark using double distilled water and transferred into the washed small PET bottle for analysis. In cases where the solution contains some undisolved particles, Whatman No. 42 filter paper was used to filter them.

A blank reagent was prepared by following all steps without meat sample.

3.9.3. Mineral content determination using atomic absorption spectrophotometer (AAS)

Minerals were ran using the ASPECT LS software for the AAS machine. The instrument was initialised for it to undergo a series of diagnostic tests to set the instrument right for use. The extractor was switched on before samples were run. A method/ sequence was developed by first imputing samples IDs into the machine. The specific metal lamp was chosen and loaded. Sequence of running the samples were imputed and the machine calibrated with right standards. Samples were run after calibration with standards and data saved.

3.10. pH determination

Ten grams (10 g) of sausage was weighed using Satorius digital scale (CP 224S). The weighed samples were ground using laboratory mortar and pestle and homogenised with 10 ml of deionised water and allowed for 30 minutes before taking readings. Readings were taken in triplicates per sample using pH meter (CpH METER BASIC 20).

The meter was calibrated using Crison buffer solutions; soluzione tampone of pH 7 and 4.01 at 25°C at 92 % sensitivity.

3.11. Peroxide value determination

Five (5) (±0.05) grams of sample was weighed into a 250 ml glass stoppered Erlenmeyer flask. The weight was recorded to the nearest 0.01 g. 30 ml of acetic acid – chloroform solution (480 ml Acetic acid and 320 ml Chloroform) was added to the sample in the flask. The flask was carefully swirled until the sample was completely dissolved on a hot plate. 0.5 ml of saturated Potassium was added using a 10 ml pipette. The flask was stoppered and contents of the flask swirled for exactly one minute. An amount of 30 ml of distilled water was immediately added using a graduated cylinder, stoppered and shook vigorously to liberate the iodine from the chloroform layer. The burette was filled with 0.01 N Sodium thiosulphate. When the colour of the solution was deep red orange, it was titrated slowly with mixing till the colour lightens. A solution with an initial light amber colour was mixed with 1 ml starch solution as an indicator. It was then titrated until the blue gray colour disappeared in the aqueous (upper) layer. The volume was recorded to two decimal places as the sample titre value.

Calculations:

V_S = Sample (s) titre value, V_B = Blank titre value

Peroxide value = $(V_S - V_B) \times 1000$ / Weight of Sample

3.12. Formulation cost of "niri" extended beef sausages

The cost of a kilogram of minced beef and raw "niri" seeds as well as the cost of processing each kilogram of "niri" seeds were determined. The cost of each percentage inclusion level (0, 5, 15 and 25 %) was determined as a proportion of the respective kilogram cost. There was no cost for a kilogram of "niri" chaff except processing cost. This is because the chaffs are waste which would have hitherto been thrown away. The cost of spices, curing salt and ice cubes for processing a kilogram of beef sausage was added equally across treatments. Transportation cost was shared equally to all treatments except the control. This is because, minced beef was bought and processed at the same place.

3.13. Statistical analysis

Data collected were analysed by two- way analysis of variance (ANOVA) using GenStat Discovery Edition 4. Where there were differences, means were separated using Tukey test at 5 %.

CHAPTER FOUR

4.0. RESULTS

4.1. Proximate and mineral compositions of whole and processed "Niri" seed

Table 4.1 shows the proximate results of "niri" seeds and processed materials. The results indicate that the whole seed had significantly ($p < 0.05$) higher amount of ash, fat and protein than the processed "Niri" (raw/roasted puree and raw/roasted chaff) but lower in carbohydrate and moisture. The chaffs have high carbohydrate (69.850 and 47.120) content than the purees (11.100 and 4.730) but lower (8.340 and 9.950) in protein than the purees (13.000 and 13.790). The moisture content of purees were significantly ($p <0. 001$) higher than the chaffs and whole seed.

Table 4. 1: Proximate composition of whole "Niri" seeds and processed materials in percentage per gram (%/g).

Parameter	Whole grain	Processed "Niri" Seeds					
		Raw Puree	Raw Chaff	Roasted Puree	Roasted Chaff	S.e.d.	P-value
Ash	2.273^a	0.904^c	0.816^c	0.966^c	1.171^b	0.1816	0.002
Carbohydrate	20.860^c	11.100^d	69.850^a	4.730^e	47.120^b	0.8420	< 0.001
Ether extract	42.270^a	29.580^c	16.980^e	26.710^d	38.18^b	0.5020	< 0.001
Moisture	14.290^c	45.420^b	4.020^d	53.600^a	3.780^d	0.6360	< 0.001
Protein	20.300^a	13.000^c	8.340^d	13.790^b	9.950^d	0.3880	< 0.001

S. e. d. = standard error of difference, Rows with different superscripts are statistically different ($P < 0.05$).

The mineral results showed no significant ($p > 0.05$) difference in calcium content between whole seed and test materials. The whole seed was significantly higher in iron, potassium, magnesium and zinc. Roasted chaffs recorded significantly lower values in potassium, magnesium and zinc than the rest of the test materials. These results are shown in Table 4.2.

Table 4. 2: Mineral composition of whole "Niri" seeds and processed materials in mg/g

Parameter	Whole grain	Raw Puree	Raw Chaff	Roasted Puree	Roasted Chaff	S.E.D.	P-value
Calcium	14.80	8.40	10.20	34.70	7.30	16.82	0.493
Iron	4.077^{a}	0.657^{d}	2.513^{b}	0.657^{d}	1.170^{c}	0.033	< 0.001
Potassium	32.963^{a}	23.743^{c}	23.347^{d}	26.543^{b}	14.913^{e}	0.0823	< 0.001
Magnessium	28.350^{a}	27.503^{c}	26.780^{d}	27.740^{b}	24.973^{e}	0.0671	< 0.001
Zinc	0.5567^{a}	0.400^{b}	0.2367^{d}	0.370^{c}	0.1767^{e}	0.00816	< 0.001

S. E. D. = standard error of difference, Rows with different superscripts are statistically different (P < 0.05).

4.2. Sensory results of processed "Niri" extended beef sausages

4.2.1. Sensory characteristics of raw and roasted "Niri" puree extended beef sausages

The sensory evaluation was done once a week for three weeks and the following results were observed (Table 4a and 4b). No significant (p > 0.05) difference was observed in all sensory attributes except for tenderness and colour during the first week of evaluation. Raw puree at 25 % inclusion in the products recorded the highest mean value (3.400) for juiciness. Roasted puree at 15 % inclusion recorded the highest mean value (3.33) for overall likening, although it did not differ (P > 0.05) with the rest of the samples. Tenderness was significant (p < 0.05) in the raw puree products at 25 % inclusion and roasted puree at 5 % inclusion being more tender than the rest. The less tender product was the control. On colour, raw puree products were similar but significantly ($p < 0.05$) pale than roasted puree products which were very dark.

For the second week, significant difference ($p < 0.05$) was observed for colour alone. Raw puree products recorded significantly pale while roasted puree products and control were dark and intermediate respectively. The highest colour mean value (4.133) was observed for 15 % raw puree products. Raw and roasted purees at 25 % inclusions recorded the highest mean (3.800) for juiciness though not significant from the rest of the treatments. The most liked was the 15 % raw puree inclusions sausages but the mean (3.867) was not significant from the rest of the treatments.

A similar trend was observed for colour for the third week with raw puree products recording high mean values the than roasted puree products and the control. The rest of the sensory attributes showed no significance ($p > 0.05$) in the third week.

The results are presented in Table 4.3a and 4.3b.

Table 4. 3a: Sensory results of "Niri" puree products

Storage period	Parameter	Control	RaP 5 %	RaP 15 %	RaP 25 %	RoP 5 %	RoP 15 %	RoP 25 %	S.e.d.	P-Value		
										Treat-ment	Level	Treatment* Level
1	oma	2.730	3.000	2.670	2.730	2.600	2.870	2.600	0.421	0.693	0.974	0.784
	vour Intensity	3.000	2.930	3.070	3.070	3.600	3.270	3.070	0.431	0.317	0.831	0.662
	vour liking	2.467	2.933	3.000	3.133	3.000	2.933	3.000	0.3950	0.866	0.137	0.986
	ciness	2.667	2.800	2.933	3.400	3.200	3.267	2.867	0.3914	0.799	0.318	0.318
	nderness	2.533^{d}	2.600^{d}	3.133^{c}	3.533^{ab}	3.667^{a}	3.067^{c}	3.200^{bc}	0.3572	0.353	0.010	0.034
	xture	2.600	3.400	3.200	3.000	3.067	3.200	3.533	0.3688	0.787	0.035	0.422
	ste	3.000	3.267	3.267	3.400	3.400	3.200	2.733	0.3094	0.334	0.409	0.274
	lour	2.533^{bc}	3.467^{a}	3.533^{a}	3.600^{a}	2.667^{b}	2.267^{c}	1.733^{d}	0.3376	<.001	0.059	0.003
	erall liking	2.867	3.133	3.200	2.867	3.067	3.333	3.200	0.3651	0.585	0.484	0.873
7	oma	3.333	3.067	3.067	3.133	3.733	3.400	3.400	0.2976	0.036	0.864	0.470
	vour Intensity	3.000	3.400	3.067	3.133	3.267	2.867	2.933	0.3005	0.377	0.291	0.961
	vour liking	3.400	3.800	3.800	3.400	3.400	3.333	3.467	0.2766	0.151	0.681	0.410
	ciness	3.000	3.067	3.533	3.800	3.133	2.933	3.800	0.2806	0.344	<.001	0.298
	nderness	2.867	2.867	3.400	3.733	3.000	2.533	3.400	0.3293	0.108	0.011	0.146
	xture	2.800	3.467	3.667	3.800	3.133	3.133	3.600	0.2567	0.040	<.001	0.516
	ste	3.267	3.600	3.667	3.933	3.600	3.400	3.267	0.2670	0.083	0.243	0.249
	lour	3.067^{cd}	3.600^{b}	4.133^{a}	3.267^{c}	2.933^{d}	2.467^{e}	1.800^{f}	0.2743	<.001	<.001	<.001
	erall liking	3.400	3.733	3.867	3.600	3.600	3.467	3.400	0.2936	0.214	0.494	0.809

w Puree, RoP- Roasted Puree, S.e.d. Standard error of difference, Rows with the same superscripts are statistically

Table 4. 3b: Sensory results of "Niri" puree products

Storage period	Parameter	Control	RaP 5 %	RaP 15 %	RaP 25 %	RoP 5 %	RoP 15 %	RoP 25 %	S.e.d.	P-VALUE		
										Treat-ment	Level	Treatment* Level
14		3.067	3.333	3.333	3.067	3.133	3.600	3.267	0.3807	0.727	0.498	0.821
	Intensity	2.930	3.200	3.130	2.930	3.470	3.270	3.130	0.407	0.463	0.521	0.972
	liking	3.670	3.670	3.470	3.470	3.600	3.600	3.130	0.412	0.747	0.587	0.877
	ss	2.933	3.000	3.200	3.200	3.267	2.533	4.333	0.3285	0.010	0.004	0.091
	ness	2.933	3.267	3.000	3867	3.267	2.533	3.733	0.3844	0.604	0.018	0.622
		2.600	3.400	3.467	3.667	3.067	3.600	3.867	0.3166	1.000	<.001	0.641
		3.600	3.667	3.267	3.400	3.267	3.933	4.000	0.3794	0.256	0.858	0.152
		2.867^{bc}	3.200^{b}	3.667^{a}	3867^{a}	2.467^{d}	2.267^{d}	2.600^{cd}	0.3671	<.001	0.407	0.034
	liking	3.600	3.730	3.870	3.470	3.600	3.670	4.070	0.427	0.756	0.832	0.236

w Puree, RoP- Roasted Puree, S.e.d. Standard error of difference, Rows with the same superscripts are statistically

4.2.2. Sensory results of raw and roasted "Niri" chaff beef sausages

There were no significant ($p > 0.05$) differences in all sensory attributes for the three weeks of evaluation except for colour. The colour of the control products, raw chaffs (5, 15 and 25 %) and 5 % roasted chaff sausages where similar but were significantly ($p < 0.05$) paler than 15 and 25 % roasted chaff sausages for the first week. Twenty-five percent (25 %) roasted chaff sausage inclusions recorded the lowest mean value (1.467) indicating a darker colour than the rest of the treatments. Although there was no significant differences ($p > 0.05$) in the overall liking for the first week, mean values decreased as the inclusion level of chaffs (raw and roasted) increased across treatments. Similar trend was recorded for the taste, texture, tenderness and juiciness of the products.

In the second week, the colour was the only parameter with significant differences ($p < 0.05$). The control, 15 and 25 % raw chaff products were statistically similar but significantly higher ($p < 0.05$) than the other products. The control recorded high mean values than the rest of the products though not significant ($p > 0.05$) in the rest of the sensory qualities. These sensory quality determinants though not significant ($p > 0.05$) decreased as the inclusion levels of the raw and roasted "niri" chaffs increased in sausages for the second week.

Colour recorded significant differences ($p < 0.05$) in the third week with 15 and 25 % raw chaff products recording high mean values of 3.867 and 3.667 respectively than the other products. The colour mean values generally decreased as inclusion level of roasted "niri" chaff increased in sausages in all three weeks of evaluation.

The third week recorded no significant differences ($p > 0.05$) in the other sensory parameters evaluated. The mean values however, decreased for most of the parameters as the inclusion levels of raw and roasted "niri" chaffs increased in products.

The results are presented in Table 4.4a and 4.4b below.

Table 4. 4a: Sensory results of "Niri" chaffs products

Storage period	Parameter	Control	RaC 5 %	RaC 15 %	RaC 25 %	RoC 5 %	RoC 15 %	RoC 25 %	S.e.d.	P-VALUE Treat-ment	Level	Treatment*Level
1		2.730	3.330	2.670	3.070	2.670	2.470	2.730	0.419	0.155	0.482	0.720
	Intensity	3.000	3.000	2.730	3.070	3.000	2.600	2.800	0.452	0.659	0.688	0.971
	liking	2.470	3.070	2.930	2.730	2.600	2.530	2.530	0.410	0.196	0.629	0.851
	ıs	2.667	2.600	2.533	2.333	2.333	2.200	1.867	0.3632	0.145	0.174	0.831
	ıess	2.533	2.667	2.200	2.467	2.467	2.067	1.867	0.3333	0.164	0.128	0.616
		2.600	2.467	2.200	2.067	2.400	2.000	1.800	0.2933	0.365	0.006	0.915
		3.000	3.200	2.867	2.667	2.800	2.667	2.200	0.3155	0.094	0.039	0.721
		2.533^{ab}	2.667^{a}	2.600^{a}	2.733^{a}	2.867^{a}	2.200^{b}	1.467^{c}	0.3572	0.042	0.069	0.023
	liking	2.867	3.067	2.933	2.533	2.667	2.533	2.200	0.3561	0.114	0.159	0.833
7		3.333	3.133	3.000	2.800	3.067	3.067	2.733	0.2795	0.905	0.044	0.984
	Intensity	3.000	2.867	2.467	2.133	2.667	3.000	2.600	0.3165	0.209	0.047	0.287
	liking	3.400	3.333	2.600	2.267	3.067	3.000	2.600	0.3078	0.450	<.001	0.390
	ıs	3.000	2.533	1.867	1.667	2.533	2.333	1.400	0.2616	0.703	<.001	0.259
	ıess	2.867	2.400	1.733	1.667	2.600	2.067	1.400	0.2917	0.648	<.001	0.496
		2.800	2.200	1.600	1.600	2.400	1.867	1.400	0.2746	0.628	<.001	0.623
		3.267	3.067	3.067	2.800	3.000	3.067	2.667	0.2138	0.641	0.007	0.966
		3.067^{a}	2.733^{b}	3.133^{a}	3.133^{a}	2.600^{b}	2.333^{b}	1.600^{c}	0.3324	<.001	0.034	0.005
	liking	3.400	2.733	2.400	2.000	2.933	2.667	1.867	0.2840	0.558	<.001	0.740

asted Chaff, RaC - Raw Chaff, S.e.d. - Standard error of difference, Means in a row with the same Superscripts are ficantly different.

Storage period	Parameter	Control	RaC 5 %	RaC 15 %	RaC 25 %	RoC 5 %	RoC 15 %	RoC 25 %	S.e.d.	P-Value		
										Treat-ment	Level	Treatment*Level
14	a	3.067	2.800	2.733	2.933	3.133	3.267	2.933	0.3581	0.229	0.959	0.656
	ur Intensity	2.930	2.930	2.800	2.000	2.730	2.800	2.930	0.416	0.380	0.420	0.220
	ur liking	3.667	3.000	3.067	2.933	3.067	2.800	2.733	0.3916	0.611	0.014	0.920
	ıess	2.933	2.467	2.267	2.133	2.467	2.400	1.533	0.3112	0.455	<.001	0.347
	ərness	2.933	2.400	1.733	1.533	2.333	1.933	1.667	0.3081	0.666	<.001	0.926
	.re	2.600	2.200	1.800	1.867	2.533	2.133	1.533	0.2906	0.567	<.001	0.311
		3.600	3.067	3.000	2.800	3.200	3.067	3.067	0.3251	0.474	0.023	0.947
	ır	2.867[c]	3.333[b]	3.867[a]	3.667[a]	2.333[d]	2.267[e]	2.067[e]	0.2909	<.001	0.657	<.001
	ıll liking	3.600	2.933	2.600	2.267	2.800	2.667	2.200	0.3761	0.860	<.001	0.984

4b: Sensory results of "Niri" chaffs products

oasted Chaff, RaC = Raw Chaff, S.e.d. = Standard error of difference, Means in a row with the same Superscripts ignificantly different.

4.3. Proximate and mineral composition of "Niri" extended beef sausages

4.3.1. Proximate composition of raw and roasted "Niri" puree sausages

No significant difference ($p > 0.05$) was recorded for ash and carbohydrate contents of the products. Though there were no significant differences in ash content of extended products, the level increased as the inclusion level of "niri" increased. The carbohydrate content of the raw puree products increased as the quantity of "niri" added increased.

Significant difference ($p < 0.05$) were recorded for fat, moisture and protein contents of products. Fat content ranged from 0.429 % in control products to 3.079 % in 25 % roasted puree products. The fat content increased as the inclusion level of roasted puree increased. The control products recorded the highest mean value of 78.730 % and the least of 70.887 % for 25 % raw puree products in terms of moisture. The amount of moisture decreased as the inclusion level of "niri" purees increased. The protein content of 25 % raw and roasted products was statistically similar but different and higher than the rest of the products. Amount of protein however increased as the quantity of roasted puree increased. The protein content of the control product was only significantly ($p < 0.05$) higher than 15 % raw "niri" puree and 5 % roasted "niri" puree extended products.

The results are presented in Table 4. 5.

Table 4. 5: Proximate results of raw and roasted "Niri" puree beef sausages

Parameter	Control	RaP 5 %	RaP 15 %	RaP 25 %	RoP 5 %	RoP 15 %	RoP 25 %	S.e.d.	P-Value Treat-ment	P-Value Level	P-Value Treatment*Level
Ash	.394	1.881	2.004	2.169	1.319	1.591	1.877	0.1668	0.005	0.004	0.186
Carb	.260	0.650	2.000	2.940	2.030	0.490	1.590	0.720	0.334	0.028	0.068
Ether	.429^{f}	1.877^{c}	1.138^{e}	2.197^{b}	1.089^{e}	1.373^{d}	3.079^{a}	0.0760	0.063	<.001	<.001
Mois	8.730^{a}	76.315^{d}	75.654^{e}	70.887^{g}	77.032^{b}	76.847^{c}	71.434^{f}	0.1194	<.001	<.001	<.001
Prote	9.190^{c}	19.080^{c}	18.140^{d}	21.850^{a}	18.530^{d}	19.700^{b}	22.020^{a}	0.438	0.216	<.001	0.047

aw Puree, RoP = Roasted Puree, S.e.d. = Standard error of difference, Means in a row with the same Superscripts are ficantly different.

6: Mineral composition of raw and roasted "Niri" puree products (mg/g)

P	Control	RaP 5 %	RaP 15 %	RaP 25 %	RoP 5 %	RoP 15 %	RoP 25 %	S.e.d.	P-Value Treat-ment	P-Value Level	P-Value Treatment* Level
C	2.6733^{g}	2.8300^{e}	3.2933^{b}	3.6367^{a}	2.7767^{f}	2.9133^{d}	3.4933^{b}	0.03689	<.001	<.001	<.001
Ir	0.2467^{d}	0.2000^{g}	0.3433^{a}	0.2733^{c}	0.2367^{e}	0.2267^{f}	0.3200^{b}	0.00645	0.020	<.001	<.001
P	29.910^{a}	28.963^{d}	29.403^{b}	29.853^{a}	29.237^{c}	29.333^{bc}	27.330^{e}	0.0979	0.002	<.001	<.001
M	15.100^{f}	15.880^{e}	19.960^{c}	21.610^{b}	17.017^{d}	20.173^{c}	21.863^{a}	0.2173	0.002	<.001	0.010
Z	0.6200^{a}	0.5600^{b}	0.5067^{d}	0.4500^{f}	0.5500^{b}	0.4767^{e}	0.5267^{c}	0.0100	0.085	<.001	0.010

aw Puree, RoP = Roasted Puree, S.e.d. = Standard error of difference, Means in a row with the same Superscripts ignificantly different.

4.3.2. Mineral composition of raw and roasted puree products

Mineral compositions of products are presented in Table 4.6. Significant differences ($p < 0.05$) where recorded in all minerals analysed. Calcium content ranged from 2.6733 mg/g in control to 3.6367 mg/g in 25 % raw puree sausage. Increasing the quantity of roasted “niri” puree from 5 – 25 % significantly ($p < 0.05$) increased calcium content from 2.9133 mg/g to 3.4933 mg/g in products. Iron content varied from 0.200 mg/g in 5 % raw “niri” puree to 0.3433 mg/g in 15 % raw “niri” puree sausages. The control recorded the highest potassium value of 29.910 mg/g while the lowest was 27.330 mg/g in 25 % roasted “niri” puree products. Magnesium was highest (21.863 mg/g) in 25 % roasted “niri puree and lowest in the control (15.100 mg/g). Magnesium content however increased as the inclusion level of raw and roasted “niri” content increased in the samples. Zinc content was highest (0.6200 mg/g) in the control product than in raw and roasted “niri” treated products.

4.3.3. Proximate composition of raw and roasted “niri” chaff sausages

Table 4.7. Shows results of the proximate analyses of beef sausages containing 0, 5, 15 and 25 % raw and roasted “niri” chaffs. Significant differences ($p < 0.05$) were observed in all parameters measured in samples. Ash content was lowest in control (1.394 %) and highest (2.192 %) in 25 % roasted “niri” chaff products and the values increased as the inclusion level of roasted “niri” chaff increased. Products containing chaffs had higher carbohydrate values (2.060 – 20.810 %) than the control product (0.260 %). Fat content was as low as 0.429 % in the control products to 3.281 % in 25 % roasted “niri” chaff products. The fat values increased as the proportion of “niri” chaffs increased in the products. The control products recorded a moisture value of 78.73 % while the lowest was 25 % roasted chaff of 62.34 %.

The amount of moisture decreased as the inclusion levels of chaffs increased in the products. Products containing 25 % raw and 25 % roasted “niri” chaffs had protein values of 18.590 and 11.670 % respectively lower than the control (19.190 %). The others with lower inclusion levels had higher protein values than the control. The protein content of raw and roasted “niri” chaff products decreased as the inclusion level increased across the treatments.

4.3.4. Mineral composition of raw and roasted “niri” chaff sausages

Table 4.8 shows that there were significant differences ($p < 0.05$) in all minerals analysed. The control had low calcium values (2.673 mg/g) than “niri” chaff included products. The iron content in “niri” chaff (raw and roasted) products increased as the inclusion level of chaffs increased. Potassium and zinc contents decreased as the inclusion levels of chaffs increased across treatments while magnesium content increased from 15.100 – 20.677 mg/g as the amount of roasted “niri” chaff included increased in products. The zinc value of the control products was significantly ($p < 0.001$) higher than all “niri” chaff extended products. The values decreased as inclusion level increased. There were similar zinc values between the control and 5 % raw chaff products. The results are shown in Table 4.8.

Table 4. 7: Proximate composition of raw and roasted “Niri” chaffs products

Parameter	Control	RaC 5 %	RaC 15 %	RaC 25 %	RoC 5 %	RoC 15 %	RoC 25 %	S.e.d.	P-VALUE		
									Treat-ment	Level	Treatment* Level
Ash	1.394^{d}	1.849^{b}	1.318^{d}	2.078^{a}	1.517^{c}	1.906^{b}	2.192^{a}	0.1115	0.134	<.001	<.001
Carbo	0.260^{g}	2.940^{d}	2.890^{e}	8.210^{b}	2.060^{f}	6.570^{c}	20.810^{a}	0.542	<.001	<.001	<.001
Ether	0.429^{e}	1.500^{d}	2.071^{c}	2.639^{b}	1.718^{d}	2.445^{b}	3.281^{a}	0.2185	0.022	<.001	0.011
Moist	78.73^{a}	75.110^{b}	72.190^{d}	66.540^{f}	73.690^{c}	69.670^{e}	62.340^{g}	0.428	<.001	<.001	<.001
Protei	19.190^{d}	21.520^{a}	20.530^{b}	18.590^{e}	20.290^{b}	19.860^{c}	11.670^{f}	0.423	<.001	<.001	<.001

oasted Chaff, RaC = Raw Chaff, S.e.d. = Standard error of difference, Means in a row with the same Superscripts ignificantly different.

Pa	Control	RaC 5 %	RaC 15 %	RaC 25 %	RoC 5 %	RoC 15 %	RoC 25 %	S.e.d.	P-Value		
									Treat-ment	Level	Treatment* Level
Ca	2.673^{g}	2.940^{f}	3.983^{f}	4.157^{d}	4.193^{b}	4.220^{c}	9.550^{a}	0.0664	<.001	<.001	<.001
Iro	0.2467^{g}	0.2900^{f}	0.3933^{d}	0.4167^{c}	0.3467^{e}	0.4400^{b}	0.6467^{a}	0.00707	<.001	<.001	<.001
Pot	30.483^{a}	29.910^{b}	27.963^{e}	25.280^{f}	29.607^{c}	28.603^{d}	27.153^{e}	0.0815	<.001	<.001	<.001
Ma	15.100^{g}	17.310^{e}	17.557^{d}	18.500^{c}	17.010^{f}	19.327^{b}	20.677^{a}	0.2196	<.001	<.001	<.001
Zir	0.6200^{a}	0.6267^{a}	0.4200^{d}	0.3933^{e}	0.5800^{b}	0.5067^{c}	0.3600^{e}	0.0100	0.743	<.001	<.001

8: Mineral composition of raw and roasted “Niri” chaff beef sausages

oasted Chaff, RaC = Raw Chaff, S.e.d. = Standard error of difference, Means in a row with the same Superscripts ignificantly different.

4.4. pH of Products

5.4.1. The pH of raw and roasted "Niri" puree beef sausages

Figure 4.1. indicates the pH of beef sausages containing various levels of raw and roasted "niri" purees. A high pH (6.15) was recorded in 25% roasted puree product. The control had higher (5.93) pH than 5 and 15 % raw puree and 15 % roasted puree products of 5.84, 5.83 and 5.84 respectively.

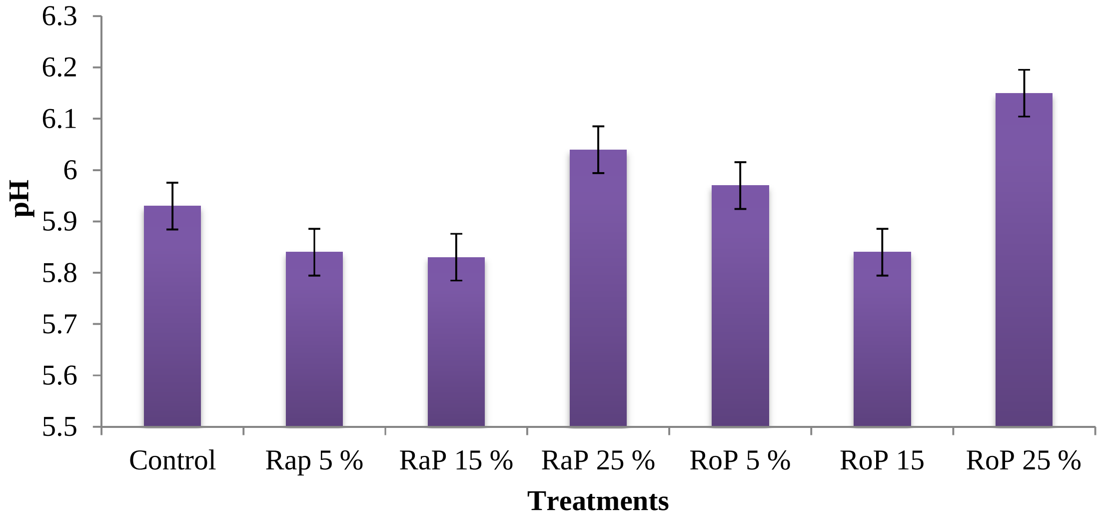
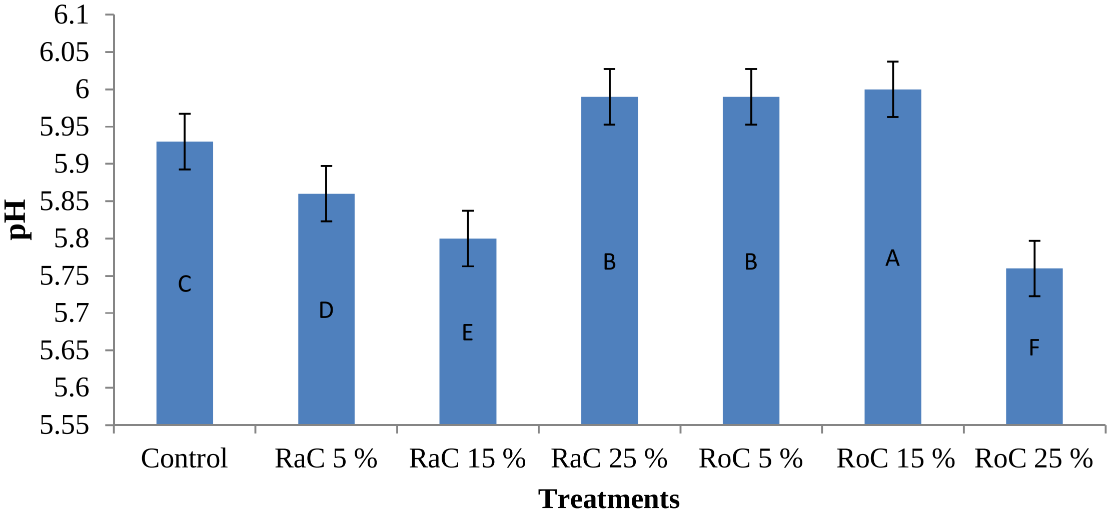


Figure 1: **pH results of raw and roasted "niri" puree beef sausages**

4.4.2. pH results of raw and roasted "Niri" chaffs beef sausages

Figure 4.2. presents the pH results of "niri" chaff sausages. Significant differences ($p < 0.05$) were recorded among treatments. Products containing 15 % roasted chaffs had the highest pH (6.00) and the lowest of 5.76 in 25 % roasted chaffs. The pH of the control (5.93) was higher than 5 % raw chaff (5.86), 15 % raw chaff (5.80) and 25 % roasted chaffs products.



Bars with similar letters are not significantly different
Figure 2: pH results of raw and roasted "Niri" chaff beef sausages

4.5. Lipid peroxidation in "Niri" sausages

4.5.1. Peroxide results of raw and roasted "Niri" puree beef sausages.

Figure 4.3 shows peroxide values of beef sausages with different inclusion levels of raw and roasted "niri" purees. The results were taken in triplicates once every week for three weeks of storage and averages taken to determine the trend of increase or decrease in peroxides values. This was to observe changes in peroxidation as the products were stored overtime. There were a significant difference ($p < 0.05$) among treatments and the values were increasing overtime and with increasing inclusion levels.

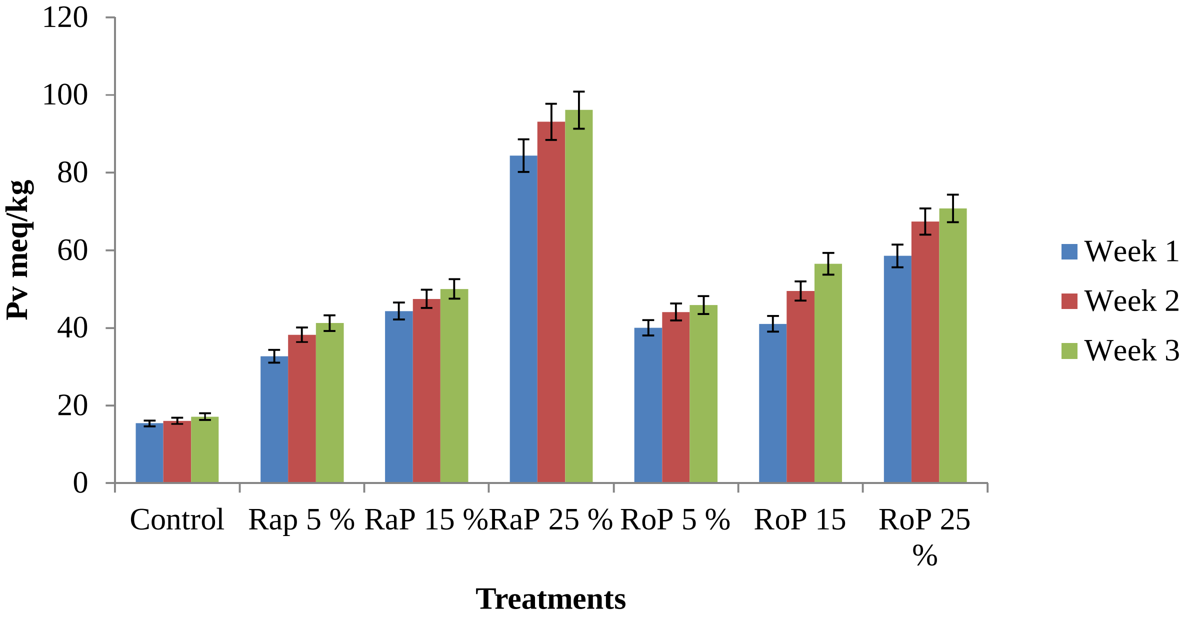


Figure 3: Lipid peroxidation in "Niri" puree beef sausages

4.5.2. Peroxide results of raw and roasted "Niri" chaffs beef sausages

It was observed that the peroxide scores of the raw chaffs increased as the inclusion level increased and higher than the roasted "niri" chaff products for the entire three weeks period. For instance the values for the first week of raw "niri" products were 88.76, 90.81 and 100.24 meq/kg for 5, 15 and 25 %, respectively of raw "niri" puree, while that of the roasted products were 29.37, 39.39 and 25.84 meq/kg respectively for 5, 15 and 25 % roasted "niri" puree.

The results are presented in Figure 4.4.

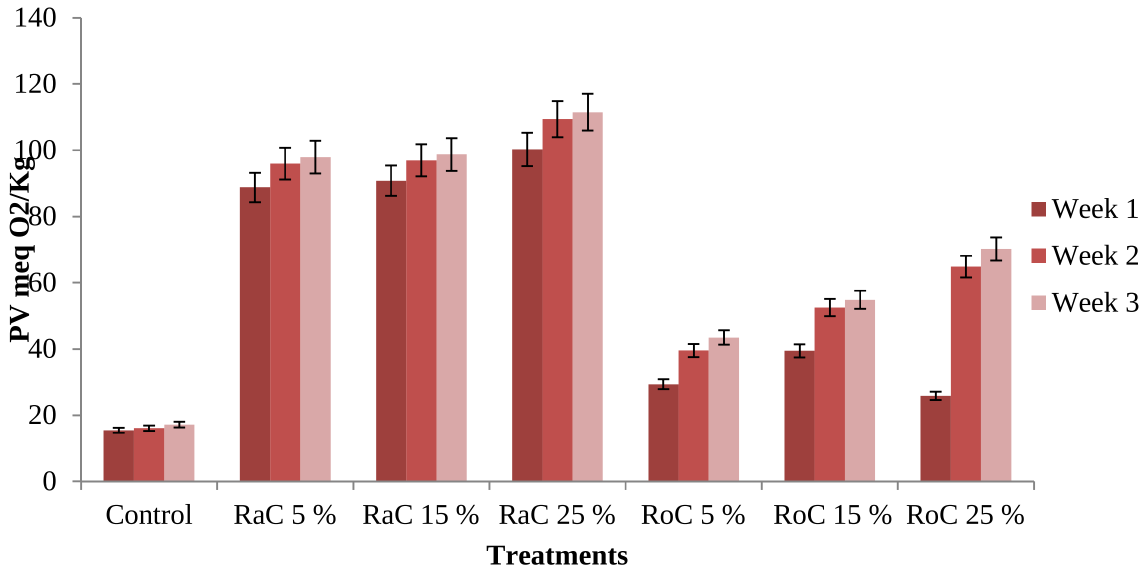


Figure 4: Lipid peroxidation "Niri" Chaff Beef Sausages

4.6. Formulation cost of "niri" extended beef products

The cost of formulating a kilogram of 0 % (control), purees (raw and roasted) and chaff (raw and roasted) are presented in table 4.9 and 4.10. The formulation cost in Ghana cedis was 20.1, 20.58, 19.54, 18.5, 20.69, 19.87 and 18.85 for the control, raw purees (5, 15 and 25 %) and roasted (5, 15 and 25 %) respectively as in Table 4.9.

Formulation cost for control, RaC 5 %, RaC 15 %, RaC 25 %, RoC 5 %, RoC 15 % and RoC 25 % was 20.1, 19.35, 17.85, 16.35, 19.35, 17.85 and 16.35 respectively. Formulation cost at higher inclusion level was lower than 5 % inclusion levels. Products extended with raw purees cost less than roasted products. These are found Table 4.10.

Table 4.9 Formulation cost for raw and roasted "niri" extended proucts

Ingredient	Rate Gh¢/Kg	Control	RaP 5 %	Rap 15 %	Rap 25 %	RoP 5 %	RoP 15 %	RoP 25 %
Minced beef	19	19	18.05	16.15	14.25	18.05	16.15	14.05
"Niri"	7	-	0.35	1.05	1.75	0.35	1.05	1.75
Roasting of "niri"	2	-	-	-	-	0.1	0.3	0.5
Milling of "niri"	1	-	0.04	0.12	0.2	0.05	0.15	0.25
Water for Processing "niri"	0.8	-	0.04	0.12	0.2	0.04	0.12	0.2
Spice mix	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Curing salt	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Transportation	6	-	1	1	1	1	1	1
Ice cubes	0.3	03	0.3	0.3	0.3	0.3	0.3	0.3
Total Gh¢		**20.1**	**20.58**	**19.54**	**18.5**	**20.69**	**19.87**	**18.85**

RaP - Raw Puree, RoP- Roasted Puree

Table 4.10 Formulation cost for raw and roasted "niri" chaff products

Ingredient	Rate Ghana cedis/Kg	Control	RaC 5 %	RaC 15 %	RaC 25 %	RoC 5 %	RoC 15 %	RoC 25 %
Minced beef	19	19	18.05	16.15	14.25	18.05	16.15	14.25
"Niri" chaff cost	-	-	-	-	-	-	-	-
Drying of chaff	3	-	0.15	0.45	0.75	0.15	0.45	0.75
Milling of chaff	1	-	0.05	0.15	0.25	0.05	0.15	0.25
Spice mix	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Curing salt	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Ice cubes	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Total Gh¢		**20.1**	**19.35**	**17.85**	**16.35**	**19.35**	**17.85**	**16.35**

RaC - Raw Chaff, RoC- Roasted Chaff

CHAPTER FIVE

5.0. DISCUSSION

5.1. Proximate and mineral composition of whole "Niri" seeds and processed materials

5.1. 1. Proximate Composition of Whole "Niri" Seed and processed materials

The high carbohydrate content in whole *Citrullus vulgaris* ("niri") seeds is attributed to the processing which removed almost all cell contents to produce the purees. The remaining cell wall or seed coat contents (chaffs) are structural in nature and are generally energy giving. Extraction of purees increases the fraction of seed coat to flour content in chaffs hence the high carbohydrate content in chaffs. The carbohydrate content of 20.860 % is higher than the 7.22 % for *Citrullus lanatus* reported by Jacob *et al*., (2015), 10.6 % for "egusi" reported by Osagie and Eka (1998) and 5.1 % for *Colocynthis citrullus* reported by Ojieh *et al*., (2008). The carbohydrate content is however, lower than the 65 – 75 % recommended for cereals (Jacob *et al*., 2015), since it is not a major source of carbohydrate.

The high inorganic content of cell walls accounted for the high ash contents of chaffs. These results are lower than what was reported for *Citrullus vulgaris* ("guna") in Nigeria (Penuel *et al*., 2013). They reported 4.83, 4.85 and 3.30 % for undefatted (raw), defatted and protein concentrate respectively. Ash content of *Citrullus lanatus* was found to be 6.70 % (Jacob *et al*., 2015) while for "egusi" was 3.70 % (Ojieh *et al*., 2008) and 6.84 – 6.99 % (Bankole *et al*., 2005). The low ash content of "niri" means it will have low mineral values and should therefore not be used as a major mineral source in human nutrition.

The fat content of whole "niri" seeds, raw puree, roasted puree, raw chaff and roasted chaff (42.270, 29.580, 16.980, 26.710 and 38.18 % respectively) were similar to the fat content of 42.60, 43.21 and 40.60 % for unprocessed, roasted and germinated groundnut respectively (Kavitha and Paramavalli, 2014). The results indicate that the oil content of whole "niri" seeds in this study is lower than that of raw undefatted "guna" (49.00 %) as reported by Penuel *et al*. (2013). The test materials however, had higher values than defatted "guna" (5.5 %) and "guna" protein concentrate (2.73 %). The values are also lower than that of *Citrullus lanatus* (49.05 %) (Jacob *et al.,* 2015), 57.26 % for *Citrullus lanatus* in Southern Nigeria (Ediong *et al.*, 2013) and 53.85 % for *Colocynthis citrullus* (Bankole, 2005). High oil content of "niri" seed makes it a potential oil producing crop. This when exploited in commercial bases will create jobs for the youth and rural farmers to enhance economic growth. The high oil content of test materials might improve eating quality and energy levels when eaten or incorporated into beef sausages.

Moisture values of purees were significantly ($p < 0.001$) higher than chaffs and whole seed flour. This means that the water that was used to process the flour into purees was not completely removed by the decantation method. These moisture values are higher than those reported for raw undefatted "guna" (5.05 %), defatted "guna" (5.5 %) and "guna" protein concentrate (4.50 %) (Penuel *et al*., 2013), 7.10 % for *Citrullus lanatus* (Jacob *et al*., 2015) and 4.75 – 5.21 % for melon seeds (Elinge *et al*., 2012). The high moisture content of test materials make products prepared from them were juicy and tender. Products incorporated with "niri" purees are likely to have better sensory qualities than chaff products. The high moisture values of purees will make them prone to microbial spoilage. The moisture content of whole seeds is similar to that (13.56 ± 1.94 %) for unprocessed wheat flour (Kavitha and

Paramalavalli, 2014). The moisture values for chaffs were however lower than 10 %. This means whole seeds and chaffs can be stored for long as low moisture content increases shelf life of food products (Alozie *et al*., 2009). This is as a result of reduction of microbial activity (Oyenuga, 2013) as high moisture increases microbial growth leading to spoilage (Temple *et al*., 1996).

Protein content of whole seeds (20.30 %) was significantly ($p < 0.001$) higher than for the processed materials (8.34 – 13.79 %). This implies that the methods used for processing (roasting and decantation) reduced much of the nutrients but higher than most cereals. The protein values in this study were far lower than those reported by Penuel *et al*. (2013) due to the decantation and roasting. They reported a protein content of 36.58, 50.93 and 83.56 % for raw undefatted "guna", defatted "guna" and "guna" protein concentrate respectively. The value for whole unprocessed seeds is again lower than 30.63 % for *Citrullus lanatus* (Jacob *et al*., (2015), 28.63 % for *Colocynthis citrullus* (Bankole *et al*., 2005) and 45.83 % for soya beans (Temple *et al*., 1996). The results for whole seeds are in agreement to those obtained for lean beef (22.3%) and beef carcass (16.5 %) (Heinz and Hautizinger, 2007). The values are however, higher than the 8 – 17.5, 8.8 – 11.9 and 7 – 10 % respectively for wheat, maize and rice (Guerrieri, 2004).

5.1.2. Mineral composition of whole "Niri" seeds and processed materials

There was no significant difference ($p > 0.05$) in the calcium content between "niri" seeds and processed materials (Table 4.2). This means that the methods of processing did not affect calcium content. The results disagree with that of Penuel *et al*. (2013), who reported significant ($p < 0.05$) difference between unprocessed and processed "guna". Their results showed that raw undefatted "guna", defatted "guna" and "guna" protein concentrate had calcium values of 33.00, 42.00 and 36.50 mg/100g respectively. The calcium contents of whole seeds in this study were higher than the 28.2 mg/100g for "egusi" (Ojieh *et al*., 2008). These results suggest that "niri" is a good source of calcium which could promote bone formation and neurological performance of consumers, especially children, nursing mothers and pregnant women.

The iron content of whole seeds was significantly ($p<0.001$) higher for the processed materials. Methods of processing used in this study greatly reduced iron content in test materials. The results are lower than those of Penuel *et al*. (2013). In that study, raw undefatted seeds recorded a value of 136 mg/100 g, defatted seeds had 180 mg/100g and protein concentrate recorded 115.5 mg/100 g iron. The results are again lower than the 50,800, 54,830 and 48,510 mg/100 g iron for soya beans, fluted pumpkin and melon seeds (Osagie and Eka, 1998). The results however meet the WHO recommended dietary iron requirement of 10 and 15 mg/day for children and adults respectively (World Health Organisation, 2003). Consuming "niri" on 100g bases will meet the dietary iron requirements. This will enhance haem formation (Adeyeye and Fagbohon, 2005) which will reduce anaemia in the population.

Potassium is key in a healthy performance of the heart. It is also associated in the contraction of smooth muscles. A major source of potassium in human diet is from plants. Processing significantly ($p<0.001$) reduced potassium content in test materials. These results are higher than the 4.94 mg/100g reported by Jacob *et al*. (2015) for *Citrullus lanatus*. They are however, lower than those of groundnut (705 mg/g), cowpea (278 mg/g) and finger millet

(408 mg/g) according to Kinabo (2015) which are usually consumed with "niri". An adequate concentration of potassium in a diet enhances the utilization of iron (Adeyeye, 2002). This suggests proper utilization of iron as there is high concentration of potassium in "niri". The results of this study showed that potassium is the only mineral with the highest concentration in "niri". Consuming "niri" on 100g bases per day will meet the 3,500 mg/day minimum requirement (Jacob *et al*., 2015) which is needed for healthy heart and muscle performance.

The Magnesium results were higher on 100 g bases than the 81.00 mg/100 g for raw undefatted "guna", 82.00 mg/100 g for defatted "guna" and 71.00 mg/100 g "guna" protein concentrate (Penuel *et al*., 2013). The results are also higher than "egusi" which recorded a mean value of 31.4 mg/100 g (Ojieh *et al*., 2008). With these results, consuming "niri" will therefore meet the magnesium requirement of 80 – 420 mg/day (Institute of Medicine, 1997). Magnesium is essential in metabolism in bones, control of insulin secretion, blood pressure and circulatory disease prevention (Umar *et al*., 2005) and would therefore be met with "niri" consumption.

Ingestion of zinc promotes healthy growth of hair and function of senses like smell and taste (Payne, 1990). The zinc values as shown in this study in Table 4.2 are in the range of 0.176 - 0.5567 mg/g with highest in whole "niri" seeds. The purees recorded higher values than chaffs indicating that zinc is found more in cell content (flour) than cell wall materials (chaffs). Jacob *et al*. (2015) reported zinc value of 21.05 mg/100 g in *Citrullus lanatus*. Penuel *et al*. (2013) also reported 49.50, 62.50 and 35.5 mg/100 g for raw undefatted "guna", defatted "guna" and "guna" protein concentrate respectively. This shows that whole seed "niri" has high zinc content than those of the same family on 100 g bases. Consuming "niri" or its incorporated products would meet the 15 mg/day for adults and 10 mg/day for children according to WHO standards (World Health Organisation, 2003). Consumption of “niri” or its incorporated beef sausages will undoubtedly improve the mineral requirements of consumers.

5.2. Sensory characteristics of beef sausages

5.2.1. Sensory characteristics of “Niri” puree extended products

The types of ingredients used in processing meat products affects much of the sensory properties of products. This correlates significantly to the physico-chemical properties of products (El-Sayed, 2013). The sensory results of “niri” purees extended beef sausages are in Table 4.3a and 4.3b. There was no significant differences ($p > 0.05$) in all parameters except colour and tenderness for the first week of evaluation.

Colour determines the acceptability of a product as consumers will not patronize anything that does not have an appealing colour. They are also not likely to buy or eat any product that has a colour different from what they are familiar with. The colour difference in this study was due to the roasting of “niri” seeds in some treatments. Roasting may result in the browning of seeds (Mishra *et al*., 2014). Roasting therefore caused the dark colour of roasted puree and their extended beef products (1.733 – 2.667). Ranathunga *et al*. (2015) reported dark appearance of sausages extended with cowpea and mung bean. The raw puree products recorded mean values of 3.467 – 3.600 which indicates intermediate colour on the hedonic scale. The values are however skewed towards paleness than the control treatment.

Roasted puree products recorded significance ($p < 0.05$) differences in tenderness for the first week. There was however stabilization with time. Roasting therefore resulted in tenderness of roasted puree extended products. Moisture loss overtime resulted in stabilization of tenderness as storage time increased. Tenderness is highly correlated to moisture content of products and ability of minced meat fibres to hold moisture decreases with time. Tenderness and colour differences did not result in the dislike of products by panelists.

The addition of raw and roasted "niri" purees therefore had similar sensory characteristics as the control. The results are similar to the findings of Teye *et al*. (2012), who reported no differences in sensory characteristics when cowpea was used as an extender up to 10 % in beef and ham burgers. Akwetey *et al*. (2012) concluded that there was no sensory lapse with the use of cowpea up to 5 % as an extender in frankfurter – type sausages. The results also agreed with Haluk (2014) who reported no sensory difference except texture between potato puree and bread crumbs (control) in meatballs.

5.2.2. Sensory characteristics of "Niri" chaffs extended products

Dietary fibre is the remains of edible portion of plants and related carbohydrates that are indigestible and non-absorbable in the small intestine of humans (Prosky, 1999). Its addition helps in freeing of bowels, decrease colorectal cancers and to increase the bulk of feed hence its usage in this study. Dietary fibre is added to meat and meat products in the form of vegetables, fruits, legumes and cereals as binders, fillers and extenders (Zuhaib and Hina, 2011). Meat products containing dietary fibres are excellent meat replacers. This is because of their characteristic nutritional and functional effects (Kumar *et al*., 2010; Hur *et al*., 2009) hence the addition of "niri" chaffs (raw and roasted) in the extended beef sausages.

The results showed no differences ($p > 0.05$) in all sensory parameters during the period of study except for colour ($p < 0.05$). Though there were no differences in most parameters, increasing inclusion levels of chaffs led to decreasing sensory values. The results agree with Turhan *et al.* (2005) who reported a decline in flavour, juiciness, colour and appearance scores, as levels of hazelnut pellicle in beef burgers increased. The addition of fruits (apple, orange and peach) and cereals (oat and wheat) above 3 % inclusion level in dry fermented sausages decrease sensory quality significantly (Garcia *et al.*, 2002). The results also agree with findings of Gringelmo-Miguel *et al.* (1999) that the addition of 17 and 29 % peach dietary fibre suspension had no significant effect in sensory quality of frankfurters.

The colour decline was much observed in the roasted chaff products. This is because roasting led to browning of chaffs. The chaffs were obtained from roasted "niri" after extraction of puree and further blending which caused darkening of chaffs hence the subsequent impact on products. The colour scores decreased as inclusion level of roasted chaffs increased, but increased as the inclusion of raw chaffs increased in products.

This result suggests that "niri" chaffs could be included in beef sausages as the colour difference did not impact negatively on overall acceptability of products.

5.3. Proximate and mineral composition of beef sausages

5.3.1. Proximate composition of "Niri" puree extended beef sausages

The moisture values of puree products decreased as inclusion levels increased. This implies that "niri" as a thickener thickens products making free water unavailable in the paste hence the low values. The roasted puree products however, had higher values than the raw puree products, implying that roasting reduced the ability of the puree to bind together. Moisture in products has the ability of improving the juiciness and tenderness of meat products thereby enhancing sensory qualities. This result disagrees with Akwetey *et al.* (2012) who reported increasing moisture content as the inclusion level of whole cowpea flour increased from 0 – 20 % in frankfurter-type sausages. Dzudie *et al.* (2002) also reported increasing sensory scores as common flour increased in beef sausages. Most flours have water absorption and retention abilities (Philips *et al.*, 2003) hence the high moisture values in "niri" puree extended products (70.887 – 77.032 %).

Fat content of "niri" puree extended products had significantly ($p < 0.001$) higher values than the control. Fat values of roasted puree products increased as inclusion level increased. Roasting led to reduction of moisture content thereby making fat available in roasted "niri" seeds than raw seeds.

The increasing fat content as inclusion increase agrees with Hegazy (2011) who reported increased fat content with increased inclusion level of fenugreek in beef sausages. The results however disagree with Teye *et al.* (2012). They reported that increased inclusion level of cowpea decreased fat content of beef and ham burgers.

High dietary fat is being implicated in cardiovascular diseases due to the presence of saturated fatty acids that these are made of. This health concern has made the World Health Organization to put a restriction on dietary fat intake. There is also an increasing call for the consumption of fats from plants which are safer than animal sources. Despite the health concerns, dietary fat has positive impact on juiciness, flavour and texture of processed meat products (Crehan *et al.*, 2000) as well as making diets flavourful. Reduction in fat content will therefore negatively affect sensory attributes of products. The high fat content in this study may positively affect sensory qualities of "niri" extended beef sausages.

Ash content did not record any significant differences ($p > 0.05$). The values were 1.394 % the in control, 1.881 – 2.169 % in raw puree products and 1.319 – 1.877 % in the roasted products. Despite the insignificant differences, raw puree products had higher ash content than roasted products. The scores increased as the inclusion levels of treatments increased. This trend will increase mineral content of products which will reduce mineral deficiencies in consumers. This result disagrees with Akwetey *et al*. (2012) who reported decrease ash content as inclusion level of whole cowpea flour increased in frankfurter-type sausages.

Protein is one of the main nutrients of meat and meat products. Though boneless meat is expensive in formulating meat products, any low cost ingredient that is added should not drastically reduce protein levels far below that of pure meat or meat products. This is because protein is needed for the growth and maintenance of body tissues. Protein is also needed for embryo formation during pregnancy and milk production during lactation. This study showed a high protein content as inclusion level of "niri" increased in products (Table 4.5). The protein scores of "niri" extended products were higher than the 13.3 % reported for raw cooked sausage finely comminuted without an extender (Heinz and Hautzinger, 2007). The results agrees with Teye *et al*. (2012) where there was an increased protein content (17.89 – 23.67 %) as inclusion level of cowpea increased in beef and ham burgers. When whole cowpea flour was used as an extender in frankfurter-type sausages, it led to a decline in protein content as the inclusion level was increased (Akwetey *et al*., 2012) contrasting current findings.

The high protein results of this study (18.14 – 21.85 %) will satisfy the contemporary global Recommended Dietary Allowance (RDA) of 0.8 g per kg body weight irrespective of age (Food and Nutrition Board, 2005; WHO, 2007). This suggests that, a small quantity of the product will be needed to meet the protein demand of consumers. As protein content increased with increasing inclusion level of "niri" purees, their use will therefore enhance the nutritional attributes of beef sausages.

5.3.2. Mineral composition of "Niri" puree products

Calcium content increased as inclusion level of purees increased in products. Raw puree products generally had higher calcium values than roasted puree products. This means roasting is antagonistic to calcium content of purees. Calcium content of purees (2.7767 – 36367 mg/g) was significantly ($p < 0.001$) higher than the control products (2.6733 mg/g). This means consuming sausages extended with "niri" purees will have a positive impact on calcium gain of consumers. The calcium content on 100 g bases will be higher than the FAO/WHO requirement of 100 mg/day and 130 mg/day for persons below 65 years and above 65 years respectively. It is evident from the findings that consuming "niri" puree products will provide more calcium to consumers than the control products. "Niri" therefore is capable of reducing bone malformation in children and the aged.

Iron is an essential component of blood haem in promoting respiration. This mineral is high in "niri" extended products. Iron content increased in roasted products as the inclusion level increased (Table 4.8). This means roasting is not detrimental to iron content of "niri". Consuming these extended sausages on 100 g serving will meet the iron requirement for all age groups (Institute of Medicine, 2001). This implies consuming these extended sausages will reduce anaemia in children, pregnant and lactating mothers.

Potassium content of the control (29.91 mg/g) was higher than "niri" extended products. It was only comparable to 15 % raw "niri" puree (29.853 mg/g). The results indicate that "niri" is a good source of potassium hence its incorporation led to improved potassium content of sausages. The values on 100 g bases however fall short of the Institute of Medicine (1997) requirement. The board recommends 400 – 1500 mg/day for infants and for lactating mothers. "Niri" can however be used as supplementary potassium ingredient to enhance heart, muscle and skeletal performance.

Magnesium content of "niri" extended products (15.88 – 21.863 mg/g) was significantly ($p < 0.001$) higher than the control (15.1 mg/g). The content increased as inclusion levels of raw and roasted "niri" puree increased in products. This means the temperature at which "niri" seeds were roasted is not detrimental to magnesium content of the test materials. The results from extended sausages suggests that consuming these products on 100 g bases for a day will far exceed the 80 – 420 mg/day recommended by the Institute of Medicine (1997). This is the requirement for all categories of people. Consuming these extended products will counter deficiencies of magnesium in human diet. These deficiencies include hyperactivity, depression, low stress tolerance, sleep disorders and poor atheletic performance (Gröber, 2009).

Control sausages had the highest zinc content of 0.62 mg/g. This supports the findings of Williams *et al*. (2002), they stated that beef contains 4.6 mg/100 g of lean meat. Consuming "niri" extended products will however meet the 1.0 and 1.4 mg/day respectively for females and males (WHO, 1996). The zinc values agree with the findings that it is a common source in meat, fish and cereals (Desphande *et al*., 2013). Consuming "niri" puree based products will therefore reduce the over 800, 000 infant mortalities as a result of zinc deficiencies like diarrhoea, infections (Hambidge and Krebs, 2007) and growth retardation (Brown *et al*., 2002). The consumption of "niri" extended products would improve the nutritional status of consumers. It will also improve reproduction in males (Nriagu, 2007) and reduce deficiencies in sickle cell persons (Desphande *et al*., 2013) with the high zinc values.

5.3.3. Proximate Composition of "Niri" Chaff Extended Beef Sausages

Ash content determines the amount of minerals in a material. This study reveals a significant difference ($p < 0.001$) in ash content between the control and the "niri" extended chaff products. The high ash content (Table 4.8) in extended products guarantees high mineral content of these products than the control.

The results also show a high carbohydrate content (2.06 – 20.81 %) in extended chaff products than the control (0.260 %). This is because chaffs are largely cell wall material which have a greater proportion of carbohydrate to other nutrients. Again, plant materials have high carbohydrate content than animal products hence the large differences. The results suggest that "niri" chaff sausages will provide more energy to consumers than the control products. The significant amount of carbohydrate in roasted products implies that roasting did not negatively affect energy level of chaffs.

The control products had higher moisture (78.73 %) than chaff products (62.34 – 75.11 %). The low moisture level means the chaffs absorbed the water that was added in the formulation as they were dry. There was a decrease in moisture content as the inclusion level of chaffs increased even though water in the form of ice was added on equal amount across treatments. A low moisture level is likely to make products less juicy and tough.

Products with “niri” chaffs had appreciable amount of protein (11.670 – 21.520 %). Products with 25 % raw and 25 % roasted chaffs had 18.59 and 11.67 % protein respectively which were lower than the control (19.19 %). This means the chaffs were low in protein and their addition reduce the protein content as their inclusion increases. Raw “niri” chaff products had higher protein values than roasted chaff extended products. This means the roasting temperature negatively affected protein content of chaffs hence the low values.

Fat improves eating quality as well as energy supply to the body. Fat content increased as inclusion levels increased in all treatments. The content was high in roasted “niri” chaff sausages than the raw and control products. This implies that the heat used in roasting caused the extraction of fat which is insoluble in water and could not be removed during preparation of puree.

The addition of “niri” chaffs into beef sausages did not reduce nutritional levels below acceptable levels as some parameters were improved. This agrees with Fernandez-Gines (2003) who reported that nutritional values of dry-fermented sausages were improved by the addition of orange fibre powder (0.5 – 2 %). It also supports the findings that dietary fibre from cereals and fruits at 1.5 % in sausages increased nutritional and sensory properties of the products (Garcia *et al*., 2002).

5.3.4. Mineral composition of "Niri" chaff extended beef sausages

Calcium, Iron, Potassium, Magnesium and Zinc were the minerals analysed for the sbeef sausages extended with "niri" chaffs (raw and roasted). The results showed a high Potassium content (25 – 30.438 mg/g) in extended products. The mineral with the least value in products was Zinc.

There was high calcium content in roasted chaff products than raw products. This suggests that the difference was as a result of the roasting. The calcium values of all extended products were significantly ($p < 0.001$) higher than the control. Again, the calcium values of extended products were higher than the calcium value of 4.5 mg/g for beef (Williams *et al.*, 2002). This is an indication that "niri" chaffs are a good source of calcium and would improve bone and teeth function when eaten on 100 g bases.

All extended products were significantly ($p < 0.001$) higher than the control in terms of iron content. Higher values were recorded in roasted products than the raw products. The values also increased as the inclusion levels of chaffs increased in products. This high iron content implies that consuming them will improve haemoglobin levels of consumers and especially children, pregnant and lactating mothers. This will help reduce anaemia and improve immune functions.

There was high potassium content in products than other minerals. This supports the assertion by Hamdallah (2004) that potassium is high in plants, animals and fish. There were decreases in potassium values as the inclusion level increases. This is because, chaffs (14.913 – 23.347 mg/g) have lower potassium values than that of pure beef (250 mg/g) and replacing meat with chaffs will naturally reduce the potassium levels. The appreciable level of potassium in products means their consumption will lead to improved heart performance (Pohl *et al*., 2013). It will also improve smooth muscles and skeletal contractions.

The extended products had significantly ($p < 0.001$) high magnesium values than the control. The values also increased as inclusion level of chaffs increased across treatments. This implies that more "niri" chaffs addition to a product will led to high magnesium level in diets. The high values of magnesium in extended products confirms the conclusion drawn by Gröber *et al*. (2015) that seeds contain more magnesium than meat. Roasted products also had high values than raw products. This suggests that heat treatment by roasting causes better extraction and release of minerals from cell walls (chaffs). The consumption of "niri" chaff beef sausages on 100 g bases will satisfy the daily magnesium requirement for all ages of persons. This will reduce hyperactivity, low stress tolerance, anorexia and vomiting among consumers (Gröber, 2009).

Zinc content of the control was significantly ($p < 0.001$) higher than all treatments but similar to 5 % raw chaff products. The zinc content of the control (0.620 mg/g) was however lower than that of beef (4.6 mg/g). A similar trend was observed between products and processed materials. This shows that processing caused significant loss of zinc. There was a reduction in zinc content as inclusion of test materials increased. This is due to the low zinc content in "niri" chaffs (0.1767 and 0.2367 mg/g respectively for roasted and raw chaffs). This caused much reduction as more of the low zinc material (chaffs) replaces high zinc material (beef). Despite these low values in extended products in comparison with the control, consuming them on 100 g bases a day will meet the 1.0 – 1.4 mg/day requirement recommended for all people by WHO (1996). This can help boost spermatozoa production and maturation in males (Nriagu, 2007). It can also contribute to reducing zinc deficiencies in sickle cell persons (Desphande *et al*., 2013).

5.4. pH of extended beef sausages

5.4.1 pH of "Niri" puree extended products

The pH of higher inclusion levels recorded high values. Roasted puree products recorded high values than raw product. High values in roasted products means roasting inhibited lactic acid formation which would have resulted in low values (highly acidic). The activities of lactic acid bacteria would have led to the breakdown of glycogen or carbohydrates causing low pH values. The general slightly acidic values of products could also be due to the low carbohydrate content of products. The high values could have also been caused by endoprotease activity which releases ammonium compounds (Mokhtar *et al*., 2012) as products have high protein contents. An increase in protein enzyme (endoprotease) activity could have been aided by the heat treatment which would have broken down protein digestion inhibitors in the "niri" seeds. The pH values in this study (5.83 – 6.15) are characteristic of the hydrogen ion concentration of 5.6 – 6.2 for meat (Dilbaghi and Sharma, 2007).

The pH values in this study will not allow the proliferation of bacterial pathogens. This is because many microorganisms do not thrive well under acidic conditions (Dilbaghi and Sharma, 2007).

The results of this study agree with 5.85 – 6.10 pH values for different sausages marketed locally in São Paulo (Ferrari and Torres, 2002). It also agrees with Dzudie *et al*. (2002) who reported significance ($p < 0.05$) in pH of beef sausages extended with dehulled common bean flour. Bhat and Pathak (2011) also reported increasing pH values as inclusion level of black beans increased in chicken seekh kababs. The results of this study are however lower than the 6.27 – 6.30 reported for cooked whole cowpea flour in frankfurter-type sausages (Akwetey *et al*., 2012).

The results therefore suggest that products are likely to have extended shelf life as the pH values are acidic. Acidic conditions result in long shelf life of products (Dilbaghi and Sharma, 2007).

5.4.2. pH of "Niri" chaffs extended products

The usage of "niri" chaffs did not alter the pH from what is characteristic of meat, the main constituent of products. The pH of products is consistent with the mean values of 5.85 – 6.10 for sausages marketed in different food markets in São Paulo (Ferrari and Torres, 2002). The results however disagree with Caceres *et al*. (2004) who found no significance in pH of sausages extended with indigestible oligosaccharides and the control.

According to FAO (2007), a pH of 5.08 – 5.6 give meat its characteristic flavour and improve water binding abilities of products. The results in this study are within FAO range and are therefore expected to have a characteristic meaty flavour desired by consumers.

Low pH values restrict microbial growth thereby prolonging shelf life of products (Dilbaghi and Sharma, 2007). The slightly acidic nature of products in this study means the products can be preserved for longer periods.

5.5. Peroxide values (PV) of extended sausages

5.5.1. Peroxide values (PV) of "Niri" puree extended sausages

It can be observed from Figure 4.3 that the peroxide values increased in all treatments during the storage period (three weeks). Products extended with "niri" purees had exceedingly high PV above the maximum permissible level of 25 milliequivalent of active oxygen per kilogram product (Bell and Weaver, 2002) for all fatty foods. The high PV of extended products is attributable to the addition of "niri" because the control had lower values within acceptable limits. Lipid oxidation to a large extend depends on the level of pro oxidants like free iron and antioxidants (vitamin E) as well as the fatty acid composition of the product (Dave and Ghally, 2011). Polyunsaturated fatty acids have high tendency to oxidation due to the presence of multiple unsaturated bonds. "Niri" being a plant material implies that its oil will have higher levels of unsaturated fatty acids. The high PVs means there are multiple unsaturated bonds whose continuous oxidation increases the active oxygen values. Oxidation of highly unsaturated fatty acids leads to the production of hydroperoxides (Dave and Ghally, 2011). These hydroperoxides are primary oxidation products which are not detrimental to nutritional and sensory characteristics of products. Further decomposition of hydroperoxides then lead to the production of secondary oxidation products. Nutritional qualities and colour losses are attributable to the presence of secondary oxidation products (Simitzis and Deligeorgis, 2010). Sensory and nutritional properties of this study did not show any significant reduction in the presence of the high peroxide values. This means that even at the third week, secondary oxidation has not set in. This therefore suggests the presence of multiple unsaturation of the fatty acids of "niri".

The presence of heme or free iron in products is also another determinant catalyzing lipid oxidation. This study revealed high significant level ($p < 0.001$) of iron in "niri" products than the control, hence the high peroxide values. Heat treatment by roasting however led to lower PVs than the raw "niri" puree extended products.

The results of this study disagrees with Teye *et al.* (2012) who reported PVs below 25 meq/kg product when cowpea was used as an extender in beef and ham burgers.

The outcome of this study suggests that "niri" has low levels of natural antioxidants and will therefore require synthetic antioxidants to improve upon its PV.

5.5.2 Peroxide Values of "Niri" Chaffs Extended Products

Peroxide values of extended chaff products were significantly higher than the control in each week of study. The raw chaff products had higher values than the roasted products. This implies that roasting has a significant impact in reducing the rate of oxidation of "niri" extended products.

The exceedingly high values did not affect sensory level of products. This suggests that secondary oxidation had not set in which would have caused off odour and colour changes in products.

5.6 . Formulation cost of "niri" extended beef products

This study revealed that "niri" extended products at 15 and 25 % inclusion level were lower in formulation cost than the control. This is because the cost of 15 or 25 % lean beef cost more than the same percentage cost of "niri" on kilogram basis. The cost of roasted products was higher than raw "niri" products due to the additional cost of processing (roasting) raw "niri". At 5 % inclusion level, the cost was more than the control. This is because, the cost of 5 % minced beef per kilogram is so small that the reduction could not absorb the extra cost of processing "niri" leding to an increase in cost. Though the reductions are small, they will make impact in business where productions are in large quantities. This study reveals that the extension of beef sausages with "niri" purees will result in lower formulation cost of products. These results are similar to Malav *et al*., (2013), who concluded that the use of lentil, sorghum, potato, water chestnut and extender blend caused a drop in cost of Reconstituted Chicken Meat balls from Rs (Indian rupee) 31, 45, 16, 38 and 46 for each Kg respectively in comparison with the control. The results of this study are also similar to Akwetey *et al*., (2012) who reported reduction in formulation cost (Gh¢ 8.68 – 6.58) per kilogram product when whole cowpea flour was extended from 0 to 20% in frankfurter type sausages.

Formulation cost of chaff products was lower than the control. The higher inclusion levels cost lower than the 5 % and control. The low cost of chaff products is on account of the fact that, the chaffs are waste after the extraction of purees and would have been disposed off. The only cost incurred, is the cost of drying and milling hence the low cost of products. Marichu *et al*., (2014) reported that, the inclusion of 75 % banana pseudo stem core in scrapple reduced production cost by 31.30 % making them more affordable than the control. The inclusion of pineapple dietary fibres at 0, 60, 100 and 200 % in beef sausages led to a formulation cost of R (South African rand) 34.23, 32.88, 32.96 and 32.89 respectively (Tshalibe, 2014). This implies that the addition of the fibres did not only increase bulk but led to a reduction in formulation cost of products. This will invariably lead to low cost of the extended products making them affordable to a majority of consumers.

CHAPTER SIX

6.0. CONCLUSIONS AND RECOMMENDATIONS

6.1. CONCLUSIONS

The study revealed that "niri" (*Citrullus vulgaris*) is a good source of protein which makes it a potential extender in sausages and other meat products.

The inclusion of "niri" as an extender does not have deterimental effect on sensory characteristics of sausages except colour. Products with roasted purees and chaffs were darker than the conventional products. Sausages with 25 % raw and roasted purees increased protein and fat contents but with decreased moisture contents. There were no differences in ash and carbohydrate contents. High inclusion levels of raw purees increased calcium, iron and potassium contents but with decreased magnesium and zinc contents than roasted products. Slightly acidic products were obtained with addition of raw and roasted "niri" purees in beef sausages. The addition of "niri" purees resulted in peroxide values being higher than the acceptable limits. Products extended with 25 % raw "niri" puree had the lowest formulation cost.

The addition of raw "niri" chaffs results in high moisture and protein contents than roasted chaff products. High ash, carbohydrate and fat contents were obtained at high inclusion level of roasted chaff products. Roasted chaff products at 25 % had high calcium, iron and magnesium contents but with low potassium and zinc values. The pH of all chaff products was all slightly acidic. The peroxide values were all above the acceptable limits with raw chaff products having the highest in each week of study. Raw and roasted purees and chaffs as extenders in beef sausages require antioxidants to prevent rancidity. Low formulation cost "niri" chaff extended beef sausages were obtained at 25 % inclusion level.

6.2. RECOMMENDATION

Further works should be done to improve Peroxide value and colour in all "niri" extended products.

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APPENDICES

"Niri" seeds being measured for puchase

"Niri" seeds being washed and sun dried

Seeds being sorted after sun drying

Seeds being roasted in an oven

Mashed milled seeds being sieved with cheese Cloth

Filtrates (raw to left and roasted to the right)

Chaffs being roasted in an oven

Chaffs being blended using blender