UNIVERSITY FOR DEVELOPMENT STUDIES, TAMALE

NUTRITIONAL COMPOSITION AND SENSORY PROPERTIES OF BEEF SAUSAGES PREPARED USING PEARL MILLET (*Pennisetum glaucum*) FLOUR AS EXTENDER

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DEPARTMENT OF ANIMAL SCIENCE

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DECLARATION

STUDENT

I hereby declare that this thesis is the result of my own hard work and that no such previous work has been presented in this University or elsewhere for the award of a degree. Works done by other authorities are duly acknowledged by reference to the authors.

Name: Joseph Yaro

Signature: ……………………… Date:………………………………

SUPERVISOR

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.

Name: Prof. Frederick Adzitey (PhD)

Signature……………………. Date: ………………………………..

ABSTRACT

The study investigated the nutritional and sensory qualities of beef sausages with pearl millet (*Pennisetum glaucum*) flour as extender. Three different experiments were conducted using raw, roasted and soaked pearl millet flour to replace lean beef at 0, 5, 10 and 15%. The treatments were arranged as a completely randomised design in each experiment. There was no significant (P > 0.05) differences in protein, fat, carbohydrate and ash contents of the three forms of flour. However, the moisture content of raw pearl millet flour was significantly (P < 0.05) higher than roasted pearl millet flour. Iron, zinc and calcium contents were significantly (P < 0.05) higher in roasted pearl millet flour than in raw and soaked pearl millet flours, while magnesium and potassium contents were significantly (P < 0.05) higher in raw pearl millet flour than in roasted and soaked pearl millet flours. The proximate results of raw pearl millet flour beef sausages (RaPMFS) were not significantly (P > 0.05) different except moisture and mineral contents that were significantly (P < 0.05) different with increasing level of replacement. The pH of the control was significantly (P < 0.05) lower than the flour treated sausages, while cooking loss significantly (P < 0.05) decreased with increased levels of replacement. There were significant (P < 0.05) differences in drip loss and water activity. Peroxide value and water holding capacity of the sausages were not significantly different. Sensory qualities of the flour treated sausages and the control did not differ significantly (P > 0.05) during the storage period except for flavour liking and overall liking which differed significantly (P< 0.05) in week two. Colour properties L* (Lightness) were not significantly (P > 0.05) different, but a*(Redness) and b* (Yellowness) were significantly (P < 0.05) different. The lowest formulation cost was achieved at increasing

replacement levels of pearl millet flour. Higher replacement of lean beef with roasted pearl millet flour resulted in reduced moisture content. Ash, fat and protein contents of roasted pearl millet flour beef sausages (RoPMFS) were not significantly (P > 0.05) different. Numerically, the 15% inclusion had a higher (20.02%) crude protein content than the control (18.81%). Mineral contents of the treatments were significantly higher (P < 0.05) than the control except for the 10%RoPMFS which was lower in potassium. Zinc content of the 5% inclusion was significantly (P < 0.05) higher than the control, 10% and 15% inclusions. pH increased with increased level of replacement, while cooking loss was lower at 10% inclusion. There were no significant (P > 0.05) differences in water holding capacity and peroxide value of the sausages, whereas drip loss and water activity of the sausages were significantly (P < 0.05) different. There was a non-significant (P > 0.05) difference in the sensory qualities in week 1 and 3, however, in week two overall liking of the control was significantly (P < 0.05) higher than the 10% and 15% inclusion. Colour properties L* (Lightness) did not differ significantly (P > 0.05), but a* (Redness) and b* (Yellowness) were significantly (P < 0.05) different. Low formulation cost was achieved at higher inclusion level. The proximate results of soaked pearl millet flour beef sausages (SoPMFS) were not significantly (P > 0.05) different except moisture content. Iron, magnesium and calcium contents of the treatments were significantly (P < 0.05) higher than the control. However, potassium and zinc contents of the control were significantly (P < 0.05) higher than the treatments. The pH was not significantly (P > 0.05) different, cooking loss was lowest at 15% inclusion. Water holding capacity of the control was significantly (P < 0.05) higher than the 15% inclusion, while the water activity of the 10% inclusion was significantly (P

< 0.05) lower than the control. There were non-significant ($P > 0.05$) differences in peroxide value and sensory characteristics of the sausages. The inclusion of pearl millet flour as an extender did not impact negatively on the sensory and nutritional qualities of beef sausages. Pearl millet flour (raw, roasted and soaked) can be incorporated up to 10% in beef sausages by meat processors.

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DEDICATION

This work is dedicated to my mother Amina Yaro.

TABLE OF CONTENT

Contents Pages

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER ONE

INTRODUCTION

Meat is an animal flesh that is considered as an excellent source of high biological value protein, minerals and vitamins, and 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 increase their productivity.

Raw meats are highly susceptible to microbiological contaminates during processing and heat treatment is usually not enough to completely remove these microbes in the industries (Trindade *et al*., 2010). The 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 therefore has resulted in an increased demand for convenience meat and meat products requiring minimal home preparation (Stubbs e*t al*., 2002) and hence call for processing of convenient or ready-to-eat meat products to meet these demands.

Meat processing is a means of transforming raw meat into valuable products for consumption and storage (Aberle *et al*., 2001).

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 action. 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; Kalaloui *et al*., 2010) 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 linked to the industry and serve as source of income generation (Smith and Hui, 2008). 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 casing (Ismed, 2016).

The Expensive nature of boneless meat leads to an increased cost of production of processed meat products (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 in malnutrition and consequently decrease productivity. There is the need therefore to find ways of reducing cost of meat products to make them affordable to a majority of the population. This can be achieved by the use of extenders in meat product formulation (Teye *et al*., 2012).

Extenders or fillers according to FAO (1991) are protein or carbohydrate additives (mainly of plant or animal sources) used to increase yield and water holding ability of meat products. FAO (2013) stated that extenders are used in meat products to improve meat particle cohesion, increase processing yield and dietary fibre to improve texture and reduce formulation costs. Common examples are flours of cereals and legumes, soy proteins, starch and milk proteins. In Ghana, cassava flour, anchovy, yam flour and soy protein are the common fillers or extenders used (Anang, 1993; Annor-Frempong *et al*., 1996; Anang *et al*., 1999). 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 (Zakaria, 2003; Serdaroglu *et al*., 2004; Teye *et al*., 2006; Teye *et al*., 2009). This gave an indication that locally available materials can be used as extenders in meat products formulation. One such local food/feed resource is the pearl millet (*Pennisetum glaucum*).

Millet, a versatile grain is highly nutritious, non-glutinous and non-acid form of food (Hrideek and Nampoothiri, 2017). It contains high amount of macro as well as micro nutrients, also rich in phytochemicals including lignans, phenolic acids and phytosterols (Shahidi and Chandrasekara, 2013). Millet are small seeded cereals with excellent nutritional quality. They are comparable or superior to commonly consumed grains such as wheat and rice (Ragaee *et al*., 2006). The grains are consumed as food by millions of people throughout the world. In food industry, the plant nutrients are larger and also the cereals grain constitutes the major source of dietary fibre (Izadi *et al*., 2012). Traditionally, fermented millet products are used in Northern Ghana as a natural probiotic for the treatment of diarrhoea in young children (Lei *et al*., 2006). Consumption of whole millet has health-promoting effects that are equal to, or even in higher amount when compared to fruits and vegetables and has the ability to protect against insulin resistance, heart disease, diabetes, ischemic stroke, obesity, breast cancer, childhood asthma and premature death (Cade *et al*., 2007). Gluten is absent from the grain and can be consumed by people with celiac disease (Gabrovska *et al*., 2002). Consumption of millet can lower glycemic response which is helpful for the treatment of type II diabetes (Choi *et al*., 2005). Despite the health benefits and uses, its potential as an extender in meat products are yet to be exploited.

This study sought to evaluate the sensory and nutritional qualities of pearl millet flour as an extender in beef sausage.

The specific objectives of the study are to determine;

1. The nutritional composition (proximate and mineral) of pearl millet flour (raw, roasted and soaked).
2. The sensory properties of pearl millet flour beef sausages.
3. The nutritional composition (proximate and mineral) of peal millet flour beef sausages.
4. The pH values of the peal millet flour beef sausages.
5. The peroxide values of the pearl millet flour beef sausages.
6. The water holding capacity/ activity (a_w) of the sausages.
7. The production cost of pearl millet flour beef sausages.

CHAPTER TWO

2.0. LITERATURE REVIEW

2.1. Meat

Meat is defined by the Food Standards of Australia and New Zealand (FSANZ) (2002) as the part or entire carcass of a slaughtered goat, pig, cattle, sheep, buffalo, camel, deer, hare or rabbit other than their wild state, but does not include eggs or foetuses. 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 in to “red” or “white” depending on the source. Red meat is described as meat from cattle, goat and sheep (Williams, 2007). The most sort after in Africa, Europe, North and South America is beef (Warriss, 2010). White meat on the other hand describes meat from poultry and pork. Significant percentage of the recommended dietary allowances for proteins, vitamins-B, iron, and zinc are contributed by red meat and poultry (Pearson and Brooks, 1978).

2.1.1. Physical Composition of Meat

According to Heinz and Hautzinger (2007), muscles are attached to skeletons by tendons. A muscle consists of many muscles fibre bundles which are macroscopic containing 30 to 80 muscles fibres or muscles cells (Heinz and Hantzinger, 2007). Breed and type of animals and age are determinants of the size and diameter of muscles cells (Rehfeldt *et al.*, 2004). Blood vessels, fat (intramuscular) and connective tissues are located between muscle cells (Hocquette *et al*., 2010). Sarcolemma (cell membrane) envelops such muscle cell. Sarcoplasma (a soft protein structure) is made of numerous filaments called myofibrils. The myofibril is therefore the basic unit of the muscle (Rehfeldt *et al*.,2000).

2.1.2. Chemical Composition of Meat

Meat is composed of water, mineral, protein, fat and small proportion of carbohydrates (Aberle and Forrest, 2001). It is recognised as a highly nutritious food, being an excellent source of high-quality protein, containing a good balance of the essential amino acids and having high biological value. According to Briggs and Schweigert (1990), a muscle contains about 75%, 20%, 3% and 2% of 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, 5% fat, and a very small amount of carbohydrate, nucleotides, dipeptides and amino acid. The most valuable of these components is protein.

2.1.3. Nutritional Composition of Red Meat

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 (Williams, 2007). Biological value describes the ease with which proteins can easily be incorporated into the body tissues for growth and maintenance of body cells (Wolpert *et al*., 2015). 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 (Neumann *et* *al*., 2002). 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 28-36 g/100g than the 20-25 g/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 of 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
Vitamin B6 (mg)	0.52	0.8
Vitamin B12 (ug)	2.5	2.8

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

Table 2.1 shows that beef is a good source of protein. It also has a relatively low amount of fat and cholesterol than mutton and appreciable amount of energy, vitamins B6 and Vitamin B12. 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 sausage 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 Product/100g

Product	Moisture	Protein	Fat	Ash	Calories
Beef (lean)	7.5	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. Protein

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 has 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. Red meat enhances vitality of food because it has high quality protein and elevated bioavailable iron (Paddon-Jones and Leidy, 2014). 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 (Weigle *et al*., 2005; Bopp *et al*., 2008; Kushner and Doerfler, 2008; Wycherley *et al*., 2012).

Middle age persons are encouraged to ingest more high-quality protein so as to preserve the value of life connected with sufficient muscle mass through the consumption of meat (Dario *et al*., 2016). 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 *et al*., 2008; Paddon-Jones and Rasmussen, 2009; Paddon-Jones and Leidy, 2014).

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 Mazahari, 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 constituent 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 suggests that fat is indispensable in human diet.

2.1.3.3. Mineral Composition of Red Meat

Soetan *et al.* (2010) defined minerals as inorganic substances in all body tissues and fluids which are for the preservation of specific physicochemical processes essential to life. They play essential roles in many body activities except energy (Eruvbetime, 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 sulphur. Ultra-trace mineral includes boron, arsenic, silicon and nickel (Nielsen, 1991). Major minerals are needed in greater amounts (more than 100mg/dl) and minor minerals are needed in small quantities (less than 100 mg/dl) by the body (Murray *et al*., 2000). The biggest public health concern in most developing countries is micro nutrient 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 micronutrient for a healthy living.

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 (Williams, 2007). 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 (ug)	17	14	<10

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

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 1200 g (Ilich and Kerstetter, 2000). The skeleton and teeth constitute about 90% of body calcium where it provides rigidity while body fluids and soft tissues account for the remaining 10% (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 (Pravina *et al*., 2013). 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 hinder normal body function and conformation. Calcium deficiencies lead to inadequate calcium phosphate calcification of bones in growing children causing rickets (Prentice, 2013). 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 (Van Biljon, 2007). 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 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 source of non-haem iron (California Nutrition and Physical Activity Guideline 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 contain 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 order hand require 10 and 9 mg/day, respectively for 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 person 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 minerals 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 form animal products in their foods (Bhaskarachary, 2011).

Accordance to Kinabo (2015), beef contains 230 mg/g and 122 mg/g for fish but lower than groundnut (705 mg/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	Adequate intake (mg/day)
0-6 months	400
7-12 months	700
1-3 years	3000
4-8 years	3800
9-13 years	4500
14-18 years	4700
>18 years	4700
Pregnant women 1- 50 years	4700
Lactating women 1- 50 years	5100

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 (Grober *et al*., 2015). About 60% of total body magnesium is stored in bones while 40% is situated in extra and intracellular tissues (Grober *et al*., 2015). According to Jahnen *et al*. (2012), an adult weighing 70kg with 2% (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 (Grober *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 diarrhoea and infections (Hambidge and Krebs, 2007). Brown *et al*. (2002) undertook a study in developing countries and confirmed that, zinc deficiency was commonly found in meat, chicken, fish, cereals and vegetables. Though zinc is found in many foods, the deficiency problems 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 discourages 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 stabilization. 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 microbial 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 limits 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 source (FAO, 1992), reducing malnutrition and improving health status of consumers. Researchers have discovered that meat could be processed into products like, burgers, sausages, frankfurter, meat balls, 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 (Ehr *et al*., 2016). 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 (Trosnky, 2004; 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 product made form 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 casings of particular shape and size (University of Georgia (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 groups 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 pre-cooked and fresh sausages.

2.2.1.1. Fresh 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 (Essein, 2003). These sausages are sub-divided into semi-dry (Summer sausage or cervelat, Lebanon bologna) and dry sausages (Salami, Pepperoni and Genoa) (Essien, 2013)

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. Composition of Sausage

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 material in sausage making include; lean meat, fat, ice cubes, nitrite, phosphate, sugar, acorbates, 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 product. 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 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. The 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 peppers, sage, chilli peppers and adobo. These may be added 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 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. The 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 solutions phase of meat product 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 myofibrillar 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 with 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 excessed 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. The Role of Phosphates in Sausages

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 monophosphates (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 month need 100 mg/day, 7-12 months require 275 mg/day, 1-3 years need 460 mg/day and 4-8 years need 500 mg/day. Others are; 9-18 years need 1,250 mg/day, adults more than 19 years need 700 mg/day, expectant mothers or breastfeeding women 14 to 18 years need 1,250 mg/day and women above 18 years, 700mg/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 5 g/kg phosphorus peroxide (P_2O_5) alone or in a mixture is the maximum permissible limit of phosphates in minced meat and meat products by the European legislation (Directive No. 95/2/EC, Rev. 2006). Phosphates play essential roles on physical and sensory properties of meat and meat products. Combinations of monophosphates (monosodium phosphates, disodium phosphates and trisodium phosphates) are outstanding buffers; except diphosphate 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 bacteriostatic property when used with acidulants or amalgamation with food ingredient 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* (Buokava *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. The 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 reaction proceed but nitrites proceed 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 nitrite is recommended for products that are cooked at high temperatures (≤120ppm/kg nitrite in bacon) than products that are cooked at relatively low temperatures like ham (≤ 200ppm/kg) (Xiong, 2012). Cancer should therefore not be a major concern to the average meat consumer 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 possess 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 (Gadekar, 2009; Xiong, 2012). Nitrite is the only known compound that can simultaneously perform all these functions in cured meats (Xiong, 2012).

2.2.2.5 The Use of Ice/Water in Sausage Formulation

Product temperature could increase quite quickly during chopping and ice or ice water addition avoids this (Essien, 2003). Ice and ice water are 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. The Use of Casing in Sausages

Casings in general provide sausages shapes, 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 gastrointestinal tract of hogs and beef cattle (Essien, 2003). Ehr *et al*. (2016) classified hog casing 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-casing 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^{o}C (Essien, 2003).

Artificial casings 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 colour. 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 (Dilbaghi and Sharma, 2007). 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 the 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. Water Holding Capacity (WHC)

Van Laack (1999) stated that water holding capacity of meat products is a very important quality attribute which has an influence on product yield, with implications on economics as well as eating quality. A number of factors such as pre-and post mortem factors influence the water holding capacity of meat and meat products. Early post mortem events including rate and extent of pH decline, proteolysis and protein oxidation are key in influencing the ability of meat and products to retain moisture (Cheng and Sun, 2008). As rigor progresses after slaughter, the space for water to be held in the myofibrils is reduced and fluid can be forced into the extra myofibrillar spaces where it is more easily lost as drip (Lonergan and Lonergan, 2005). Factors such as growth and development of meat animals/species, genotype and animal diet are important due to their influence on muscle characteristics (Cheng and Sun, 2008). Cooking and cooling procedures for the final meat products can also affect the WHC of the product, in particular the cooking and cooling methods, the heating and cooling rate, the cooking temperature, and endpoint temperature (Cheng and Sun, 2008).

2.3.3. Peroxide Value (PV)

Oxidation is a hydrogenation 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 muscles 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 catalysts 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 condition. 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 catalyses 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. The Use Extenders in Meat Processing

Meat extenders are non-meat ingredients with significant protein content used in the meat industry with the prime intension 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 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 (PUFA) (Muguerza *et al*., 2004). High ratio of n-3 PUFAs exercise suppressive properties on the pathogenesis of several diseases like cardiovascular diseases (CVD), inflammatory, cancer and auto-immune diseases (Simopoulos, 2002).

Among the n-3 PUFAs, α – linolenic acid (ALNA, C18:3) can be found in large amounts in plant products (Jimenez- Colemenero, 2007) but little in animal products (Badpa and Ahmad, 2014) hence the need for extension of meat product 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, radish) (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 beef (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 (>2mm), minced (>2mm) and chunks (15-20mm) capable of absorbing 2.5 to 5 times water relative to their initial weight (Riaz, 2004). These non-meat 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 very dry if hydration is done with too little water (Asgar *et al*., 2010). A review by Badpa and Ahmad (2014) on "development 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 protein, 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 highest (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 Characteristics 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 Evaluation 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 school, 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 were 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 hamburgers. 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 bread crumb products (Ergezer *et al*., 2014).

2.5 Production Cost of Extended Beef Products

Modernity has drifted consumers' satisfaction for traditional meat product (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 protein 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% reduction in the cost of meat products (Heinz and Hautzinger, 2007). This will make processed meat product reasonably priced and afford consumers the ability to regularly purchase them (Decker and Park, 2010) through the use of plant proteins (Odiase *et al*., 2013).

2.6. Millet

2.6.1. Production, Cultivation and Consumption of Millet

Millets are small seeded cereal grains consumed as food by millions of people throughout the world (Dayakar Rao *et al*.,2017). They are hardy and grow well in dry zones as rain-fed crops, under marginal conditions of soil fertility and moisture (FAO and ICRISAT, 1996), making them the preferred cereal crop in drier areas.

Millets are among the oldest human food crops and probably the first cereal grain to be used for domestic purposes (Anonymous, 2003). The first reported records of millet cultivation date back to China at about 5,500 BC (Crawford, 2006).

They are extremely important crops in semi-arid regions where other crops normally do not survive. Pearl millet is more tolerant to drought (Nouri *et al*., 2003) and low soil fertility than sorghum and plays a major role in the world's food security and economy. These crops are commonly grown in India, Africa and China (Dendy, 2001). In 2007, total world millet production was recorded at 32 million tonnes, with India (10,610,000 tonnes) being the top producer (FAO, 2009). Millet is the sixth most important cereal and feeds one third of the world's total population (Saleh *et al*., 2013). They are easy to grow, inherently bio-diverse and can be grown with varied crops (Rachie, 1975; Dendy, 1995) and have shorter harvesting time (45-65 days) (Bukhari *et al*., 2011). According to the Statistics Research and Information Directorate (SRID) (2011) of the Ministry of Food and Agriculture pearl millet is grown in the northern sector of the country. Izadi *et al*. (2012) stated that in the food industry the plant nutrients are larger and also constitutes the major sources of dietary fibre.

According to FAOSTAT (2005), the global consumption of millet for an average of five years was found to be highest in India, followed by Nigeria, Niger, China, Burkina Faso, Mali, Sudan and Uganda.

2.6.2. Therapeutic Significance of Millet

The consumption of whole millets has health promoting effects which is equal to or even in higher amount when compared to fruits and vegetables and has the potential to protect against insulin resistance, heart diseases, diabetes, ischemic stroke, overweight, breast cancer, childhood asthma and premature mortality (Cade *et al*., 2007). These crops lack gluten, and can therefore be eaten by people with celiac disease (Gabrovska *et al*., 2002). Millet intake can also minimize glycemic response, which can be helpful in the treatment of type II diabetes (Choi *et al*., 2005). Inclusion of millet in the human diet can also lower the risk of duodenal ulcers, anaemia and constipation (Jayaraj *et al*., 1980; Nambiar *et al*., 2011).

Millets are good sources of minerals especially magnesium and phosphorus (Admassu *et al*., 2009). Intake of magnesium helps to reduce the effects of migraine, also lowers high blood pressure (Volpe, 2013). The phosphorus present in millets also is essential component of Adenosine Triphosphate (ATP) that acts as a precursor to energy in the body. Niacin helps to reduce the body's high levels of cholesterol (Shashi *et al*., 2007; Liang et al., 2010; Devi *et al*., 2011; Guigliano *et al*. 2011.;). Viswanath *et al*. (2009) and reported that extract from millet seed coat has high antibacterial and antifungal activity when compared to extract from wheat flour due to high polyphenols content in seed coat and also rich in phytochemicals including phytic acids, thereby helps to lower cholesterol and phytate levels which is associated with reduced cancer risk (Coulibaly *et al*., 2011; Izadi *et al*., 2012). Millet have higher free radical quenching potential (Devi *et al*., 2011; Quesada *et al*., 2011; Kamara *et al*., 2012).

2.6.3. Nutritional Properties of Millet

Millet grains are superior in nutritional qualities and possess several health benefits with nutraceutical potential for human health (Malleshi and Hadimani *et al*., 1993). They are good sources of carbohydrates, protein, fat and also contain high proportions of vitamins and minerals (Saleh *et al*., 2013).

The seed coat fractions enclosed comparatively higher levels of fat, protein, calcium, phosphorus and iron (Saleh *et al*., 2013). Dietary fibre is highest in the seed coat followed by powder (Malleshi and Hadimani *et al*., 1993; Mbithi-Mwikya *et al*., 2000). Vitamin 'B' is found to be important sources of millet and it possess higher amount of ash, iron, phosphorus, dietary fibre and amino acids than rice or wheat (Rao, 1986; FAO 1995; Genapati *et al*., 2008).

The presence of natural antioxidants like vitamin C, tocopherol, carotenoids and polyphenol helps to prevent the free radical damage in the body (Malleshi *et al*., 1993; Vithal *et al*., 2006; Sri Devi *et al*., 2008; Chandrashekhar and Shahidi., 2010). Among the whole grain foods, millet shows higher antioxidants activity due to the presence of minerals (Ca, Mg, K, P, Fe and Na) and phytochemicals (phytates and phenolic compounds) which play major role in the body immune system (Saleh *et al*., 2013). Millets are rich source of nutrients and contain 60-70% dietary carbohydrates, 6-19% protein, 1.5-5% fat, 12-20% dietary fibre and 2-4% minerals (Bora, 2013). The protein of pearl millet ranged from 8-19 percent (Serna-Salvidar *et al*., 1991). Ejeta *et al*. (1987) reported that pearl millet contains 27-32% more protein than maize, higher concentration of amino acids, twice the ether extract and higher gross energy than maize. Kamara *et al*. (2009) indicated that pearl millet contains 12.3% crude protein, 3.3% minerals and 72% carbohydrates which include the main components such as starch, protein, lipid, vitamin and minerals. Essential amino acids profile of pearl millet contains about 40% of lysine and methionine and it contains 30% of threonine when compared to protein present in corn (Burton *et al*., 1972; FAO/WHO, 1995; Gopalan *et al*., 2000).

2.6.4. Utilization of Millet

Millets serve as the main ingredient in traditional food and beverage preparation (Saleh *et al*., 2013). The availability of necessary nutrients in millets is sufficient for the manufacture of food items such as snack foods, baby foods and healthy foods (Bahadur *et al*., 2011). In traditional preparation, millets are consumed in the form of thick porridge, thin fermented porridge, fried or baked pancake and beverages. Millets are used as raw materials in industries for the production of biscuits and confectionery, beverages, weaning foods and beers (Anukam and Reid, 2009; Laminu *et al*., 2011). Malted and fermented millet powder are used in preparation of weaning food, instant mixes and beverages in pharmaceutical products (Gomez *et al*., 1993; Rao *et al*., 2001).

CHAPTER THREE

3.0. MATERIALS AND METHODS

3.1. Study Site

The study was conducted at the University for Development Studies (UDS), Tamale. Product preparations and formulation took place at the Meat Processing Unit of the Department of Animal Science, UDS Nyankpala. Proximate analyses, pH, and peroxide values of test materials and products were determined at the Spanish Laboratory in the Food Technology Laboratory of the University for Development Studies. Mineral analyses were carried out at the Central Laboratory of the Kwame Nkrumah University of Science and Technology, Kumasi.

3.2 Experimental Design

Completely randomized design was used to assign treatments to minced meat. The research was composed of three different experiments. Experiment one (1) was to determine the nutritional composition of raw pearl millet flour (RaPMF) and its effects on sensory properties, experiment two (2) was to determine the nutritional composition of roasted pearl millet flour (RoPMF) and its effects on sensory properties and experiment three (3) was to determine the nutritional composition of soaked pearl millet flour (SoPMF) and its effects on sensory properties of the beef sausages. All three experiments were evaluated against a control (without test materials). The treatment levels were 0%, 5%, 10% and 15% per kilogram of minced beef for all three experiments.

3.3. Source of Pearl Millet (PM)

Three bowls of PM were bought from the Aboabu local market, Tamale. The millets were sieved and then washed with tap water to remove dirt and other foreign materials.

3.3.1. Raw Pearl Millet Flour (RaPMF) Preparation

The millet grains were washed in a basin with tap water to remove dirt and foreign materials. Washing was repeated three times while decanting to obtain clean grains. The grains were then sun-dried on a polythene material for about 8 hours and milled into flour using a conventional corn mill. The flour was then stored in an airtight container awaiting product formulation.

3.3.2. Roasted Pearl Millet Flour (RoPMF)

The millet grains were washed in a basin with tap water to remove dirt and foreign materials. Washing was repeated three times while decanting to obtain clean grains. The grains were then sun-dried on a polythene material for about 8 hours after which they were roasted in a cooking pot on a red flame/hot fire by continuously stirring to ensure even browning of grains. Roasted grains were allowed to stand for about 2 hours to cool down and subsequently milled into flour using a conventional corn mill.

3.3.3. Soaked Pearl Millet Flour (SoPMF)

The millet grains were washed in a basin with tap water to remove dirt and foreign materials. Washing was repeated three times while decanting to obtain clean grains. The grains were then put in a plastic container and tap water added in a ratio of 1: 2 after which it was allowed to stand for 24 hours at room temperature. The soaked grains were removed from the plastic container and washed with fresh water after which they were milled and dried in the sun for about 8 hours using polythene material. The dried flour was then re-milled to obtain fine flour and stored in an airtight container awaiting product formulation.

3.4. Product Formulation

Raw, roasted and soaked pearl millet flours and minced beef were formulated on two-kilogram (2 kg) basis. They replaced minced beef at 0, 5, 10 and 15% on two-kilogram basis. Spices and ice cubes were added equally to each treatment. The formulations are shown in Tables 3.1, 3.2 and 3.3

Table 3.1: Sausage Formulation with Raw Pearl Millet Flour (RaPMF)

Ingredients (kg)	**Treatments**			
	0%	**5%**	**10%**	**15%**
Beef	2.00	1.90	1.80	1.70
RaPMF	0	0.10	0.20	0.30
Curing salt	0.03	0.03	0.03	0.03
Adobo	0.002	0.002	0.002	0.002
White pepper	0.004	0.004	0.004	0.004
Black pepper	0.004	0.004	0.004	0.004
Chilli pepper	0.001	0.001	0.001	0.001
Phosphate	0.01	0.01	0.01	0.01
Ice cubes	0.14	0.14	0.14	0.14
Soy oil	0.26	0.26	0.26	0.26

Table 3.2: Sausage Formulation with Roasted Pearl Millet Flour (RoPMF) on kg basis

Ingredients	Treatments			
	0%	**5%**	**10%**	**15%**
Beef	2.00	1.90	1.80	1.70
RoPMF	0	0.10	0.20	0.30
Curing salt	0.03	0.03	0.03	0.03
Adobo	0.002	0.002	0.002	0.002
White pepper	0.004	0.004	0.004	0.004
Black pepper	0.004	0.004	0.004	0.004
Chilli pepper	0.001	0.001	0.001	0.001
Phosphate	0.01	0.01	0.01	0.01
Ice cubes	0.14	0.14	0.14	0.14
Soy oil	0.26	0.26	0.26	0.26

Table 3.3: Sausage Formulation with Soaked Pearl Millet Flour (SoPMF) on kg basis

Ingredients	Treatments			
	0%	5%	10%	15%
Beef	2.00	1.90	1.80	1.70
SoPMF	0	0.10	0.20	0.30
Curing salt	0.03	0.03	0.03	0.03
Adobo	0.002	0.002	0.002	0.002
White pepper	0.004	0.004	0.004	0.004
Black pepper	0.004	0.004	0.004	0.004
Chilli pepper	0.001	0.001	0.001	0.001
Phosphate	0.01	0.01	0.01	0.01
Ice cubes	0.14	0.14	0.14	0.14
Soy oil	0.26	0.26	0.26	0.26

3.5. Sausage Preparation

Thirty kilograms (30 kg) of lean meat (boneless beef) was obtained from UDS Meats Unit and trimmed of all visible fat and connective tissue. The meat was cut into smaller sizes and minced using a 5 mm sieve table top mincer (Telleres

Rammon, Spain). The minced meat (beef) was weighed according to each treatment formula using a digital scale as indicated in Tables 3.1, 3.2 and 3.3.

The minced beef was thoroughly comminuted together with spices using 3-knife, 30 litre capacity bowl chopper (Telleres Rammon, Spain). Crushed ice cubes were added to each treatment during comminution to obtain the desired consistency and to maintain comminution temperature at 16º C.

The comminuted beef was transferred into a hydraulic stuffer (Telleres Rammon, Spain), stuffed into natural casings and manually linked into equal length of about 10 cm.

3.5.1. Smoking and Scalding

Sausages were hanged onto smoking racks and smoked for 1 hour and 45 minutes and then scalded to a core temperature of 70º C. They were then cooled in chilled water for 30 minutes and hunged on racks for adhering water to drain prior to packaging.

3.5.2. Packaging of Products

The sausages were bagged in zip lock bags and vacuum sealed using an electronic vacuum sealer (Busch, Rammon, Spain), labeled and stored in a deep freezer awaiting sensory and laboratory analysis.

3.6. Preparation of Products for Sensory Evaluation

The products were removed from the deep freezer and allowed to thaw for about three hours (3 h) under normal room temperature. The thawed samples were then grilled in an electric oven (Turbofan, Blue Seal, UK) at a temperature of 105º C for forty-five minutes (45 min.), sliced into uniform sizes of about 2 cm in length and wrapped with coded aluminium foil to keep them warm and packed into mini ice chest prior to test.

3.7. Sensory Evaluation of Products

A total of fifteen (15) panelists were selected at random from the University for Development Studies, comprising of students and staff and trained according to the British Standard Institution guidelines (BSI, 1993) to constitute the taste panel. Sensory evaluation of the products was carried out on the first, second and third week of product formulation. The products were presented to each of the panelist to independently evaluate each treatment in a well-lit room using a nine-point hedonic scale as shown in Table 3.4.

Table 3.4: Sensory Analysis Outline

Parameter	Scale								
	1	2	3	4	5	6	7	8	9
Colour	Extremely dark	Very dark	Moderately dark	Slightly dark	Intermediate	Slightly pale	Moderately pale	Very pale	Extremely pale
			Moderately weak				Moderately strong		
Flavour intensity	Extremely weak	Very weak	Dislike moderately	Slightly weak	Intermediate	Slightly strong	Like moderately	Very strong	Extremely strong
			Moderately tough				Moderately tender		Like extremely
Flavour liking	Dislike extremely	Dislike very much	Moderately rough	Dislike slightly	Intermediate	Like slightly	Moderately smooth	Like very much	
		Very tough	Moderately bitter				Moderately sweet		Extremely tender
Tenderness	Extremely tough		Moderately dry	Slightly tough	Intermediate	Slightly tender	Moderately juicy	Very tender	
		Very rough					Like moderately		Extremely smooth
Texture	Extremely rough		Dislike moderately	Slightly rough	Intermediate	Slightly smooth		Very smooth	Extremely sweet
		Very bitter							
Taste	Extremely bitter			Slightly bitter	Intermediate	Slightly sweet		Very sweet	Extremely juicy
		Very dry							
Juiciness	Extremely dry			Slightly dry	Intermediate	Slightly juicy		Very juicy	Like extremely
		Dislike very much							
Overall liking	Dislike extremely			Dislike slightly	intermediate	Like slightly		Like very much	

3.8. Physicochemical Properties

3.8.1. Water Holding Capacity (WHC)

Water holding capacity was determined according to Heywood *et al*. (2002) with slight modification where the sample was centrifuged at 3700 rpm instead of 3709 rpm. About two and a half grams (2.5 g) from each sample was placed in a pre-weighed 50 ml plastic centrifuge tubes and 10 ml of distilled water was added to form a mixture. The well mixed samples were allowed to stand for about thirty minutes at room temperature and centrifuged at 3700 rpm for thirty minutes using ROTOFIX 32 A (Hettich, IVD, CE, Germany). After centrifugation, the supernatant was carefully decanted and the sample weight taken. WHC was calculated according to the following equation:

WHC/g = Dw – Sw

$$\text{WHC (\%)} = \frac{DW - SW}{SW} \times 100$$

Where: Dw is the decant weight of sample after centrifugation

Sw is the sample weight

3.8.2. Water Activity (a_w)

The water activity values were measured with Novasina AG (CH-8853 Lachen, Switzerland) using 2.5 g of each sample. Measurement were done in triplicates.

3.8.3. Instrumental Colour Measurement

The colour measurement was performed using Chroma Meter CR 400 (Konica Minolta, Inc, Japan). Measurement were taken on day 0, day 7, day 14 and day 21 post processing. Commission Internationale de l'Eclairage (CIE) lightness (L*), redness (a*) and yellowness (b*) values were measured on both the surface and internal parts from three different randomly chosen spots of the sausage samples. Colour measurement was done according to (CIE, 1986).

3.8.4. Cooking Loss

The cooking loss was determined according to Lee *et al*. (2008). Frozen samples were removed from the freezer and allowed to thaw under room temperature for about three hours (3 h). Three fingers from each treatment were weighed separately and then grilled in an oven at 150° C for about 45 min to a core temperature of 70° C. Samples were allowed to cool at room temperature and reweighed. Cooking losses were determined by weight difference between raw and cooked/grilled sausage. Cooking loss was determined as the loss in weight during cooking and expressed as a percentage of pre -cooking weight as follows:

Cooking loss = Raw weight – Cooked weight

$$\text{Cooking loss \%} = \frac{Wr - Wc}{Wr} \times 100$$

Where:

Wr = weight of raw sausage.

Wc = weight of cooked sausage.

3.8.5. Drip Loss

Drip loss was determined by the standard bag method (Honikel, 1987). Sausages were weighed immediately after they were prepared and suspended in airtight transparent polythene bags over forty-eight hours (48 h) at 4º C in a chiller. The drip loss was measured as the weight loss during the suspension and expressed as a percentage relative to the initial weight.

Drip loss = ISW – FSW

Drip loss % = $\frac{ISW - FSW}{ISW} \times 100$

Where: ISW is the initial sample weight before suspension

FSW is the final sample weight after suspension

3.9. Laboratory Analysis

3.9.1. Protein Content Determination

The protein content of the samples was determined by the micro-kjedahl technique according to the A.O.A.C (2012). One gram (1 g) of dried samples were weighed onto filter papers and folded into dry Kjedahl flask. Kjeltabs CQ 9 (2 tablets each) were placed in each Kjedahl flask, after which 15 ml of concentrated sulphuric acid (H_2SO_4) were added, the sample contents were then digested for four hours (4 h) and cooled for two hours (2 h). Fifty millilitres (50 ml) of distilled water and sodium hydroxide (NaOH) were added and the content were placed into the distillation apparatus and distilled for 13 minutes. The ammonia evolved was received in 25 ml of 2% boric acid solution. The trapped ammonia was titrated against HCl (0.1N) solution until there was a change in colour to pale pink. The total nitrogen and protein were calculated using the following formula:

$$N\% = \frac{Volume\ of\ HCl \times N \times 14 \times 100}{Weight\ of\ sample \times 1000}$$

P% = N% × 6.25

Where:

N% = crude nitrogen.

P% = crude protein.

N = normality of HCl.

14 = equivalent weight of nitrogen

3.9.2. Fat Content

Total fat was determined according to the A.O.A.C method (2012). For each sample, three point five grams (3.5 g) was weighed into a thimble and plugged with cotton wool before placing them in the thimble holder. Fifty millilitres (50 ml) of petroleum ether (40-60º C) were added into a pre-weighed and dried fat cans. The cans and the thimble holder with the thimbles were attached to the fat extractor (Soxhlet Extractor). The samples in the thimbles were then soaked in petroleum ether in the fat cans and allowed to boil for thirty minutes (30 min.), rising was then done for twenty minutes (20 min) followed by evaporation for ten minutes (10 min). The cans with the extracted fat were allowed to cool down in a desiccator before taking the total weight (can + fat). The fat content was calculated according to the following equation:

$$Fat\% = \frac{W2 - W1}{Weight\ of\ sample} \times 100$$

Where:

W1 = weight of empty can.

W2 = weight of can with fat/oil.

3.9.3. Ash Content

The ash content of samples was measured according to the A.O.A.C method (2012) using a muffle furnace. Five grams (5 g) of each sample was weighed into a porcelain crucible and placed in a temperature-controlled furnace at 550º C to 600º C for complete ashing. After 2 h of complete ashing, the crucible with ash was transferred directly to a desiccator, cooled and weighed. The ash content was calculated as a percentage of the original weight of sample as follows:

$$\text{Ash content (\%)} = \frac{(W1 - W2)}{Sample\ weight} \times 100$$

Where:

W1 = weight of crucible and ash.

W2 = weight of empty crucible

3.9.4. Moisture Content Determination

The moisture content was determined according to the method of A.O.A.C. (2012). Eight grams (8 g) of each sample was weighed using an electronic scale (Sartorius CP 124 S) into pre-weighed aluminium drying plates. The plates were then put together with samples in an electric oven (J.P. Selecta s.a, incudigit) at 105º C for five hours (5 h) until a constant weight was reached and cooled in a desiccator, after which the dried sample weight was taken. The moisture content was calculated as shown below:

Moisture content (%) = $\frac{(W1 - W2)}{W1} \times 100$

Where:

W1 = original weight of sample.

W2 = weight of sample after drying.

3.9.5. Carbohydrate Content

The total carbohydrate (CHO) was calculated by difference according to A.O.A.C. (2012) using the formula:

Total CHO = 100 – (% moisture + % fat + % protein + % ash).

3.9.6. pH Measurement

The pH values of samples were measured using a digital pH meter (Crison, Basic 20, Spain). Before the test the meter was calibrated with two buffers of pH 4.01 and 7.00 respectively. Ten grams (10 g) of each sample was measured into cans and homogenised with ten millilitres (10 ml) of distilled water by shaking content for sixty seconds (60 s) and allowed to stand for ten minutes (10 min), after which the pH values were measured.

3.9.7. Peroxide Value (PV) Determination

Ten grams (10 g) of each sample was measured into a 100 ml Erlenmeyer flask to which 30 ml of hexane was added, the content was shaken at 250 rpm for sixty minutes (60 min) on a shaker. After shaking, they were transferred to a 50 ml falcon tubes and centrifuged at 3000 rpm for 5 minutes using Rotofix 32 A (Hettich, VID, CE, Germany). The supernatant was evaporated with an evaporator, the evaporated residues were first extracted with acetic acid-chloroform solution (5 ml), then 10 ml of additional acetic acid-chloroform was added to the evaporated residues twice, and the extracted samples were transferred to a 100 ml Erlenmeyer flask. One millilitre (1 ml) of potassium iodide saturated solution was then added, after which 5 ml of 1% starch soluble solution was added and the resulting mixture was titrated against 0.01N sodium thiosulfate solution ($Na_2S_2O_3$). The end point was identified by the transformation from a cyan or orange colour to a transparent or white colour. A blank test was used for calibration. The peroxide value was calculated according to the formula below:

$$\text{Peroxide value (mEq/kg)} = \frac{(V1 - V0) \times N}{S} \times 1000$$

Where:

V_1 = titre value of sample.

V_0 = titre value of blank.

S = weight of sample.

N = normality of sodium thiosulfate.

3.10.0. Mineral Analysis

3.10.1. Preparation of Reagents

All reagents used for the analysis were of analytical grade. Concentrated HCl (37% w/w) was diluted with double distilled water to obtain a diluted acid. A commercially prepared Cu, Zn, K, Fe and Mg was also obtained. To prepare standards for the instrument calibration, the stock solution was serially diluted with

0.1% HCl to obtain calibration solutions of different concentrations. Analyte-free solution (0.1% HCl) was used as the blank during the instrument calibration.

Flame atomic absorption spectroscopy (FAAS) measurements were carried out on Analytikjena model novAA400P atomic absorption spectrophotometer (AAS) using the single-beam optical mode. Hollow cathode lamp (HCL) for the respective elements were used as light source for the analysis. An air (compressed air) and acetylene (N26 quality, Air Liquide, Ghana) were employed as the oxidant and the fuel gas respectively, for the flame. The integration time for all the measurement was three (3). Background correction was accomplished with a deuterium lamp (D2-Lamp) except no background correction was used for the measurement of potassium.

3.10.2. Digestion Procedure of Samples

One gram (1 g) of each of the samples was put into digestion tubes and 10 ml concentrated H_2SO_4 was added, followed by the addition of 2 ml perchloric acid. The mixture was heated at a temperature of 350º C - 400º C till the solution becomes clear and colourless. The solution was allowed to cool and 2 ml of hydrogen peroxide was added. Double distilled water was added to make up to the 50 ml mark.

3.10.3. Measurement Procedure of Minerals

A small volume of the sample was aspirated by using a pneumatic nebulizer into a flame where the ions are reduced to elements and vaporized. The elements present in the sample then absorb light (generated from the HCL) at specific wavelengths as shown in Table 3.5. in the visible or the ultraviolet spectrum. This is dependent on the wavelength of maximum absorption of the analyte. After absorption, the transmitted light is detected with a detector after going through a monochromator.

Prepared standard solutions of different concentrations were used to calibrate the instrument before all the analysis. The measured absorbance of these standard solutions were used to prepare a linear calibration curve. The calibration curve was used to determine the unknown concentration of an element in the samples. Samples having high concentrations of elements beyond the linear range of the instrument was diluted prior to the analysis.

The light absorbed by the flame containing the sample is compared with the absorption from the known standards to quantify the elemental concentration.

Table 3.3. Instrumental Conditions for the Measurement of Elements

Element (Analyte)	Wavelength (nm)	Slit Width (nm)	Power Supply (mA)	Flame, Flow Setting(L/h)
Cu	324.8	1.2	2	50
Zn	213.9	0.5	2	50
K	766.5	0.8	4	80
Fe	248.3	0.2	4	65
Mg	285.2	1.2	1.5	70

3.11. Cost of Production of Pearl Millet Extended Beef Sausages

The cost of a kilogram of beef and millet, as well as the cost of processing each kilogram millet were determined. The cost of each percentage inclusion level (0, 5, 10 and 15 %) was determined as a proportion of the respective kilogram cost. The cost of spices, curing salt and ice cubes for processing a kilogram of beef sausage was added equally across treatments. Transportation cost was equally distributed to all treatments.

3.12. Data analysis

All analyses were conducted in triplicates. All the data except sensory were subjected to one-way analysis of variance (ANOVA) using XLSTAT version 2016. Sensory data was analysed using Kruskal-Wallis test. Tukey post-hoc option was used to determine significant differences between means at the level of $P < 0.05$. The results were expressed as means and standard deviations and presented in tables and figures.

CHAPTER FOUR

4.0. RESULTS

4.1. Raw Pearl Millet Flour (RaPMF), Roasted Pearl Millet Flour (RoPMF) and Soaked Pearl Millet Flour (SoPMF)

4.1.1. Proximate Compositions of Raw Pearl Millet Flour (RaPMF), Roasted Pearl Millet Flour (RoPMF) and Soaked Pearl Millet Flour (SoPMF)

Table 4.1 shows the proximate compositions of raw pearl millet flour, roasted pearl millet flour and soaked pearl millet flour. Significant differences ($P > 0.05$) were not observed in the proximate parameters measured in raw pearl millet flour, roasted pearl millet flour and soaked pearl millet flour, except moisture which was significantly ($P < 0.05$) different with RaPMF having a higher value of 9.76% and RoPMF with a lower value of 6.44%.

Table 4.1: Proximate Compositions of Raw Pearl Millet Flour (RaPMF), Roasted Pearl Millet Flour (RoPMF) and Soaked Pearl Millet Flour (SoPMF

Type of flour	Parameters				
	Moisture (%)	Ash (%)	Fat (%)	Protein (%)	Carbohydrate (%)
RaPMF	9.76 ± 0.81^{a}	9.52±2.61	4.67±1.95	10.19±1.33	65.87±5.99
RoPMF	6.44 ± 0.35^{b}	13.13±4.05	3.94±0.62	10.87±1.86	65.62±2.72
SoPMF	7.27 ± 1.95^{ab}	10.68±3.07	6.24±2.15	9.21±1.31	66.61±3.88
P-value	0.039	0.443	0.316	0.455	0.96

Values are means ± standard deviation. Values with different superscripts under the same column are significantly ($P < 0.05$) different.

4.1.2. Mineral Compositions of Raw Pearl Millet Flour (RaPMF), Roasted Pearl Millet Flour (RoPMF) and Soaked Pearl Millet Flour (SoPMF)

The results on mineral concentration indicate a highly significant (P < 0.001) difference among the treatments (Table 4.2). The iron and zinc contents of RoPMF were higher (105.62 mg/kg iron and 32.17 mg/kg zinc), followed by SoPMF (98.18 mg/kg iron and 24.53 mg/kg zinc) and RaPMF (77.63 mg/kg iron and 23.75 mg/kg zinc). The magnesium content was 2285.60 mg/kg, 2259.62 mg/kg and 2108.66 mg/kg, for RaPMF, RoPMF and SoPMF respectively. While roasted pearl millet flour recorded a calcium value of 222.89 mg/kg, followed by raw pearl millet flour with a value of 203.03 mg/kg and soaked pearl millet flour with a value of 193.05 mg/kg. The potassium content of raw pearl millet flour was the highest (1502.60 mg/kg), followed by roasted pearl millet flour with a value of 1490.76 mg/kg and soaked pearl millet flour with the least value of 1256.02 mg/kg (Table 4.2).

Table 4.2: Mineral Compositions of Raw Pearl Millet Flour (RaPMF), Roasted Pearl Millet Flour (RoPMF) and Soaked Pearl Millet Flour (SoPMF)

Type of flour	Parameters				
	Iron (mg/kg)	Magnesium (mg/kg)	Calcium (mg/kg)	Potassium (mg/kg)	Zinc (mg/kg)
RaPMF	77.63±0.67[c]	2285.60±7.90[a]	203.03±1.11[b]	1502.60±1.92[a]	23.75±0.06[c]
RoPMF	105.62±1.15[a]	2259.62±0.81[b]	222.89±0.33[a]	1490.76±1.34[b]	32.17±0.03[a]
SoPMF	98.18±0.61[b]	2108.66±0.69[c]	193.05±1.34[c]	1256.02±1.78[c]	24.53±0.05[b]
P-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

Values are means ± standard deviation. Values with different superscripts under the same column are significantly (P < 0.05) different

4.2. Raw Pearl Millet Flour Beef Sausages (RaPMFS)

4.2.1. Proximate Compositions of Raw Pearl Millet Flour Beef Sausages (RaPMFS)

Table 4.3 shows the proximate compositions of raw pearl millet flour beef sausages. There was no significant (P > 0.05) differences in the proximate parameters of raw pearl millet flour extended beef sausages except moisture which was significantly (P < 0.05) different. The moisture content ranged from 62.14% - 68.42% in the 15% level of inclusion and control respectively. The moisture value decreased with increasing level of raw pearl millet flour.

Table 4.3: Proximate Compositions of Raw Pearl Millet Flour Beef Sausages (RaPMFS)

Treatment	Parameters				
	Moisture (%)	Ash (%)	Fat (%)	Protein (%)	Carbohydrate (%)
0%RaPMFS (Control)	68.42 ± 0.43^{a}	4.47±0.57	5.53±3.22	18.81±1.50	2.77±1.70
5%RaPMFS	65.91 ± 0.75^{b}	3.85±1.31	8.19±2.11	19.25±1.22	2.80±1.58
10%RaPMFS	65.03 ± 1.13^{b}	5.00±0.28	6.63±2.68	16.90±1.35	6.44±3.64
15%RaPMFS	62.14 ± 0.60^{c}	5.24±1.13	9.86±0.56	17.83±1.39	4.93±0.26
P – value	< 0.001	0.326	0.206	0.232	0.187

Values are means ± standard deviation. Values with different superscripts under the same column are significantly (P < 0.05) different

4.2.2. Mineral Compositions of Raw Pearl Millet Flour Beef Sausages (RaPMFS)

The minerals analysed for raw pearl millet flour extended beef sausages were all highly significantly ($P < 0.001$) different (Table 4.4). The iron and calcium contents of 15%RaPMFS recorded the highest value (57.44 mg/kg iron and 99.11 mg/kg calcium), while the control (0%RaPMFS) recorded the lowest value (26.73 mg/kg iron and 64.26 mg/kg calcium). Magnesium values ranged from 594.99 mg/kg - 795.73 mg/kg in 0%RaPMFS (control) and 15%RaPMFS. Potassium values varied from 1072.52 mg/kg to 1156.90 mg/kg in 5% and 15% replacement levels respectively. The control exhibited the highest value (33.96 mg/kg) while the 15% had the least value (30.61 mg/kg) of zinc (Table 4.4).

Table 4.4: Mineral Compositions of Raw Pearl Millet Flour Beef Sausages (RaPMFS)

Treatment	Parameters				
	Iron (mg/kg)	Magnesium (mg/kg)	Calcium (mg/kg)	Potassium (mg/kg)	Zinc (mg/kg)
0%RaPMFS (Control)	26.73±0.55[d]	594.99±0.94[d]	64.26±0.12[d]	1137.46±1.24[b]	33.96±0.07[a]
5%RaPMFS	38.81±0.84[c]	712.66±1.13[b]	80.78±0.53[c]	1072.52±0.91[d]	33.45±0.13[a]
10 %RaPMFS	46.55±3.41[b]	670.54±0.60[c]	86.54±0.54[b]	1116.63±1.62[c]	33.39±0.41[a]
15%RaPMFS	57.44±0.53[a]	795.73±2.19[a]	99.11±0.93[a]	1156.90±1.26[a]	30.61±0.04[b]
P – value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

Values are means ± standard deviation. Values with different superscripts under the same column are significantly ($P < 0.05$) different

4.2.3. Physicochemical Properties of Raw Pearl Millet Flour Beef Sausages (RaPMFS)

4.2.3.1. The pH of Raw Pearl Millet Flour Beef Sausages (RaPMFS)

The pH values of the raw pearl millet flour extended beef sausages were significantly ($P < 0.001$) different from each other. The 15% inclusion recorded the highest pH value (6.03) while the control had the lowest pH value (5.94). This is shown in Table 4.5.

4.2.3.2. Cooking Loss of Raw Pearl Millet Flour Beef Sausages (RaPMFS)

There were significant differences ($P < 0.001$) in cooking loss of raw pearl millet flour extended beef sausages. The values ranged from 18.76% to 26.74% in 15% and 5% treatments respectively (Table 4.5).

4.2.3.3. Water Holding Capacity (WHC) of Raw Pearl Millet Flour Beef Sausages (RaPMFS)

The WHC of raw pearl millet flour extended beef sausages were not significantly different ($P > 0.05$) from each other. The mean values ranged from 1.18 ml/g to 1.24 ml/g in the 10% inclusion and the control (0%) respectively (Table 4.5).

4.2.3.4. Drip Loss of Raw Pearl Millet Flour Beef Sausages (RaPMFS)

There were significant ($P < 0.001$) differences in the drip loss of raw pearl millet flour extended beef sausages. The control (0%) and 10% inclusion were not different from each other, but were different from the 5% and 15% levels of inclusion (Table 4.5).

4.2.3.5. Water Activity (a_w) of Raw Pearl Millet Flour Beef Sausages (RaPMFS)

Water activity of raw pearl millet flour beef sausages were significantly ($P < 0.05$) different. The a_w values ranged from 0.805 to 0.815 in the 10% and 5% treatment levels, respectively. The control and 5% inclusion were similar ($P > 0.05$) to each other, while the 10% and 15% treatment levels were different from the 5% inclusion level, but not the control (Table 4.5).

Table 4.5: Physicochemical Properties of Raw Pearl Millet Flour Beef Sausages (RaPMFS)

Treatment	Parameters				
	pH	Cooking loss (%)	WHC (ml/g)	Drip Loss (%)	Water activity
0%RaPMFS (Control)	5.94 ± 0.02^{c}	25.00 ± 0.41^{a}	1.24 ± 0.14	NDL	0.812 ± 0.002^{ab}
5%RaPMFS	6.00 ± 0.01^{b}	26.74 ± 1.18^{a}	1.22 ± 0.06	5.88 ± 0.17^{b}	0.815 ± 0.002^{a}
10%RaPMFS	5.98 ± 0.00^{b}	21.48 ± 1.28^{b}	1.18 ± 0.07	NDL	0.805 ± 0.002^{b}
15%RaPMFS	6.03 ± 0.01^{a}	18.76 ± 0.36^{c}	1.22 ± 0.07	7.17 ± 0.17^{a}	0.807 ± 0.004^{b}
P – value	< 0.001	< 0.001	0.916	< 0.001	0.005

Values are means ± standard deviation. Values with different superscripts under the same column are significantly ($P < 0.05$) different. NDL = No Drip Loss

4.2.4. Sensory Properties of Raw Pearl Millet Flour Beef Sausages (RaPMFS)

There were no significant differences ($P > 0.05$) in the sensory attributes evaluated during the storage period except for flavour liking and overall liking which were significantly ($P < 0.05$) different in week two. Flavour and overall liking of the control had the highest mean value (7.20 and 7.53) and the 15% treatment had the least mean value (6.13 and 6.40), respectively, however, the 5% and 10% treatments were statistically similar to the control and 15% treatments. This is shown in Table 4.6.

Table 4.6: Sensory Properties of Raw Pearl Millet Flour Beef Sausages (RaPMFS)

Storage period (weeks)	Treatment (%)	Colour	Flavour intensity	Flavour liking	Texture	Tenderness	Juiciness	Overall liking
1	0	5.67±2.13	6.00±1.69	6.47±1.81	4.87±1.77	4.93±2.05	5.67±2.02	6.20±1.90
	5	5.73±1.79	6.13±1.69	5.53±1.96	5.27±1.83	6.13±1.35	6.33±1.40	6.33±1.72
	10	5.40±1.55	5.47±1.89	6.33±1.11	5.27±1.22	6.27±1.34	5.47±1.55	6.67±1.45
	15	4.53±2.13	4.73±1.75	5.67±1.40	5.67±1.59	5.80±1.47	5.20±1.37	5.93±1.16
P – Value		0.286	0.121	0.164	0.538	0.266	0.125	0.352
2	0	5.20±1.52	6.80±1.27	7.20±1.61[a]	5.47±1.73	5.40±1.81	5.73±1.58	7.53±1.36[a]
	5	5.20±1.52	5.60±1.45	6.47±1.51[ab]	5.80±1.15	6.27±1.34	5.80±1.27	6.60±1.50[ab]
	10	4.73±1.39	5.47±1.51	6.67±1.40[ab]	5.47±1.36	6.53±1.19	5.93±1.16	6.53±1.85[ab]
	15	5.13±1.77	5.40±1.92	6.13±0.92[b]	6.00±1.51	5.67±1.59	5.73±1.44	6.40±1.40[b]
P – Value		0.792	0.059	0.038	0.489	0.222	0.906	0.032
3	0	6.47±0.92	5.87±1.41	6.47±1.73	5.33±1.45	6.20±1.42	6.13±1.64	6.73±1.98
	5	5.80±1.57	5.67±0.90	6.60±0.91	5.67±1.29	6.07±1.44	5.67±1.63	6.40±1.30
	10	6.13±1.19	5.67±0.90	5.93±1.22	5.87±1.36	6.53±0.74	6.33±1.40	6.67±1.54
	15	5.87±1.13	5.60±1.12	5.73±1.44	5.80±1.86	6.07±1.67	5.53±1.51	6.33±1.29
P – Value		0.546	0.908	0.257	0.668	0.606	0.411	0.480

Values are mean ± standard deviation. Values with different superscripts under the same column are significantly ($P < 0.05$) different

4.2.5. Instrumental Colour Measurement of Raw Pearl Millet Flour Beef Sausages (RaPMFS)

The sausages were assessed base on CIE colour system of L* (Lightness), a* (Redness) and b* (Yellowness). The analysed results with the P - values are shown in appendix I.

The L* of surface colour on day 0 - day 21 did not differ significantly from each other ($P > 0.05$). However, L* of internal colour were significantly ($P < 0.05$) different on day 14 and 21 (Fig. 4.1a).

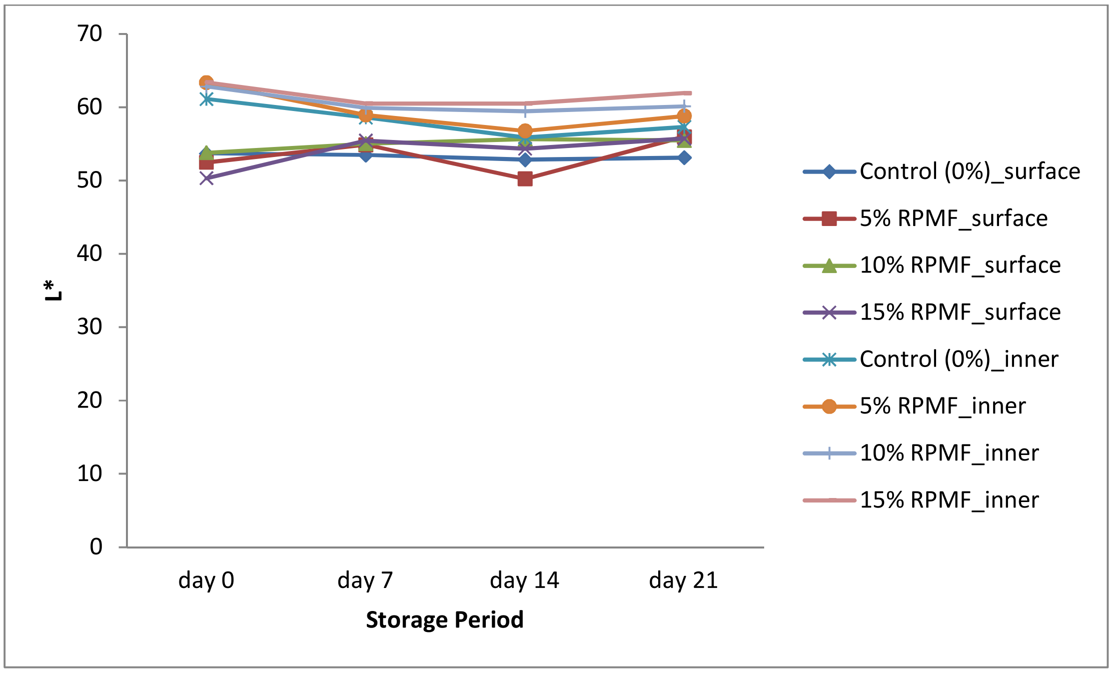

Figure 4.1a: Surface and Internal Colour (Lightness) of Raw Pearl Millet Flour (RaPMF) Beef Sausages

The a* of surface colour significantly varied on all the days except day 21. The a* of internal colour were significantly different ($P < 0.05$) on day 0 and day 14 (Fig. 4.1b).

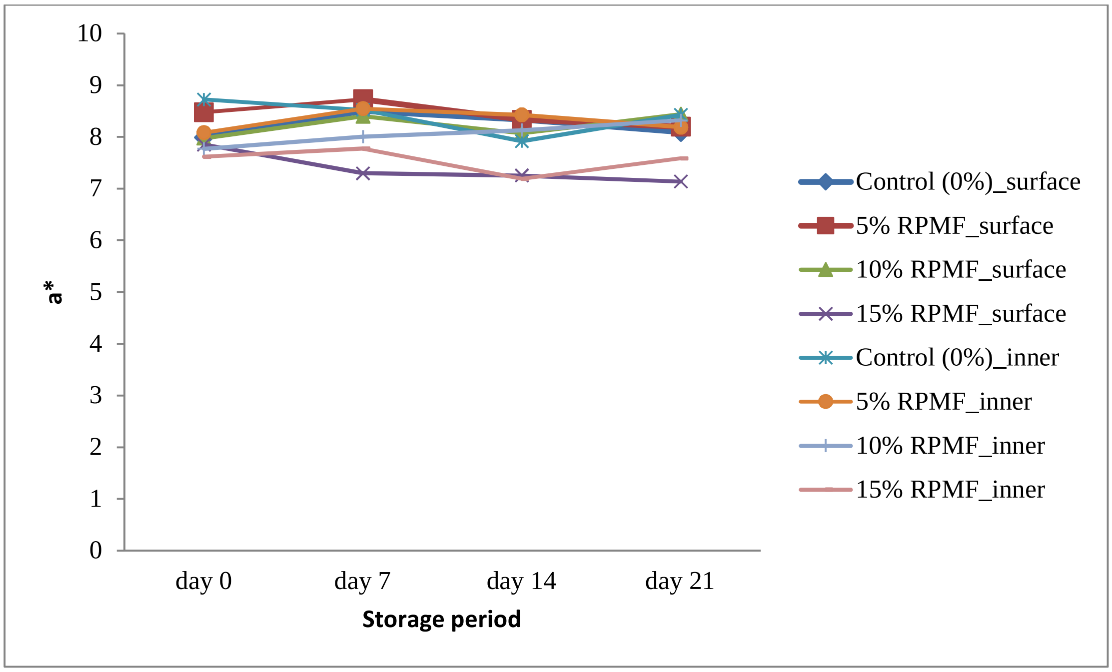

Figure 4.1b: Surface and Internal Colour (Redness) of Raw Pearl Millet Flour (RaPMF) Beef Sausages

The b* of surface and internal colour were all significantly ($P < 0.05$) different on all the days except day 0 (Fig. 4.1c).

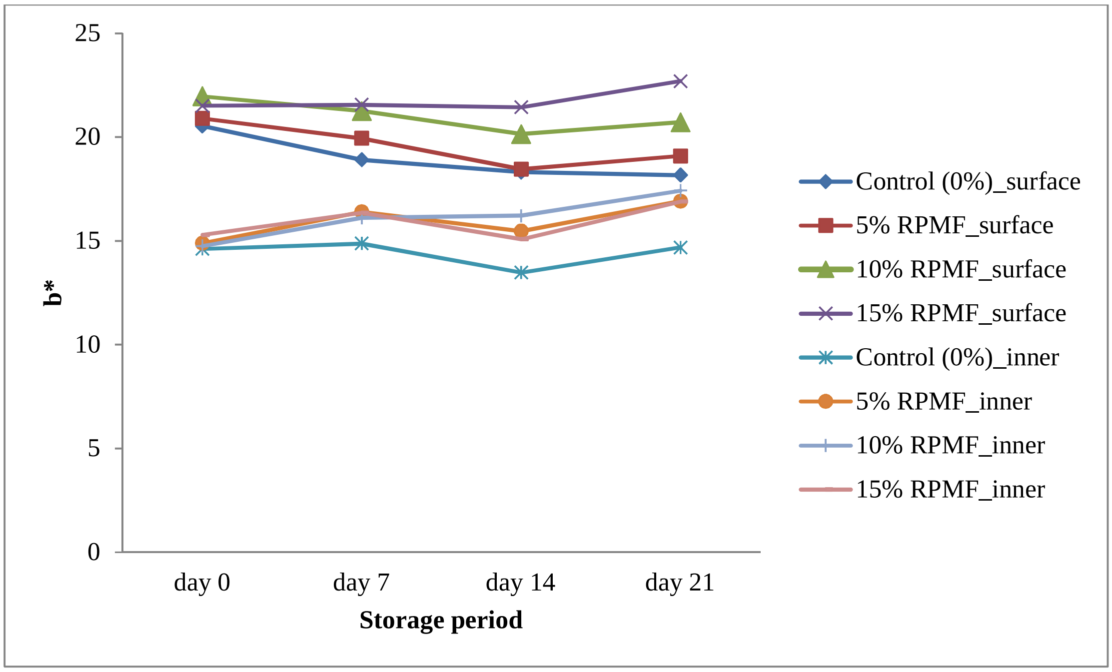

Figure 4.1c: Surface and Internal Colour (Yellowness) of Raw Pearl Millet Flour (RaPMF) Beef Sausages

4.2.6. Peroxide Value (PV) of Raw Pearl Millet Flour Beef Sausages (RaPMFS)

Figure 4.2 shows the peroxide value of raw pearl millet flour beef sausages. No significant difference ($P>0.05$) was observed in all treatments during the storage period. The peroxide values ranged from 3.16 - 3.86 meq/kg, 2.19 – 3.67 meq/kg and 1.92 – 3.27 meq/kg in week 1, week 2 and week 3, respectively. The analysed results with the P - values are shown in appendix II.

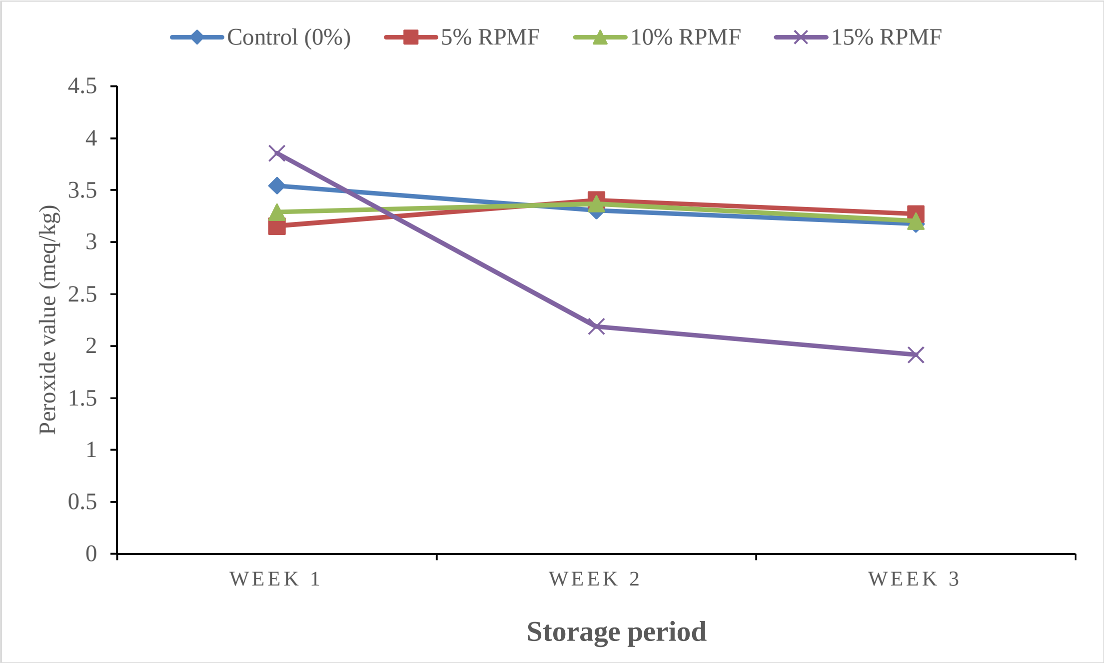

Figure 4.2: Peroxide Value of Raw Pearl Millet Flour (RaPMF) Beef Sausages

4.2.7. Formulation Cost of Raw Pearl Millet Flour Beef Sausages (RaPMFS)

The formulation cost of raw pearl millet flour beef sausages is shown in Table 4.7. The formulation cost in Ghana cedis (Gh¢) for the control (0%), 5%, 10% and 15% treatment levels are 31.50, 30.90, 29.80 and 28.70, respectively.

Table 4.7: Formulation Cost of Raw Pearl Millet Flour Beef Sausages (RaPMFS)

Ingredient	Amount (Gh¢/kg or l)	0%RaPMFS	5%RaPMFS	10 %RaPMFS	15%RaPMFS
Minced beef	26	26	24.7	23.4	22.1
Pearl millet	2	-	0.1	0.2	0.3
Milling	1	-	0.05	0.1	0.15
Water for processing millet	1	-	0.05	0.1	0.15
Spice mix	0.5	0.7	0.7	0.7	0.7
Curing salt	0.5	0.5	0.5	0.5	0.5
Soy oil	0.8	0.8	0.8	0.8	0.8
Casing	3	3	3	3	3
Ice cube	0.5	0.5	0.5	0.5	0.5
Transportation	1.5	-	0.5	0.5	0.5
Total Cost (Gh¢)		31.5	30.9	29.8	28.7

4.3. Roasted Pearl Millet Flour Beef Sausages (RoPMFS)

4.3.1. Proximate Compositions of Roasted Pearl Millet Flour Beef Sausages (RoPMFS)

The proximate results of roasted pearl millet flour extended beef sausages showed no significant (P > 0.05) differences in ash, fat and carbohydrate except moisture and protein which were significantly (P < 0.05) different. The moisture content varied from 61.07% - 68.42% in the 15% level of inclusion and control respectively while the protein content varied from 15.69% - 20.02% in 15% and 5% inclusion levels respectively (Table 4.8).

Table 4.8: Proximate Compositions of Roasted Pearl Millet Flour Beef Sausages (RoPMFS)

Treatment	Parameters				
	Moisture (%)	Ash (%)	Fat (%)	Protein (%)	Carbohydrate (%)
0%RoPMFS (Control)	68.42±0.43[a]	4.47±0.57	5.53±3.22	18.81±1.50[ab]	2.77±1.70
5%RoPMFS	67.05±0.37[b]	4.49±1.02	8.00±2.71	15.69±0.44[b]	4.77±3.04
10%RoPMFS	64.11±0.39[c]	4.77±0.87	7.73±1.18	16.62±1.32[ab]	6.76±3.42
15%RoPMFS	61.07±0.40[d]	5.94±0.92	8.97±3.99	20.02±2.55[a]	4.01±3.32
P – value	< 0.001	0.199	0.566	0.041	0.456

Values are means ± standard deviation. Values with different superscripts under the same column are significantly (P < 0.05) different

4.3.2. Mineral Compositions of Roasted Pearl Millet Flour Beef Sausages (RoPMFS)

There were significant (P < 0.001) differences in all the mineral parameters measured for roasted pearl millet flour extended beef sausages. The iron content ranged from 26.73 mg/kg – 56.15 mg/kg in control and 15% treatments. The magnesium content increased from 594.99 mg/kg to 842.89 mg/kg in the control and 15% treatment respectively. Calcium content varied from 64.26 mg/kg to 98.84 mg/kg in the control and 10% treatment while potassium values ranged from 1075.07 mg/kg – 1137 mg/kg in the 10% treatment and control respectively. The zinc content of the 5% inclusion was the highest (35.29 mg/kg) and 10% inclusion level was the least (32.20 mg/kg) as shown in Table 4.9.

Table 4.9: Mineral Compositions of Roasted Pearl Millet Flour Beef Sausages (RoPMFS)

Treatment	Parameters				
	Iron (mg/kg)	Magnesium (mg/kg)	Calcium (mg/kg)	Potassium (mg/kg)	Zinc (mg/kg)
0%RoPMFS (Control)	26.73±0.55[c]	594.99±0.94[d]	64.26±0.12[d]	1137.46±1.24[a]	33.96±0.07[b]
5%RoPMFS	54.99±0.13[a]	753.09± 1.10[c]	93.67±0.37[b]	1125.05±5.34[a]	35.29±0.18[a]
10%RoPMFS	44.55±0.75[b]	780.38±0.39[b]	98.84±0.15[a]	1075.07±2.84[b]	32.20±0.01[c]
15%RoPMFS	56.15±0.63[a]	842.89±1.82[a]	91.22±0.13[c]	1132.90±2.18[a]	32.25±0.10[c]
P – value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

Values are means ± standard deviation. Values with different superscripts under the same column are significantly (P < 0.05) different

4.3.3. Physicochemical Properties of Roasted Pearl Millet Flour Beef Sausages (RoPMFS)

4.3.3.1. The pH of Roasted Pearl Millet Flour Beef Sausages (RoPMFS)

There were significant differences ($P < 0.05$) in the pH of roasted pearl millet flour extended beef sausages. Incorporation of 15% recorded the highest pH value (6.00) and the control with the least value (5.94). The control did not differ from the 5%, but was different from the 10% and 15% inclusions, while the 15% was statistically similar to the 10% level of inclusion (Table 4.10).

4.3.3.2. Cooking Loss of Roasted Pearl Millet Flour Beef Sausages (RoPMFS)

The results of cooking loss showed significant ($P < 0.001$) differences in roasted pearl millet flour extended beef sausages. The 5% inclusion recorded the highest mean value (26.74%) while the 10% inclusion had the lowest mean value (13.32%). This is shown in Table 4.10.

4.3.3.3. Water Holding Capacity (WHC) of Roasted Pearl Millet Flour Beef Sausages (RoPMFS)

There were insignificant differences ($P > 0.05$) in the WHC of roasted pearl millet flour extended beef sausages. The values ranged from 1.12 ml/g to 1.25 ml/g in the 10% and 15% treatment levels respectively as shown in Table 4.10.

4.3.3.4. Drip Loss of Roasted Pearl Millet Flour Beef Sausages (RoPMFS)

The drip loss of roasted pearl millet flour extended beef sausages were significantly ($P < 0.001$) different. The control, 10% and 15% treatment levels did not differ from each other but were all different from the 5% treatment level as shown in Table 4.10.

4.3.3.5. Water Activity (a_w) of Roasted Pearl Millet Flour Beef Sausages (RoPMFS)

Significant differences ($P < 0.05$) were observed in the a_w of the sausages. The water activity values ranged from 0.810 to 0.814 in the 10% and 15% treatment levels respectively as shown in Table 4.10.

Table 4.10: Physicochemical Properties of Roasted Pearl Millet Flour Beef Sausages (RoPMFS)

Treatment	Parameters				
	pH	Cooking loss (%)	WHC (ml/g)	Drip Loss (%)	Water activity
0%RoPMFS (Control)	5.94 ± 0.02^{c}	25.00 ± 0.41^{a}	1.24±0.14	NDL	0.812 ± 0.002^{ab}
5%RoPMFS	$5.95 \pm 0.00b^{c}$	26.74 ± 1.18^{a}	1.16±0.12	6.61 ± 0.27^{a}	0.810 ± 0.002^{b}
10%RoPMFS	5.98 ± 0.01^{ab}	13.32 ± 0.32^{c}	1.12±0.07	NDL	0.814 ± 0.002^{a}
15%RoPMFS	6.00 ± 0.02^{a}	21.48 ± 1.28^{b}	1.25±0.13	NDL	0.810 ± 0.001^{ab}
P – value	0.003	< 0.001	0.555	< 0.001	0.029

Values are means ± standard deviation. Values with different superscripts under the same column are significantly ($P < 0.05$) different. NDL = No Drip Loss

4.3.4. Sensory Properties of Roasted Pearl Millet Flour Beef Sausages (RoPMFS)

Table 4.11 shows the sensory characteristics of roasted pearl millet flour beef sausages. There were no significant differences ($P > 0.05$) in the sensory attributes measured during the storage period except for the overall liking in week 2. The control differed significantly ($P < 0.05$) in overall liking compared to the 10% and 15% roasted pearl millet flour beef sausages.

Table 4.11: Sensory Properties of Roasted Pearl Millet Flour Beef Sausages (RoPMFS)

Storage period (weeks)	Treatment (%)	Colour	Flavour intensity	Flavour liking	Texture	Tenderness	Juiciness	Overall liking
1	0	5.67±2.13	6.00±1.69	6.47±1.81	4.87±1.77	4.93±2.05	5.67±2.02	6.20±1.90
	5	6.47±1.06	6.00±1.36	6.20±2.15	5.60±1.64	6.00±1.46	5.33±1.68	7.00±1.00
	10	5.40±1.60	6.00±1.51	6.13±2.03	6.33±1.50	6.00±1.41	4.87±1.41	6.13±2.03
	15	5.40±1.84	5.20±0.86	6.20±1.32	5.47±1.64	5.80±1.70	5.47±1.89	6.67±1.45
P – Value		0.260	0.153	0.779	0.124	0.492	0.332	0.629
2	0	5.20±1.52	6.80±1.27	7.20±1.61	5.47±1.73	5.40±1.81	5.73±1.58	$7.53±1.36^{a}$
	5	5.40±1.40	5.67±1.50	6.13±1.55	6.07±1.34	6.07±1.39	6.20±1.27	$6.67±1.54^{ab}$
	10	4.47±1.30	5.67±1.50	6.00±1.65	5.47±1.25	6.00±1.07	5.53±1.41	$6.00±1.93^{b}$
	15	5.53±1.41	5.53±1.64	6.20±1.47	5.73±1.10	6.20±1.42	6.07±0.80	$6.40±1.06^{b}$
P – Value		0.111	0.094	0.082	0.643	0.636	0.376	0.011
3	0	6.47±0.92	5.87±1.41	6.47±1.73	5.33±1.45	6.20±1.42	6.13±1.64	6.73±1.98
	5	5.67±1.50	5.67±1.55	5.93±1.49	6.07±1.28	5.93±1.16	5.60±1.55	6.60±1.35
	10	5.87±1.60	5.53±1.85	6.33±1.63	5.87±1.73	6.13±1.36	5.53±1.69	6.60±1.55
	15	5.13±1.64	5.33±1.92	6.60±1.40	5.27±1.79	5.33±1.80	5.00±2.00	6.67±1.40
P – Value		0.055	0.749	0.650	0.404	0.375	0.367	0.867

Values are mean ± standard deviation. Values with different superscripts under the same column are significantly ($P < 0.05$) different.

4.3.5. Instrumental Colour Measurement of Roasted Pearl Millet Flour Beef Sausages (RoPMFS)

The sausages were assessed base on CIE colour system of L* (Lightness), a* (Redness) and b* (Yellowness). The analysed results with the P - values are shown in appendix I. The L* of surface colour of the sausages were not significantly (P > 0.05) different on all the days with the exception of day 14. The L* of internal colour of the sausages were not significantly (P > 0.05) different from each other (Fig. 4.3a).

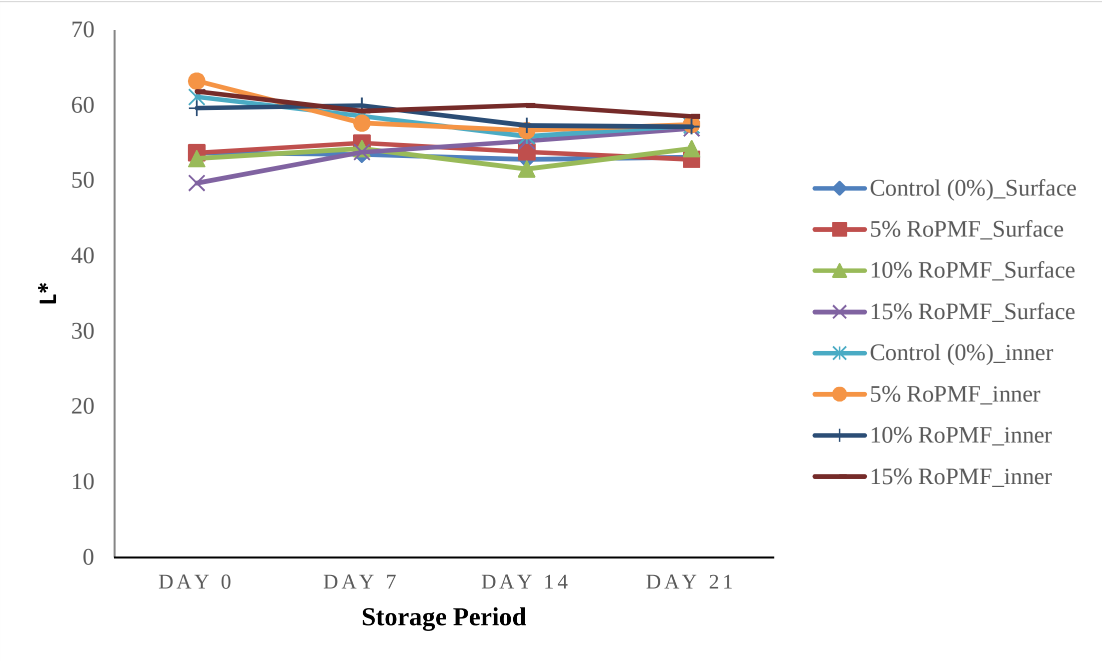

Figure 4.3a: Surface and Internal Colour (Lightness) of Roasted Pearl Millet Flour (RoPMF) Beef Sausages

The a* of surface colour of the sausages were significantly different (P < 0.05) on all the days except day 14. The internal colours were all significantly (P < 0.05) different on all the days. This is shown in Fig. 4.3b.

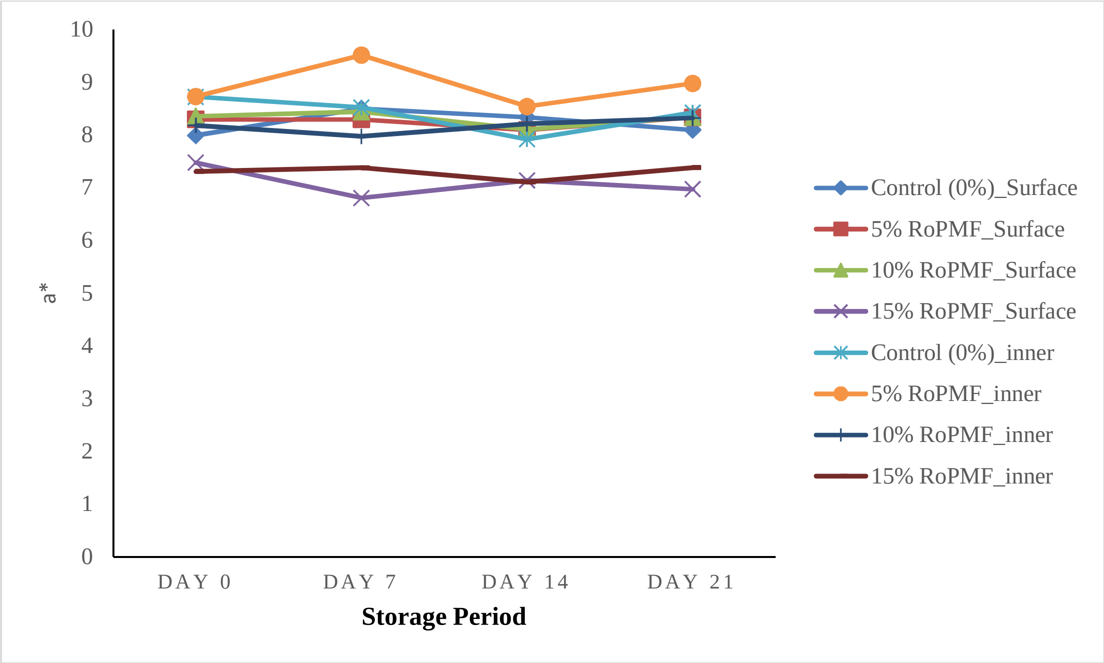

Figure 4.3b: Surface and Internal Colour (Redness) of Roasted Pearl Millet Flour (RoPMF) Beef Sausages

The b* of both surface and internal colour of the sausages on all the days differed significantly (P < 0.05) as shown in Fig. 4.3c.

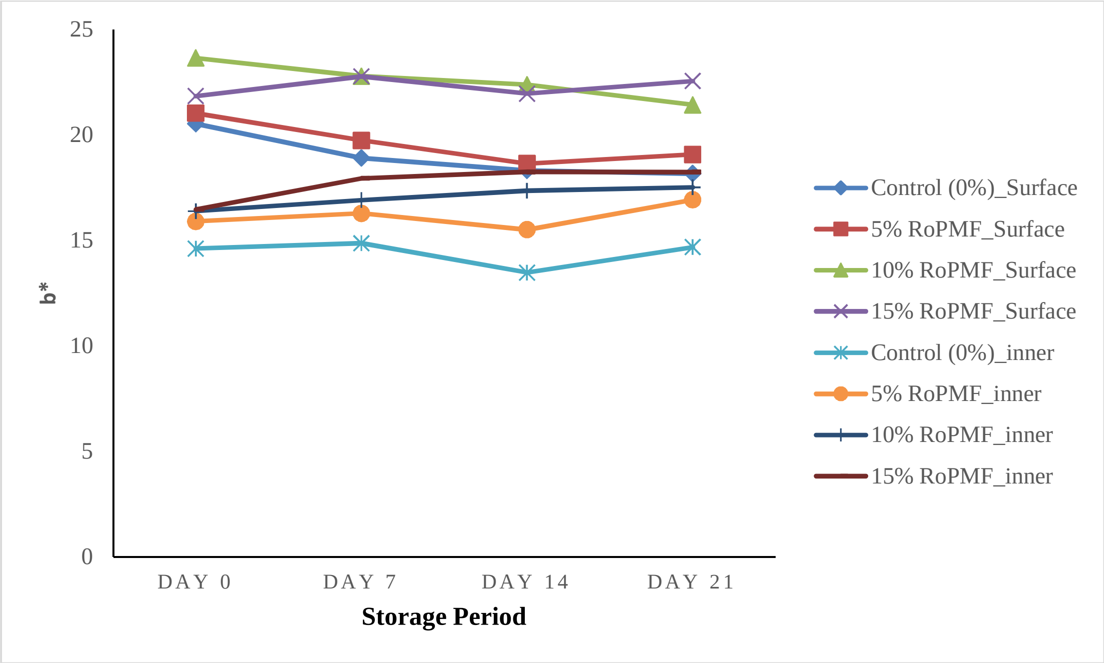

Figure 4.3c: Surface and Internal Colour (Yellowness) of Roasted Pearl Millet Flour (RoPMF) Beef Sausages

4.3.6. Peroxide Value of Roasted Pearl Millet Flour Beef Sausages (RoPMFS)

There were no significant (P > 0.05) differences in all the treatment levels during the storage period. The peroxide values ranged from 2.84 - 3.59 meq/kg, 2.41 – 3.80 meq/kg and 2.21 – 3.47 meq/kg in week 1, week 2 and week 3 respectively (Fig. 4.4). The analysed results with the P - values are shown in appendix II.

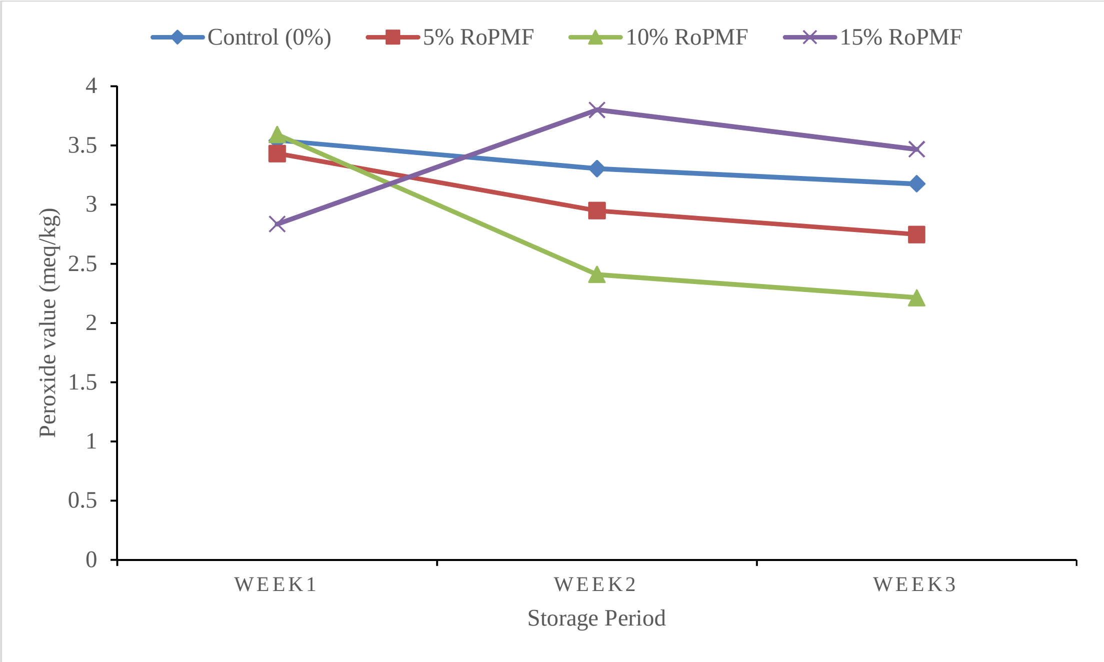

Figure 4.4: Peroxide Value of Roasted Pearl Millet Flour (RoPMF) Beef Sausages

4.3.7. Formulation Cost of Roasted Pearl Millet Flour Beef Sausages (RoPMFS)

Formulation cost in Ghana cedis (Gh¢) of roasted pearl millet flour beef sausages for the control (0%), 5%, 10% and 15% incorporation levels are 31. 50, 31.00, 30.00 and 29.00, respectively (Table 4.12).

Table 4.12: Formulation Cost of Roasted Pearl Millet Flour Beef Sausages (RoPMFS)

Ingredient	Amount (Gh¢/kg or l)	0% RoPMFS	5% RoPMFS	10% RoPMFS	15% RoPMFS
Minced beef	26	26	24.7	23.4	22.1
Pearl millet	2	-	0.1	0.2	0.3
Milling	1	-	0.05	0.1	0.15
Water for processing millet	1	-	0.05	0.1	0.15
Roasting of millet	2	-	0.1	0.2	0.3
Spice mix	0.5	0.7	0.7	0.7	0.7
Curing salt	0.5	0.5	0.5	0.5	0.5
Soy oil	0.8	0.8	0.8	0.8	0.8
Casing	3	3	3	3	3
Ice cube	0.5	0.5	0.5	0.5	0.5
Transportation	1.5	-	0.5	0.5	0.5
Total cost (Gh¢)		31.5	31.0	30.0	29.0

4.4. Soaked Pearl Millet Flour Beef Sausages (SoPMFS)

4.4.1. Proximate Compositions of Soaked Pearl Millet Flour Beef Sausages (SoPMFS)

There were no significant ($P > 0.05$) differences in ash, fat and protein content in soaked pearl millet flour extended beef sausages except moisture and carbohydrate which were significantly different ($P < 0.05$). The moisture content differs from the control (68.42%) to 15% level of replacement (61.69%), while the carbohydrate content ranged from 2.77% - 7.53% in control and 15% level of replacement respectively (Table 4.13).

Table 4.13: Proximate Compositions of Soaked Pearl Millet Flour Beef Sausages (SoPMFS)

Treatment	Parameters				
	Moisture (%)	Ash (%)	Fat (%)	Protein (%)	Carbohydrate (%)
0%SoPMFS (Control)	68.42±0.43[a]	4.47±0.57	5.53±3.22	18.81±1.50	2.77±1.70[b]
5%SoPMFS	66.28±1.34[b]	4.05±0.96	8.31±1.35	17.60±0.98	3.76±1.90[b]
10%SoPMFS	65.11±0.72[b]	5.09±0.65	10.04±1.71	16.87±1.55	2.88±0.86[b]
15%SoPMFS	61.69±0.29[c]	6.11±2.48	7.98±2.13	16.70±1.16	7.53±2.48[a]
P – value	< 0.001	0.362	0.177	0.265	0.04

Values are means ± standard deviation. Values with different superscripts under the same column are significantly ($P < 0.05$) different

4.4.2. Mineral Compositions of Soaked Pearl Millet Flour Beef Sausages (SoPMFS)

All the minerals measured for soaked pearl millet flour extended beef sausages were significantly ($P < 0.001$) different. Iron content ranged from 26.73 mg/kg – 69.54 mg/kg in the control and 15% products while the magnesium content ranged from 594.99 mg/kg – 789.60 mg/kg in the control and 15% products. Calcium content was highest (99.99 mg/kg) in 10% inclusion and least (64.26 mg/kg) in control. The potassium and zinc content ranged from 1044.87 mg/kg in 10% inclusion to 1137.46 mg/kg in control and 29.69 mg/kg in 5% inclusion to 33.96 mg/kg in control respectively (Table 4.14).

Table 4.14: Mineral Compositions of Soaked Pearl Millet Flour Beef Sausages (SoPMFS)

Treatment	Parameters				
	Iron (mg/kg)	Magnesium (mg/kg)	Calcium (mg/kg)	Potassium (mg/kg)	Zinc (mg/kg)
0%SoPMFS (Control)	26.73±0.55^{c}	594.99±0.94^{c}	64.26±0.12^{d}	1137.46±1.24^{a}	33.96±0.07^{a}
5%SoPMFS	46.21±0.91^{b}	598.71±1.70^{c}	68.13±0.07^{c}	1045.02±2.44^{c}	29.69±0.04^{d}
10%SoPMFS	48.50±0.40^{b}	732.02±0.96^{b}	99.99±0.51^{a}	1044.87±0.76^{c}	33.53±0.08^{b}
15%SoPMFS	69.54±0.17^{a}	789.60±0.71^{a}	78.46±0.55^{b}	1080.54±1.75^{b}	31.02±0.03^{c}
P – value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

Values are means ± standard deviation. Values with different superscripts under the same column are significantly (P < 0.05) different

4.4.3. Physicochemical Properties of Soaked Pearl Millet Flour Beef Sausages (SoPMFS)

4.4.3.1. The pH of Soaked Pearl Millet Flour Beef Sausages (SoPMFS)

The pH values of the soaked pearl millet flour extended beef sausages were not significantly (P > 0.05) different in all the treatments as shown in Table 4.15.

4.4.3.2. Cooking Loss of Soaked Pearl Millet Flour Beef Sausages (SoPMFS)

There were significant differences ($P < 0.05$) in cooking loss of soaked pearl millet flour extended beef sausages. The values ranged from 14.33% to 31.21% in 15% and 10% treatments respectively. The control, 5% and 10% treatment levels were not significantly different ($P > 0.05$), but differed from the 15% inclusion (Table 4.15).

4.4.3.3. Water Holding Capacity (WHC) of Soaked Pearl Millet Flour Beef Sausages (SoPMFS)

There were significant ($P < 0.05$) differences between the control (0%) and the 15% inclusion. The control, 5% and 10% were not statistically ($P > 0.05$) different from each other (Table 4.15).

4.4.3.4. Drip Loss of Soaked Pearl Millet Flour Beef Sausages (SoPMFS)

Significant differences ($P < 0.05$) were detected in the drip loss of soaked pearl millet flour beef sausages. The control, 10% and 15% treatment levels did not differ from each other, but were all different from the 5% treatment level (Table 4.15).

4.4.3.5. Water Activity (a_w) of Soaked Pearl Millet Flour Beef Sausages (SoPMFS)

The water activity values of soaked pearl millet flour extended beef sausages were significantly ($P < 0.05$) different. The a_w values ranged from 0.806 to 0.812 in the 10% and control treatments respectively (Table 4.15).

Table 4.15: Physicochemical Properties of Soaked Pearl Millet Flour Beef Sausages (SoPMFS)

Treatment	Parameters				
	pH	Cooking loss (%)	WHC (ml/g)	Drip Loss (%)	Water activity
0%SoPMFS (Control)	5.94±0.02	25.00±0.41^{a}	1.24±0.14^{a}	NDL	0.812±0.002^{a}
5%SoPMFS	5.97±0.02	27.19±3.96^{a}	1.11±0.04^{ab}	6.64±0.11^{a}	0.808±0.001^{ab}
10%SoPMFS	6.01±0.01	31.21±5.04^{a}	1.08±0.03^{ab}	NDL	0.806±0.001^{b}
15%SoPMFS	5.98±0.05	14.33±0.58^{b}	1.03±0.02^{b}	NDL	0.809±0.003^{ab}
P – value	0.102	0.001	0.049	<0.001	0.03

Values are means ± standard deviation. Values with different superscripts under the same column are significantly ($P < 0.05$) different. NDL = No Drip Loss

4.4.4. Sensory Properties of Soaked Pearl Millet Flour Beef Sausages (SoPMFS)

Sensory characteristics of soaked pearl millet flour beef sausages did not differ significantly ($P > 0.05$) in all the treatments during the storage period as shown in Table 4.16.

Table 4.16: Sensory Properties of Soaked Pearl Millet Flour Beef Sausages (SoPMFS)

Storage period (weeks)	Treatment (%)	Colour	Flavour intensity	Flavour liking	Texture	Tenderness	Juiciness	Overall liking
	0	5.67±2.13	6.00±1.69	6.47±1.81	4.87±1.77	4.93±2.05	5.67±2.02	6.20±1.90
1	5	5.60±1.99	5.40±1.45	5.87±1.89	5.40±1.72	5.53±1.41	5.93±1.71	6.33±1.29
	10	5.53±1.81	5.73±1.62	5.40±1.72	5.40±1.64	5.13±1.51	5.47±1.46	5.67±1.45
	15	6.13±1.46	5.40±1.40	5.93±0.88	5.27±1.53	5.67±1.68	6.20±1.61	5.93±1.49
P – Value		0.804	0.508	0.161	0.746	0.697	0.755	0.424
	0	5.20±1.52	6.80±1.27	7.20±1.61	5.47±1.73	5.40±1.81	5.73±1.58	7.53±1.36
2	5	4.67±1.63	5.53±1.55	6.33±1.50	5.60±1.30	5.87±1.36	6.07±1.79	6.53±1.41
	10	4.40±1.35	5.40±1.60	6.07±1.44	5.73±1.03	5.40±1.60	5.53±1.64	6.40±1.60
	15	5.33±1.50	5.73±1.28	6.47±1.46	5.67±1.23	5.80±1.32	5.73±1.49	7.00±1.85
P – Value		0.411	0.052	0.103	0.940	0.824	0.853	0.086
	0	6.47±0.92	5.87±1.41	6.47±1.73	5.33±1.45	6.20±1.42	6.13±1.64	6.73±1.98
3	5	5.80±1.42	5.60±1.12	6.27±1.34	5.40±1.12	5.80±1.21	6.00±1.36	6.67±1.29
	10	5.80±1.57	5.20±1.21	6.47±1.13	5.73±1.79	5.93±1.44	6.20±1.15	6.47±1.19
	15	5.73±1.16	5.40±1.72	6.13±1.25	6.00±1.36	6.13±1.41	5.67±1.45	6.60±1.12
P – Value		0.261	0.610	0.889	0.591	0.908	0.769	0.670

Values are mean ± standard deviation. Values with different superscripts under the same column are significantly ($P < 0.05$) different.

4.4.5. Instrumental Colour Measurement of Soaked Pearl Millet Flour Beef Sausages (SoPMFS)

The sausages were assessed base on CIE colour system of L* (Lightness), a* (Redness) and b* (Yellowness). The analysed results with the P - values are shown in appendix I.

The L* of surface colour of the sausages differed significantly ($P < 0.05$) on all the days except day 0. However, the L* of internal colour were significantly ($P < 0.05$) different on all the days as shown in Fig. 4.5a.

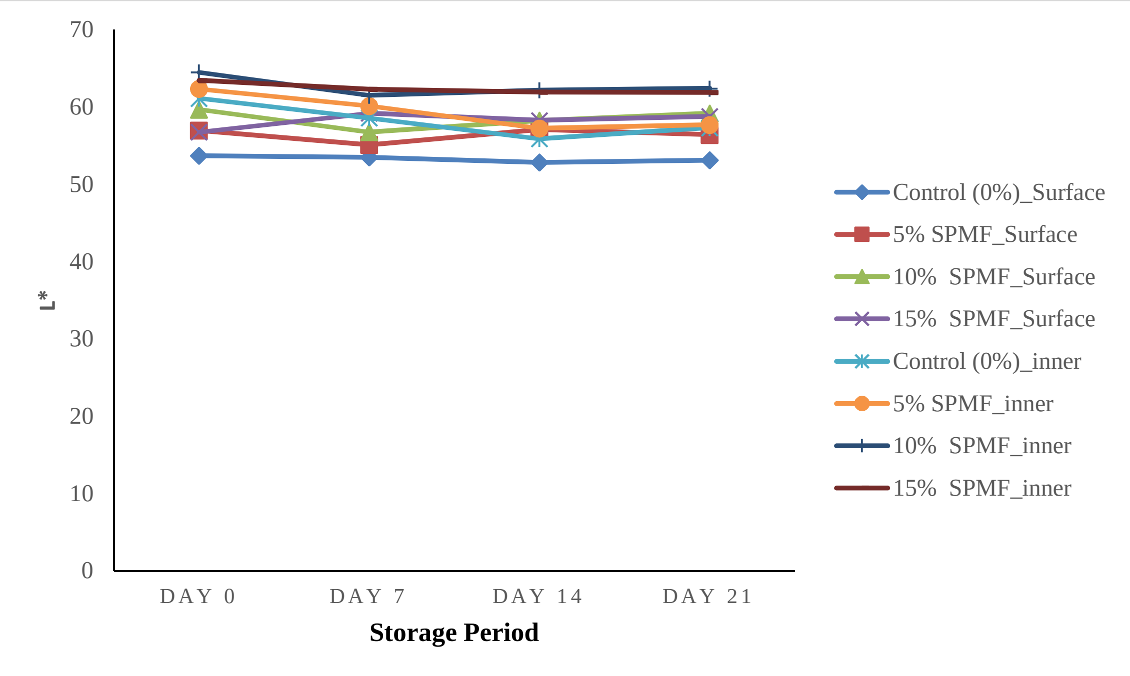

Figure 4.5a: Surface and Internal Colour (Lightness) of Soaked Pearl Millet Flour (SoPMF) Beef Sausages

The a* of surface colour of the sausages did not differ significantly ($P > 0.05$) on all the days except day 7 which was significant ($P < 0.05$). a* of internal colour were all significantly ($P < 0.05$) different except day 0 (Fig. 4.5b).

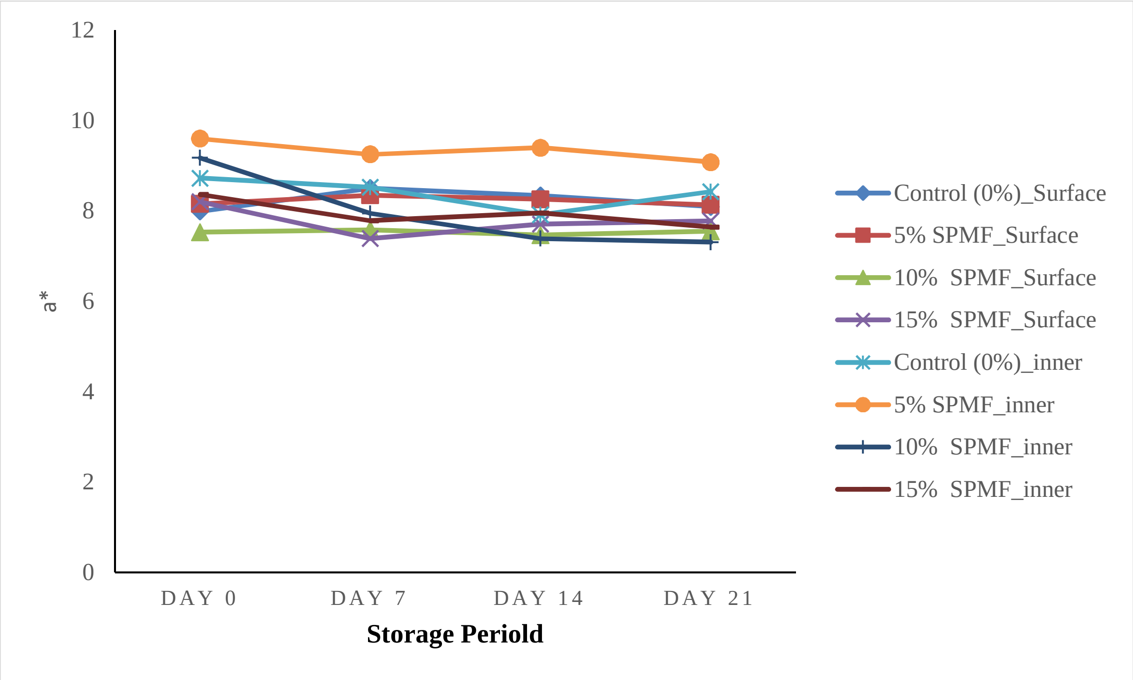

Figure 4.5b: Surface and Internal Colour (Redness) of Soaked Pearl Millet Flour (SoPMF) Beef Sausages

The b* of surface colour of the sausages were significantly ($P < 0.05$) different on day 7 and day 14 but were not different ($P > 0.05$) on day 0 and day 14. The b* of internal colour were all significantly ($P < 0.05$) different from each other on all days. This is shown in Fig. 4.5c.

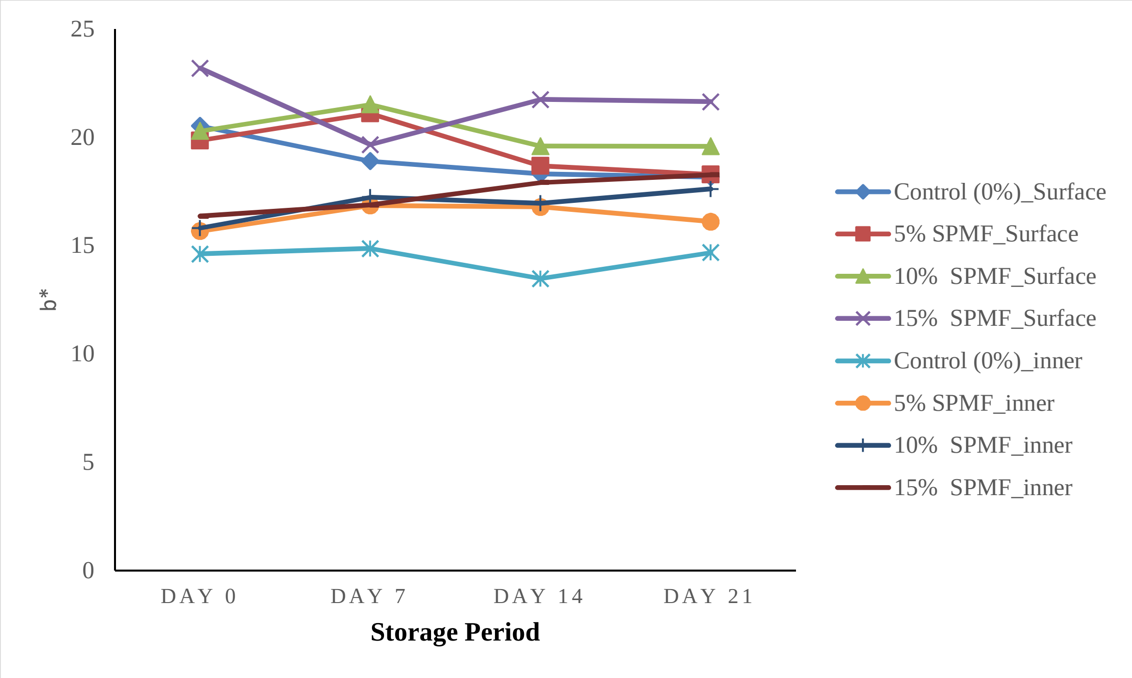

Figure 4.5c: Surface and Internal Colour (Yellowness) of Soaked Pearl Millet Flour (SoPMF) Beef

4.4.6. Peroxide Value of Soaked Pearl Millet Flour Beef Sausages (SoPMFS)

There were no significant (P > 0.05) differences in all the inclusion levels during the storage period. The peroxide values ranged from 2.98 - 4.80 meq/kg, 2.59 - 3.68 meq/kg and 2.35 – 3.31 meq/kg on week 1, week 2 and week 3, respectively as shown in Fig. 4.6. The analysed results with the P - values are shown in appendix II.

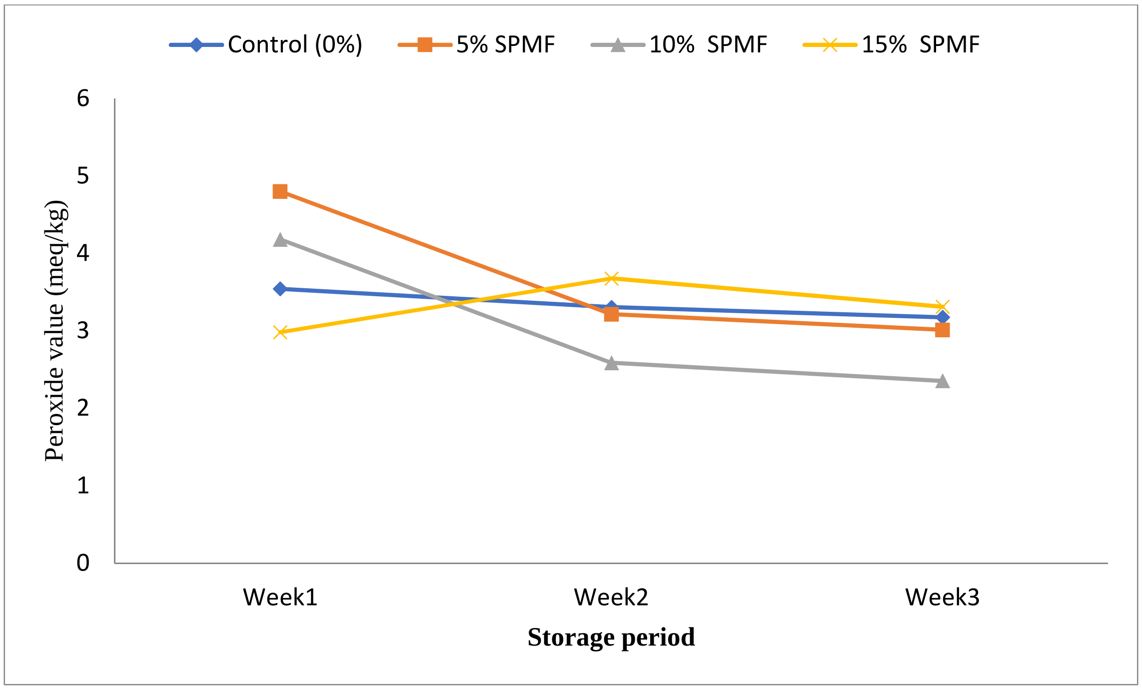

Figure 4.6: Peroxide Value of Soaked Pearl Millet Flour (SoPMF) Beef Sausages

4.4.7. Formulation Cost of Soaked Pearl Millet Flour Beef Sausages (SoPMFS)

The formulation cost of soaked pearl millet flour beef sausages is shown in Table 4.17. The formulation cost in Ghana cedis (Gh¢) for the control (0%), 5%, 10% and 15% treatment levels are 31.50, 30.925, 29.85 and 28.775, respectively.

Table 4.17: Formulation Cost of Soaked Pearl Millet Flour Beef Sausages (SoPMFS)

Ingredient	Amount (Gh¢/kg or l)	0% SoPMFS	5% SoPMFS	10% SoPMFS	15% SoPMFS
Minced beef	26	26	24.7	23.4	22.1
Pearl millet	2	-	0.1	0.2	0.3
Milling	1	-	0.05	0.1	0.15
Water for processing millet	1.5	-	0.075	0.15	0.225
Spice mix	0.5	0.7	0.7	0.7	0.7
Curing salt	0.5	0.5	0.5	0.5	0.5
Soy oil	0.8	0.8	0.8	0.8	0.8
Casing	3	3	3	3	3
Ice cube	0.5	0.5	0.5	0.5	0.5
Transportation	1.5	-	0.5	0.5	0.5
Total cost (Gh¢)		31.5	30.925	29.85	28.775

CHAPTER FIVE

5.0. DISCUSSION

5.1. Raw Pearl Millet Flour (RaPMF), Roasted Pearl Millet Flour (RoPMF) and Soaked Pearl Millet Flour (SoPMF)

5.1.1. Proximate Compositions of Raw Pearl Millet Flour (RaPMF), Roasted Pearl Millet Flour (RoPMF) and Soaked Pearl Millet Flour (SoPMF)

The moisture content of raw pearl millet flour was significantly higher than roasted pearl millet flour. Soaked pearl millet flour was, however, similar to raw pearl millet flour and roasted pearl millet four. Moisture content ranged from 6.44% to 9.76%. This is in line with Varriano – Marston and Hoseney (1980) who found that the moisture content of pearl millet ranged from 7.8 to 14.2%. The moisture content also indicated that the flours could be safely stored and this agrees with Young *et al*. (1991) who stated that the safe moisture level for the storage of cereals is 10 - 12%.

The ash content of roasted pearl millet flour was higher than raw pearl millet flour and soaked pearl millet flour, but it was insignificant. The ash content varied from 9.52 to 13.13%. This indicates that the flours contain high amount of minerals. The results collaborate with the findings of Rao (1986), FAO (1995), and Genapati *et al*. (2008) who stated that millet possess higher (3.3%) amount of ash than rice (2%) and wheat (2%).

There was insignificant difference in the fat content of raw pearl millet flour, roasted pearl millet flour and soaked pearl millet flour. The values ranged from 3.94 to 6.24% which is higher than the findings of Bora (2013) who stated that millet contains 1.5 – 5% fat.

The protein content of raw pearl millet flour, roasted pearl millet flour and soaked pearl millet flour did not differ from each other. Protein content ranged from 9.21 to 10.87%. The result is in line with Serna-Salvidar *et al*. (1991) who reported that pearl millet protein ranged from 8 to 19%.

The greater proportion of millet is made up of carbohydrate. There was non-significant differences in the carbohydrate content of raw pearl millet flour, roasted pearl millet flour and soaked pearl millet flour. The carbohydrate content varied from 65.62 to 66.61% which agrees with the findings of Bora (2013) who stated that millet contains 60 to 70% dietary carbohydrates.

5.1.2. Mineral Compositions of Raw Pearl Millet Flour (RaPMF), Roasted Pearl Millet Flour (RoPMF) and Soaked Pearl Millet Flour (SoPMF)

The iron content of roasted pearl millet flour was significantly higher than the raw pearl millet flour and soaked pearl millet flour. They were in the range of 77.63 – 105.62 mg/kg. This result meets the World Health Organisation (WHO) recommended dietary iron requirement of 10 and 15 mg/day for children and adults, respectively (World Health Organisation, 2003).

Magnesium content of raw pearl millet flour differs significantly from roasted pearl millet flour and soaked pearl millet flour. The magnesium content varied from 2108.66 – 2285.00 mg/kg which is above the recommended requirement of 80 – 420 mg/day (Institute of Medicine, 1997).

The calcium content of roasted pearl millet flour was significantly higher than raw pearl millet flour and soaked pearl millet flour. They were in the range of 193.05 – 222.89 mg/kg. Sehgal *et al*. (2003) reported that pearl millet contains

44. 5 – 49.7 mg/100g of calcium, which is lower than what this study found. Calcium is an important mineral in bone formation especially in children.

Potassium content of raw pearl millet flour was significantly higher than roasted pearl millet flour and soaked pearl millet flour. The potassium content ranged from 1256.02 – 1502.60 mg/kg. Kinabo (2015) stated the magnesium content of finger millet to be 408 mg/g, which was also lower than what was found in this study. Potassium is an important mineral that is needed for a healthy heart and muscle function (Jacob *et al*., 2015).

The zinc content of roasted pearl millet flour differs significantly from raw pearl millet flour and soaked pearl millet flour. The values ranged from 23.75 – 32.17 mg/kg which is higher than what was reported by Sehgal *et al*. (2003) for pearl millet (2.7 – 2.8 mg/100g).

5.2. Raw Pearl Millet Flour Beef Sausages (RaPMFS)

5.2.1. Proximate Compositions of Raw Pearl Millet Flour Beef Sausage (RaPMFS)

The moisture content significantly decreased with increasing level of raw pearl millet flour from 0%RaPMFS to 15%RaPMFS. The control product had the highest (68.42%) value and the 15% inclusion the least (62.12%) value while the 5% and 10% inclusion levels were comparable to each other. This agrees with Musa *et al*. (2020) who reported a decreased in moisture content with increasing cowpea seeds powder, and does not support the findings of 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. Moisture is the amount of water molecules contained in a product. The moisture content of meat is a good indicator of its relative components of energy, protein and lipids (Aberoumad and Pourshafi, 2010) and has an impact on juiciness. Increased moisture makes meat and meat products juicier while less moisture leads to less juiciness (Colmenero, 2000). Warriss (2010) stated that high moisture content makes meat and meat products susceptible to microbial growth and hence reduce shelf life of products.

The amount of ash present in food/product indicates a rough estimation of the mineral content of the product (Fasai *et al.,* 2009). There was no significant increase in ash content of products. The 10% and 15% inclusion levels numerically had a higher ash value (5.00 and 5.24%, respectively) than the control. This indicates that raw pearl millet flour is a good source of minerals and therefore can be used to enhance the mineral content of sausages.

The key contribution of fat to human diet is energy or calories (Heinz and Hautzinger, 2007). There was an insignificant increase in fat content of the products. The fat values ranged from 5.53–9.86% with the 15% inclusion having the highest value. This agrees with Taylor (2004) who stated that pearl millet possess higher fat content due to presence of unsaturated fatty acids in germ layer thereby increasing the concentration of fat to about 1.5–6.8%. Fat is an important factor in sensory evaluation of products as it contributes to juiciness (mouth feel) and flavour (Moghazy, 1999).

The addition of raw pearl millet flour to beef sausages did not reduce the protein content significantly. The protein content ranged from 16.90–19.25% with the 5% inclusion having the highest value numerically. This is in line with the report of FAO (2007) who stated that meat extenders are non-meat ingredients with significant protein content. Pond *et al.* (1995) stated that proteins are needed in higher amounts in growing children and also for reproductive functions such as pregnancy and lactation.

There was no significant increase in the carbohydrate content of the sausages. The 10%RaPMFS had the highest (6.44%) value and the 0%RaPMFS (control) had the least (2.77%) value. The high values of carbohydrate in the treatments as compare to the control is because of the added raw pearl millet flour which is a cereal and has high (75%) proportion of carbohydrates (Sheng *et al*., 2018). Sanchez-Zapata *et al*. (2010) stated that most of meat foods are rich in fat and protein but lack complex carbohydrates.

5.2.2. Mineral Compositions of Raw Pearl Millet Flour Beef Sausage (RaPMFS)

There was a significant increased in iron content of the sausages. The iron content ranged from 26.73–57.44 mg/kg indicating an increased iron content with increasing levels of replacement of beef with raw pearl millet flour from 0 – 15%. The 15%RaPMFS had the highest (57.44 mg/kg) and 0%RaPMFS (control) with the least (26.73 mg/kg) value. Iron is essential component of blood haem in promoting respiration. This result shows that the consumption of RaPMFS will not affect the iron requirement of the population as it will meet the Institute of Medicine (2001) requirement. Therefore, RaPMFS can serve as a good source of iron when consumed.

Magnesium is a vital electrolyte in all living organisms (Grober *et al*., 2015). The magnesium content of products with raw pearl millet flour was significantly higher than the control. The values varied from 594.99 – 795.73mg/kg with 15%RaPMFS having the highest value and 0%RaPMFS (control) with the least.

The recommended daily requirement of 80 – 420 mg/kg by the Institute of Medicine (1997) will be met by consuming this product. Magnesium is noted for reducing the severity of asthma and migraine attack and also lowers high blood pressure (Ensminger *et al*., 1986).

Calcium content increased as the inclusion level of raw pearl millet increased. The calcium content ranged from 64.26 – 99.11mg/kg. All the inclusion levels (5%, 10% and 15%) were significantly higher than the control (0%). Murray *et al*. (2000) stated that calcium is needed for proper bone formation especially in children to prevent ricket and adults to prevent osteoporosis. Potassium is a major component in every living cell and an indispensable nutrient needed in large quantities by humans (Hamdallah, 2004). The potassium content of the 15%RaPMFS and 0%RaPMFS (control) were higher than the 5%RaPMFS and 10%RaPMFS. The values varied from 1072 – 1156 mg/kg with the 15% inclusion having the highest value and 5% inclusion the least. Pohl et al. (2013) stated that potassium is important for the normal functioning of all parts of the human body. Raw pearl millet flour beef sausages will help meet the potassium needs of the body when consumed.

The zinc content of 0%RaPMFS, 5%RaPMFS and 10%RaPMFS significantly differed from the 15%RaPMFS. The values ranged from 30.61 – 33.96 mg/kg with the control (0%) having the highest and 15% inclusion the least. These values meet the WHO (1996) recommended requirement of 1.4 mg/day for adult males and 1.0 mg/day for females. According to Prasad (2003), about two billion people in the third world countries are zinc deficient. The consumption of the products will help meet the zinc needs of the body.

5.2.3. Physiochemical Properties of Raw Pearl Millet Flour Beef Sausage (RaPMFS)

5.2.3.1. The pH of Raw Pearl Millet Flour Beef Sausages (RaPMFS)

The pH value of the control was significantly lower than products with test materials. The 15%RaPMFS had a higher (6.03) pH while the control (0%RaPMFS) had a lower (5.94) pH value. These values are in line with the pH ranges of 5.8 – 6.0 and 5.2 – 6.02 reported by FAO (2007) and Warriss (2010), respectively as the ideal pH for quality meat and meat products. Oshibanjo *et al*. (2013) reported that higher pH of meat is important in maintaining colour, holding water and improving tenderness. However, Young *et al*. (2004) stated that pH values as high as 6.9 causes colour defects. Acidic pH is reported to lower water holding capacity while increasing cooking and drip losses (Northcutt *et al*., 1994) and result in PSE meat (Barbut, 1997).

5.2.3.2. Cooking Loss of Raw Pearl Millet Flour Beef Sausages (RaPMFS)

Cooking loss of beef sausages incorporated with test material significantly decreased with increased levels of replacement. This may be due to fact that the raw pearl millet flour act as a binder and prevented loss of moisture during the cooking process as reported by Pearson and Gillett (1999) that plant protein used as binders and extenders absorb large amount of water and make ground meat adhere to each other. Pietrasik *et al*. (2007) stated that non-meat proteins are used to replace gelling substances in processed meat products to improve the feel and yield of products by enhancing water-binding properties. The increase in water holding during cooking may be due to the degradation of protein. Lawrie (1991) reported that the heat degradation of protein increases the concentration of peptides and amino acids and result in increases intracellular osmotic pressure leading to increase water holding capacity.

5.2.3.3. Water Holding Capacity (WHC) of Raw Pearl Millet Flour Beef Sausages (RaPMFS)

Water holding capacity is the ability of meat to retain its water or added water during application of external forces such as cutting, pressing, heating or grinding (Judge *et al*., 1990). There was insignificant difference in the control and the products incorporated with test material. This shows that, raw pearl millet flour has the ability to form gel and to retain moisture as reported by Petersson *et al*. (2014).

5.2.3.4. Drip Loss of Raw Pearl Millet Flour Beef Sausages (RaPMFS)

The 0%RaPMFS and 10%RaPMFS were not affected by drip loss. This may be due to the ability of the control and 10% inclusion to bind together and to prevent loss of moisture. The 5%RaPMFS and 15%RaPMFS decrease in mean weight by 5.88% and 7.17%, respectively. High drip losses affect the colour, texture and nutritional value of fresh meat and meat products (Otto *et al*., 2004).

5.2.3.5. Water Activity (a_w) of Raw Pearl Millet Flour Beef Sausages (RaPMFS)

Water activity is the ratio of the water vapour pressure of food substrate to the vapour pressure of pure water at the same temperature (Adams *et al*., 2008). The water activity of the 0%RaPMFS (control), 10%RaPMFS and 15%RaPMFS were similar to each other. The 10% and 15% inclusions did not differ, but differed from the 5% treatment, while the control was similar to the 5%. The values ranged from 0.805 – 0.815 in 10% and 15% inclusions, respectively. The a_w values of this study would limit the growth of most spoilage bacteria and yeasts as they require a minimum a_w of 0.90 and 0.88 respectively to grow (Adams and Moss, 2008). According to Ghaly *et al.* (2010) food pathogens are unable to grow at a_w of 0.85. The a_w values of this study are an indication that the storage and shelf life of the products can be prolonged.

5.2.4. Sensory Properties of Raw Pearl Millet Flour Beef Sausages (RaPMFS)

The inclusion of raw pearl millet flour did not impact negatively on sensory characteristics of beef sausages evaluated (Table 3.3). The colour of the sausages did not differ significantly from each other throughout the storage period. This implies that sausages formulated with test materials were equally acceptable to panelists as the control. Lawrie and Ledward (2006) mentioned colour as one of the important factors in determining the quality of meat and meat products. Flavour intensity of the sausages were not significantly different from each other. Flavour liking in week two of 0%RaPMFS (control) was significantly higher than 15%RaPMFS but not 5%RaPMFS and 10%RaPMFS. No significant differences were observed in texture, tenderness and juiciness of the sausages throughout the storage period. This agrees with James and Berry (1997) who found similar results in juiciness, flavour and tenderness in patties of beef and goat. The overall liking of the sausages did not vary significantly from each other in week 1 and 2. Overall liking of 0%RaPMFS was significantly higher than 15%RaPMFS but not the 5%RaPMFS and 10%RaPMFS in week 3. This indicates that raw pearl millet flour can be incorporated in beef sausages up to 10% and be acceptable to consumers which affirms the findings of Teye *et al*. (2009) who stated that inclusion of cowpea flour up to 10% in comminuted beef and pork frankfurter-type sausages gave positive outcomes in sensory and yield of products.

5.2.5. Instrumental Colour Measurement of Raw Pearl Millet Flour Beef Sausages (RaPMFS)

Surface colour of the sausages in terms of L* (lightness) did not differ significantly (P > 0.05) from each other during the storage period from day 0 – day 21. The internal colour in terms L* did not differ significantly from each other on day 0 and day 7. The L* value of 15%RaPMFS was significantly higher than the 0%RaPMFS, 5%RaPMFS and 10%RaPMFS on day 14 and day 21. Lightness generally increased with increasing replacement levels of raw pearl millet flour and with storage time in both surface and internal colour. Garcia (2005) stated that colour is an indication of meat freshness and directly impacts on the decision of consumers to purchase.

The surface colour of the sausages in terms of a* (Redness) differed significantly (P < 0.05) from each other on day 0 - day 14, but not on day 21. The internal colour in terms of a* of 0%RaPMFS was significantly higher than 10%RaPMFS (7.77) and 15%RaPMFS (7.62) on day 0 but was similar to the 5%RaPMFS (8.08). The 5%RaPMFS was significantly higher (8.43) than 10%RaPMFS (7.19) but similar to 0%RaPMFS (8.13) and 15%RaPMFS (7.92) on day 14. It was observed that the redness value of the test products reduced slightly with increased replacement levels. The surface colour of the sausages in terms of b* (Yellowness) varied significantly from each other on day 7 to day 21. In the case of internal colour, b* value differed significantly from each other on day 7 – day 21. The 15%RaPMFS was significantly higher than 0%RaPMFS (control) but similar to 10%RaPMFS on day 7 of formulation. b* value of 10%RaPMFS was significantly higher than 0%RaPMFS (control) but similar to 5%RaPMFS and 15%RaPMFS on day 14 of formulation. The b* value on day 21 of 10%RaPMFS was significantly higher than 0%RaPMFS (control) but not the 5%RaPMFS and 15%RaPMFS. In general, the yellowness of the test products increased as the treatment level increases.

5.2.6 Peroxide Value (PV) of Raw Pearl Millet Flour Beef Sausage (RaPMFS)

Peroxide values of the sausages with test materials and control product did not vary significantly from each other during the storage period. The mean PV ranged from 3.16 – 3.86 meq/kg, 2.19 – 3.67 meq/kg and 1.92 – 3.27 meq/kg in week 1, week 2 and week 3, respectively. These values are far below the maximum permissible limit of 25 meq/kg of active oxygen/kg of product (Evranus, 1993). The lower values of products with test materials could be assigned to the presence of raw pearl millet flour which served as antioxidants to stop lipid oxidation. Millet have higher free radical quenching potential (Devi *et al*., 2011) with natural antioxidants like vitamin C, tocopherol and carotenoids.

5.2.7. Formulation Cost of Raw Pearl Millet Flour Beef Sausages (RaPMFS)

The formulation cost of extended sausages was lower than the control product. There was a trend in reduction of cost as inclusion level increases. The 15% inclusion level had the lowest cost of production followed by the 10% and 5%

respectively. This is because the same proportion of lean beef cost more than the same percentage cost of pearl millet on kilogram basis. This result agrees with Heinz and Hautzinger (2007) who mentioned that the use of extenders and fillers in meat processing could cause about 10 to 30% reduction in cost of meat products.

5.3. Roasted Pearl Millet Flour Beef Sausages (RoPMFS)

5.3.1. Proximate Compositions of Roasted Pearl Millet Flour Beef Sausages (RoPMFS)

There was a trend in the moisture content of extended sausages. Higher replacement of lean beef with roasted pearl millet flour result in reduced moisture content. This could be the result of its ability to hold most of the water as bound water. The values ranged from 68.42 – 61.07%. Moisture content of sausage is about 66.7% (Agnihotri and Pall, 2000). This implies that the juiciness of the products would not be affected negatively as moisture plays a major role in juiciness of meat products.

The ash content of the sausages with test materials increased with increasing levels of inclusion. Ash content varied from 4.47 – 5.94% in the control (0%RoPMFS) and 15%RoPMFS respectively. These indicate that roasted pearl millet flour is a rich source of minerals which are vital for biological functions of the human body (Ullah *et al*., 2010).

Fat content of products were not statistically different from each other. The sausages which contained test materials had higher values than the control. Hegazy (2011) reported increased in fat content with increased level of inclusion of fenugreek in beef sausages. This implies that the sausages would not be affected negatively in their sensory attributes as dietary fat impacts positively on juiciness, flavour and texture of processed meat products (Crehan *et al*., 2000).

Protein content of the 15% was significantly higher than the 5% inclusion, but similar to the control and 10% inclusion. The control, 5% and 10% did not differ from each other. The 15% inclusion had the highest (20.02%) protein content. The increase in protein content could be attributed to the high protein value of roasted pearl millet flour which is similar to the findings of Teye *et al*. (2012) who mentioned increased in protein content as the inclusion level of cowpea increased in beef and ham burgers. Ranathunga *et al*. (2015) reported a decreased in protein content of maize flour as an extender on physical, chemical and sensory characteristics of sausages.

5.3.2. Mineral Compositions of Roasted Pearl Millet Flour Beef Sausages (RoPMFS)

The study revealed that beef sausages formulated with roasted pearl millet flour at various inclusion levels contain significantly higher amount of minerals. Iron and magnesium content increased with increased replacement of lean beef with roasted pearl millet flour. The consumption of sausages extended with roasted pearl millet flour would serve as a source of iron for humans (Kaiser and Allen, 2008).

The calcium content of the sausages did not follow a specific pattern. The 10%RoPMFS recorded the highest (98.84 mg/kg) value, followed by 5%RoPMFS with a value of 93.67 mg/kg, 15%RoPMFS with a value of 91.22 mg/kg and 0%RoPMFS with a value of 64.26 mg/kg. Calcium is needed for proper bone formation especially in children to prevent ricket and adults to prevent osteoporosis (Murray *et al*., 2000).

Potassium content of the control, 5% and 15% inclusions are statistically not different from each other, but were different from the 10% inclusion. Beef sausages prepared with incorporation of roasted pearl millet flour contain significantly higher amount of potassium which is important for normal body function (Pohl *et al*., 2013).

The zinc content ranged from 35.29 mg/kg to 32.20 mg/kg. The 5%RoPMFS had the highest value, followed by 0%RoPMFS while the 10%RoPMFS and 15%RoPMFS did not differ from each other. The consumption of sausages incorporated with roasted pearl millet flour could help to reduce zinc deficiency related diseases and infections (Hambidge and Krebs, 2007).

5.3.3. Physicochemical Properties of Roasted Pearl Millet Flour Beef Sausages (RoPMFS)

5.3.3.1. The pH of Roasted Pearl Millet Flour Beef Sausages (RoPMFS)

The pH of 15%RoPMFS was significantly higher than the control (0%RoPMFS) and 5%RoPMFS but did not differ from the 10%RoPMFS. The control and 5% inclusion were statistically not different. Shelf life is influence by pH of products (FAO, 2007) lower values do not permit the growth of pathogenic bacteria. The pH range of 5.94 – 6.00 found in this study is similar to the findings of Ibrahim (2008) who reported the pH of beef sausages to range from 6.40 – 6.44.

5.3.3.2. Cooking Loss of Roasted Pearl Millet Flour Beef Sausages (RoPMFS)

The 10% inclusion recorded a lower percentage cooking loss as compared to the 15%, 5% and the control. The control and the 5% inclusion were statistically not different from each other. The percentage cooking loss ranged from 13.32 – 26. 74% which is similar to the findings of Teye *et al*. (2012) who stated 24.50 – 27.00g in weight loss of extended beef and ham burgers.

5.3.3.3. Water Holding Capacity (WHC) of Roasted Pearl Millet Flour Beef Sausages (RoPMFS)

The addition of roasted pearl millet flour did not affect the water holding capacity of the sausages. The values varied from 1.12 – 1.25ml/g. This can be attributed to the ability of test materials to bind water in the sausages which is in line with Serdaroglu and Degirmencioglu (2004) who mentioned that corn flour has the ability to keep moisture in meat products.

5.3.3.4. Drip Loss of Roasted Pearl Millet Flour Beef Sausages (RoPMFS)

There was no drip loss in 0%RoPMFS, 10%RoPMFS and 15%RoPMFS. These sausages maintained their weight throughout the forty-eight-hour period which may be due to the ability of the sausages to hold moisture as a result of added roasted pearl millet flour. The 5%RoPMFS lost about 6.61% in weight due to drip loss. This may be because the 5% inclusion was not adequate to hold back moisture as compared to the 10% and 15% inclusions. High drip losses affect the colour, texture and nutritional value of fresh meat and meat products (Otto *et al*., 2004).

5.3.3.5. Water Activity (a_w) of Roasted Pearl Millet Flour Beef Sausages (RoPMFS)

Water activity is the ratio of the vapour pressure of water in a material to the vapour pressure of pure water at the same temperature (Bhandari and Adhikari, 2008). Water activity in meat products is equivalent to the relative humidity of air in equilibrium with the product (Comaposada *et al.*, 2000). The a_w values of the sausages were statistically different from each other. The 10%RoPMFS was statistically different from the 5%RoPMFS, but similar to the control and 15% inclusion. The values ranged from 0.810 – 0.814. Scott (1957) indicated that microorganisms have a limiting a_w level below which they will not grow. The lowest water activity at which most food spoilage bacteria would grow is about 0.90 (Adams and Moss, 2008). Ghaly *et al.* (2010) stated that pathogens are unable to grow at a_w of 0.85 which is higher than the values found in this study.

5.3.4. Sensory Properties of Roasted Pearl Millet Flour Beef Sausages (RoPMFS)

There was a non-significant difference in colour, flavour intensity, flavour liking, texture, tenderness, juiciness and overall liking of the extended sausages and the control during the storage period. However, mean score for overall liking in week two was higher in the control than 10% and 15% inclusions. The mean scores for all the parameters were within the intermediate of a 9-point hedonic scale which is indicative of consumers' acceptability of the sausages which agrees with the findings of Teye *et al.* (2009) who stated that inclusion of cowpea flour up to 10% in comminuted beef and pork frankfurter-type sausages gave positive outcomes in sensory and yield of products.

5.3.5. Instrumental Colour Measurement of Roasted Pearl Millet Flour Beef Sausages (RoPMFS)

The lightness (L*) of the sausages in terms of the surface colour were not significantly different from each other on day 0, day 7 and day 21 but on day 14 the 15% inclusion was significantly higher than the 10% inclusion but similar to the 5% inclusion and the control. Internal colour in terms of L* were not significantly different from each other during the storage period. The inclusion of roasted pearl millet flour in beef sausages did not affect the lightness of the sausages with regards to surface and internal colour as the treatments were comparable to the control.

Surface colour in terms of a* (Redness) of the sausages were significantly different from each other on day 0 to day 21 but not on day 14. With the internal colour, a* of the sausages on all the days were significantly different from each other. The redness of the test products reduced with increasing level of inclusion with the 5% inclusion having the highest value compared to the control in terms of internal colour. Surface and internal colour in the case of b* (Yellowness) of the sausages varied significantly from each other in all the days. In general, yellowness increased with increased replacement level and with storage period which may be as a result of the presence of yellow pigment in millet.

5.3.6. Peroxide Value (PV) of Roasted Pearl Millet Flour Beef Sausages (RoPMFS)

Peroxide values of the sausages did not vary significantly from each other during the storage period. PV values varied from 2.84 meq/kg – 3.59 meq/kg, 2.41meq/kg – 3.80 meq/kg and 2.21 meq/kg – 3.47 meq/kg in week 1, week 2 and week 3, respectively. The peroxide values of this study were below the maximum permissible limit of 25 meq/kg of oxygen/kg of products (Evranus, 1993). The sausages incorporated with test materials had lower values due to the presence of roasted pearl millet flour which served as antioxidant to stop lipid oxidation. Millet have higher free radical quenching potential (Devi *et al*., 2011; Quesada *et al*., 2011; Kamara *et al*., 2012).

5.3.7. Formulation Cost of Roasted Pearl Millet Flour Beef Sausages (RoPMFS)

The formulation cost of 5%RoPMFS, 10%RoPMFS and 15%RoPMFS were lower than 0%RoPMFS (control). The reason is that the cost of 5, 10 or 15% lean beef cost more than the same percentage cost of pearl millet on kilogram basis. This shows that inclusion of roasted pearl millet flour in beef sausages could reduce the cost of production making the products more affordable compared to the control. Malav *et al*. (2013) stated that high cost of meat products limits its regular usage by the average income earner due to expensive nature of lean meat.

5.4. Soaked Pearl Millet Flour Beef Sausages (SoPMFS)

5.4.1. Proximate Compositions of Soaked Pearl Millet Flour Beef Sausages (SoPMFS)

The moisture content of the control (0%SoPMFS) product was significantly higher than the 5%SoPMFS, 10%SoPMFS and 15%SoPMFS. The 5%SoPMFS and 10%SoPMFS did not differ from each other, but were significantly higher than the 15%SoPMFS. The moisture content varied from 61.69 – 68.42%. As the percentage of soaked pearl millet flour increased in the formulation, moisture content decreased as the flour has ability to hold back moisture as bond water. This result does not agree with Santhi and Kalaikannan (2014) who mentioned increased in moisture content as oat flour increased in low-fat chicken nuggets. However, the values are similar to the finding of Agnihotri and Pall (2000) who stated the moisture content of sausages to be 66.7%.

Ash content of soaked pearl millet flour beef sausages did not vary significantly from each other. The 10% and 15% inclusions had higher (5.09% and 6.11%) ash contents than 5% inclusion (4.05%) and the control (4.47%). This is an indication that soaked pearl millet flour possess minerals which are vital for biological functions of the human body (Ullah *et al*., 2010).

There was no trend in fat content of soaked pearl millet flour beef sausages. However, the fat content of the test products was numerically higher than the control. The fat content ranged from 5.53 – 10.04%. These results do not support the findings of Ergezer *et al*. (2014) who stated a reduction of fat in low fat meat balls incorporated with potato puree and bread crumbs. The values were lower than the values (11.46% and 11.6%) reported by Amir *et al*. (2015) in chickpea and lentil flour.

Protein content of soaked pearl millet flour beef sausages and the control product were not significantly different from each other. As the percentage of soaked pearl millet flour increased, protein content decreased slightly with the control product having the highest value. The protein content varied from 16.70 – 18.81%. This result is in line with Yang *et al*. (2007) who mentioned reduction in protein content with added hydrated oat meal in low-fat pork sausages.

The carbohydrate content of the 15%SoPMFS was significantly higher than the 5%SoPMFS, 10%SoPMFS and 0%SoPMFS (control). The 0%SoPMFS (control), 5%SoPMFS and 10%SoPMFS did not differ from each other. This is because millet is a cereal and has higher amount of carbohydrates.

5.4.2. Mineral Compositions of Soaked Pearl Millet Flour Beef Sausages (SoPMFS)

The iron content of sausages formulated with the incorporation of soaked pearl millet flour were significantly higher than the control product. The 15%SoPMFS was higher than the 5%SoPMFS, 10%SoPMFS and 0%SoPMFS (control). The 5% and 10% inclusions did not differ from each other, but were significantly higher than the control. This is an indicative of high iron content in soaked pearl millet flour which when incorporated in sausages would help to meet the iron needs of humans. Inadequate iron intake leads to tiredness, susceptibility to infection, reduced intellectual performance, anorexia and decreased cardiovascular endurance (Institute of Medicine, 2001).

Magnesium content of 15%SoPMFS was significantly higher than the 5%SoPMFS, 10%SoPMFS and 0%SoPMFS (control). The 10% inclusion was significantly higher than the 5% inclusion and the control. The control and 5% inclusion were not statistically different from each other. This shows that magnesium is high in soaked pearl millet flour which is in line with Grober *et al*. (2015) who mentioned seeds and unrefined cereals as rich sources of magnesium.

The calcium content of the 10% inclusion was significantly higher than the control, 5% and 15% levels of inclusion. The 15% inclusion had a higher value than 5% inclusion and the control while 5% replacement had a higher value than the control. The results indicate that soaked pearl millet flour has high amount of calcium which is needed for bone formation. Calcium helps in proper bone formation especially in children to prevent ricket and in adults to prevent osteoporosis (Murray *et al*., 2000).

The potassium content of the control was significantly higher than the 5%, 10% and 15% levels of incorporation with soaked pearl millet flour. The 15% inclusion recorded a higher value than the 5% and 10% inclusions. The values varied from 1137.46mg/kg – 1044.87mg/kg. Hamdallah (2004) stated that potassium is an indispensable nutrient that is needed in large quantities by humans.

Zinc content of the control product was significantly higher than the sausages incorporated with soaked pearl millet flour. The 10% inclusion had a higher value than the 5% and 15% levels of incorporation while the 15% inclusion was higher than the 5%. This may be due to the leaching of the mineral during the soaking process which confirms the findings of Lestienne *et al*. (2005) who stated that soaking can cause the total loss of iron and zinc. FAO and WHO (2004) mentioned that zinc has an essential role in polynucleotide transcription and genetic expression.

5.4.3. Physicochemical Properties of Soaked Pearl Millet Flour Beef Sausages (SoPMFS)

5.4.3.1. The pH of Soaked Pearl Millet Flour Beef Sausages (SoPMFS)

There was no significant increase in the pH values of the treatments and the control. The values ranged from 5.94 – 6.01. These values are in line with the pH ranges of 5.8 – 6.0 and 5.2 – 6.02 reported by FAO (2007) and Warriss (2010), respectively as the ideal pH for quality meat and meat products.

5.4.3.2. Cooking Loss of Soaked Pearl Millet Flour Beef Sausages (SoPMFS)

The 15% inclusion had a significantly lower cooking loss compared to the control, 5% and 10% inclusions. The control, 5% and 10% inclusions were not statistically different from each other. This may be because the soaked pearl millet flour served as a binder to retain moisture. Pietrasik *et al*. (2007) stated that non-meat proteins are used to replace gelling substances in processed meat products to improve the feel and yield of products by enhancing water-binding properties.

5.4.3.3. Water Holding Capacity (WHC) of Soaked Pearl Millet Flour Beef Sausages (SoPMFS)

The WHC of the control was significantly higher than the 15% replacement but similar to 5% and 10% inclusions, while 5% and 10% were similar to the 15% inclusion. This indicates that increased replacement of soaked pearl millet flour above 10% would not result in increased water holding capacity. Serdaroglu and Degirmencioglu (2004) mentioned an increase in moisture retention with the inclusion of corn flour at 2 and 4% level in meat balls.

5.4.3.4. Drip Loss of Soaked Pearl Millet Flour Beef Sausages (SoPMFS)

The control, 10% and 15% replacement levels were not affected by drip loss. These sausages maintained their weight throughout the forty-eight-hour period which may be due to the ability of the sausages to hold moisture as a result of added soaked pearl millet flour. The 5%SoPMFS lost about 6.61% in weight due to drip loss. This may be because the 5% inclusion was not adequate to hold back moisture as compared to the 10% and 15% inclusions. High drip losses affect the colour, texture and nutritional value of fresh meat and meat products (Otto *et al*., 2004).

5.4.3.5. Water Activity (a_w) of Soaked Pearl Millet Flour Beef Sausages (SoPMFS)

Water activity is the ratio of the water vapour pressure of food to the water vapour pressure of pure water under the same conditions (Ghaly *et al.,* 2010). Water activity value of 10% inclusion was significantly lower than the control, but similar to 5% and 15% replacement levels. The control was similar to the 5% and 15% inclusion. The values ranged from 0.806 – 0.812. These values would not be favourable for the growth of most pathogenic microorganisms which affect the quality and shelf life of meat products. Quality of meat and meat products degrade as a result of digestive enzymes, microbial spoilage and fat oxidation (Berkel *et al*., 2004).

5.4.4. Sensory Properties of Soaked Pearl Millet Flour Beef Sausages (SoPMFS)

There were non-significant differences in sensory qualities evaluated among the treatments and the control during the storage period. All the parameters recorded a high mean score which is an indication of its acceptability by panelists. This agrees with the findings of Santhi and Kalaikannan (2014) who studied the effect of the addition of oat flour in low-fat chicken nuggets and found insignificant differences in the treatments and control.

5.4.5. Instrumental Colour Measurement of Soaked Pearl Millet Flour Beef Sausages (SoPMFS)

The L* (Lightness) of surface colour of 10%SoPMFS was significantly higher than the 0%SoPMFS (53.69), but was similar to the 5%SoPMFS and 15%SoPMFS on day 0. On day 7 the L* value of 15% (59.18) inclusion was significantly higher than the control (53.48) and 5% (55.10) inclusion, but was similar to 10% (56.76) inclusion level. L* of treatments (5%SoPMFS, 10%SoPMFS and 15%SoPMFS) on day 14 were significantly higher (57.06, 58.23 and 58.26) than the control (52.83). L* of 10% (58.23) inclusion differed significantly from the control (52.83) and 5% (57.06) inclusion, but similar to 15% (58.26) replacement on day 21. The lightness of the sausages in terms of the surface colour did not follow a particular trend. However, the values of the 10% and 15% treatments were significantly higher than the control and decreased with storage period. The L* of internal colour of 10%SoPMFS (64.48) was significantly higher than the 0%SoPMFS (61.11), but was similar to the 5%SoPMFS and 15%SoPMFS on day 0. L* of 15% (62.30) and 10% (61.49) recorded significantly higher values than the control (58.58), but were similar to the 5% (60.12) inclusion on day 7. On day 14, the 10% and 15% treatments were significantly higher (62.17 and 61.92) than the control (55.89) and 5% (57.23) treatment. L* of 10% (62.40) and 15% (61.87) treatments were significantly higher than the control (57.31) and 5% (57.68) treatment on day 21. Lightness of the sausages in terms of the internal colour did not follow a specific pattern. The 10% and 15% inclusions were significantly higher than the control, but at a decreasing value as the number of days' increases.

The a* (Redness) of surface colour of the treatments and the control were not significantly different from each other on day 0, day 14 and day 21. a* of the control (8.50) was significantly higher than the 10% and 15% (7.58 and 7.39) inclusions, but similar to the 5% on day 7. The redness of the sausages in terms of surface colour remain stable on day 0 and significantly increased on day 7 and continued to be stable on day 14 to day 21. This implies that the addition of soaked pearl millet four did not affect the redness of the sausages which is one of the qualities consumers consider in making purchases. The a* of internal colour of the treatments and the control did not differ significantly from each other on day 0. a* of the 5% (9.25) treatment was significantly higher than 10% and 15% (7.94 and 7.78) treatments, but was similar to the control (8.52) on day 7. On day 14 the a* of 5% treatment was significantly higher than the 10% (7.39) treatment but similar to the control. The a* of 5% (9.08) inclusion and the control (8.43) were significantly higher than the 10% and 15% (7.31 and 7.64) inclusions on day 21. Redness of the of sausages in the case of internal colour on day 0 did not differ from each other. The results however, revealed that higher inclusion levels led to reduced redness value. Redness value was optimum at 5% inclusion and comparable to the control.

The b* (Yellowness) of surface colour of the treatments and the control were not significantly different from each other on day 0, day 14 and day 21. b* of 10% (21.52) inclusion differed significantly from the control (18.91), but similar to 5% and 15% inclusions on day 7. The yellowness of the sausages in terms of the surface colour did not vary from each other on day 0, 14 and 21, but the 10% inclusion significantly differed from the control on day 7. This may be as a result of the presence of yellow pigment in millet. The b* of internal colour of 15% (16.36) and 10% (15.81) treatments were significantly higher than the control (14.61), but were similar to the 5% treatment on day 0. b* values of the treatments (16.85, 17.24 and 16.87; 16.79, 16.96 and 17.92) were significantly higher than the control (14.87 and 13.48) on day 7 and day 14, respectively. The b* value of the 15% (18.27) treatment was significantly higher than the control (14.68) and 5% (16.11) inclusion, but was similar to the 10% (17.62) treatment on day 21. Yellowness of the sausages in the case of internal colour increased with increasing inclusion level and with storage period.

5.4.6. Peroxide Value (PV) of Soaked Pearl Millet Flour Beef Sausages (SoPMFS)

The peroxide values of the treatments and the control were statistically not different from each other. The 5% inclusion recorded the highest mean value in week 1 while the 15% had the highest mean value in week 2 and week 3. However, the peroxide values were below the maximum permissible limit of 25meq/kg of active oxygen/kg of product (Evranus, 1993).

5.4.7. Formulation Cost of Soaked Pearl Millet Flour Beef Sausages (SoPMFS)

The formulation cost of 5%SoPMFS, 10%SoPMFS and 15%SoPMFS were lower than 0%SoPMFS (control). This is because the cost of 5, 10 or 15% lean beef cost more than the same percentage cost of pearl millet on kilogram basis. This is an indication that the inclusion of soaked pearl millet flour up to 15% in beef sausages could reduce the cost of production making the products available to most consumers. Malav *et al*. (2013) stated that high cost of meat products limits its regular usage by the average income earner due to expensive nature of lean meat.

CHAPTER SIX

6.0. CONCLUSION AND RECOMMENDATION

6.1. Conclusion

Pearl millet (*Pennisetum glaucum*) is a good source of protein which can be used as an extender in beef sausages and other meat products. It contains significant quantities of macro and micro minerals that are essential for good body function.

The inclusion of raw pearl millet flour did not affect the protein, ash, fat and carbohydrate content of the sausages. The moisture content of the control product was higher (68.42%) than the test products with the 15% inclusion having the least (62.12%) value. The iron, magnesium and calcium content of the test products (5%RaPMFS, 10%RaPMFS and 15%RaPMFS) were significantly higher than the control (0%RaPMFS). The 15% inclusion had the highest potassium value and the control had the highest zinc value. pH of 15% inclusion was significantly higher (6.03) than the control (5.94), while water holding capacity of the control and treatments did not differ.

The inclusion of roasted pearl millet flour did not significantly increase the protein, ash and fat contents of the treatments and control. However, the 15% inclusion recorded a higher value of protein, ash and fat contents. Moisture content reduced with increased level of replacement. Iron, magnesium and calcium content of the treatments (5%RoPMFS, 10%RoPMFS and 15%RoPMFS) were significantly higher than the control (0%RoPMFS). The potassium content of the control, 5% and 15% inclusions were similar, while 5% treatment had the highest value of zinc. The pH of the 15% treatment had a significantly higher (6.00) value than the control (5.94), while 10% inclusion recorded a significantly lower cooking loss compared to the control, 5% and 15% inclusions.

The addition of soaked pearl millet flour did not reduce significantly the protein, ash and fat content of the test products and the control. Moisture content decreased with increased replacement. The iron, calcium and magnesium content of test products (5%SoPMFS, 10%SoPMFS and 15%SoPMFS) were significantly higher than control (0%SoPMFS). The control recorded significantly higher content of potassium and zinc than the test products. The pH of the sausages did not differ significantly from each other. Water activity values were lower in the treatments as compared to the control. Sensory attributes of the sausages in all three experiments were not affected negatively; treatments were equally comparable to the control product. The presence of raw, roasted and soaked pearl millet flour in the sausages reduced the peroxide value as it contains antioxidants, which is a good sign for reducing lipid oxidation. There was a trend in reduction of cost as inclusion level increases. The 15% inclusion level had the lowest formulation cost.

6.2. Recommendations

1. Further study should be conducted on the microbial quality of the products.

2. Future work should concentrate on germination and malting process of pearl millet and how it affects sensory qualities of beef sausages.

3. Processors can achieve desirable qualities in beef sausages by incorporating up to 10% raw, roasted or soaked pearl millet flour.

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APPENDICES

Appendix I : Analysed Data on Instrumental Colour Measurement

Surface Colour of RaPMFS, Day 0

Treatment	L*	a*	b*
0%RaPMFS(Control)	53.693	7.990^{ab}	20.533
5%RaPMFS	52.473	8.477^{a}	20.900
10%RaPMFS	53.800	7.973^{ab}	21.960
15%RaPMFS	50.313	7.850^{b}	21.507
P-value	0.319	0.039	0.244

Surface Colour of RaPMFS, Day 7

Treatment	L*	a*	b*
0%RaPMFS(Control)	53.483	8.500^{ab}	18.907^{c}
5%RaPMFS	54.873	8.727^{a}	19.940^{b}
10%RaPMFS	55.013	8.400^{ab}	21.250^{a}
15%RaPMFS	55.453	7.297^{b}	21.560^{a}
P-value	0.125	0.025	0.000

Surface Colour of RaPMFS, Day 14

Treatment	L*	a*	b*
0%RaPMFS(Control)	52.830^{ab}	8.337^{a}	18.313^{c}
5%RaPMFS	50.223^{b}	8.333^{a}	18.457b^{c}
10%RaPMFS	55.643^{a}	8.070^{a}	20.140^{ab}
15%RaPMFS	54.350^{ab}	7.253^{b}	21.437^{a}
P-value	0.053	0.004	0.002

Surface Colour of RaPMFS, Day 21

Treatment	L*	a*	b*
0%RaPMFS(Control)	53.113	8.093	18.167^{c}
5%RaPMFS	55.983	8.197	19.093^{bc}
10%RaPMFS	55.470	8.437	20.707^{ab}
15%RaPMFS	55.717	7.137	22.687^{a}
P-value	0.401	0.069	0.002

Internal Colour of RaPMFS, Day 0

Treatment	L*	a*	b*
0%RaPMFS(Control)	61.113	8.723[a]	14.617
5%RaPMFS	63.360	8.083[ab]	14.883
10%RaPMFS	62.827	7.770[b]	14.750
15%RaPMFS	63.400	7.617[b]	15.280
P-value	0.208	0.009	0.172

Internal Colour of RaPMFS, Day 7

Treatment	L*	a*	b*
0%RaPMFS(Control)	58.577	8.523	14.870[b]
5%RaPMFS	58.927	8.547	16.397[a]
10%RaPMFS	59.897	8.003	16.110[ab]
15%RaPMFS	60.493	7.773	16.357[a]
P-value	0.247	0.062	0.027

Interenal Colour of RaPMFS, Day 14

Treatment	L*	a*	b*
0%RaPMFS(Control)	55.877[c]	7.917[ab]	13.477[b]
5%RaPMFS	56.770[bc]	8.427[a]	15.467[ab]
10%RaPMFS	59.447[ab]	8.130[ab]	16.213[a]
15%RaPMFS	60.500[a]	7.190[b]	15.083[ab]
P-value	0.007	0.041	0.024

Internal Colour of RaPMFS, Day 21

Treatment	L*	a*	b*
0%RaPMFS(Control)	57.310[b]	8.427	14.680[b]
5%RaPMFS	58.810[b]	8.187	16.913[a]
10%RaPMFS	60.127[ab]	8.320	17.417[a]
15%RaPMFS	61.923[a]	7.587	16.897[a]
P-value	0.005	0.116	0.004

Surface Colour of RoPMFS, Day 0

Treatment	L*	a*	b*
0%RoPMFS(Control)	53.693	7.990^{ab}	20.533^{b}
5%RoPMFS	53.697	8.297^{ab}	21.033^{b}
10%RoPMFS	52.937	8.353^{a}	23.647^{a}
15%RoPMFS	49.683	7.473^{b}	21.843^{ab}
P-value	0.365	0.041	0.014

Surface Colour of RoPMFS, Day 7

Treatment	L*	a*	b*
0%RoPMFS(Control)	53.483	8.500^{a}	18.907^{b}
5%RoPMFS	54.993	8.297^{a}	19.743^{b}
10%RoPMFS	54.257	8.440^{a}	22.787^{a}
15%RoPMFS	53.773	6.803^{b}	22.773^{a}
P-value	0.753	0.037	0.000

Surface Colour of RoPMFS, Day14

Treatment	L*	a*	b*
0%RoPMFS(Control)	52.830^{ab}	8.337	18.313^{b}
5%RoPMFS	53.810^{ab}	8.093	18.643^{b}
10%RoPMFS	51.533^{b}	8.107	22.387^{a}
15%RoPMFS	55.240^{a}	7.137	21.957^{a}
P-value	0.036	0.100	0.000

Surface Colour of RoPMFS, Day 21

Treatment	L*	a*	b*
0%RoPMFS(Control)	53.113	8.093^{a}	18.167^{b}
5%RoPMFS	52.830	8.333^{a}	19.080^{b}
10%RoPMFS	54.260	8.340^{a}	21.427^{a}
15%RoPMFS	56.920	6.973^{b}	22.553^{a}
P-value	0.064	0.037	0.000

Internal Colour of RoPMFS, Day 0

Treatment	L*	a*	b*
0%RoPMFS(Control)	61.113	8.723^{a}	14.617^{b}
5%RoPMFS	63.223	8.730^{a}	15.900^{a}
10%RoPMFS	59.620	8.183^{ab}	16.390^{a}
15%RoPMFS	61.817	7.310^{b}	16.473^{a}
P-value	0.082	0.004	0.003

Internal Colour of RoPMFS, Day 7

Treatment	L*	a*	b*
0%RoPMFS(Control)	58.577	8.523^{b}	14.870^{c}
5%RoPMFS	57.637	9.513^{a}	16.283^{b}
10%RoPMFS	59.973	7.973^{bc}	16.913^{b}
15%RoPMFS	59.240	7.377^{c}	17.947^{a}
P-value	0.362	0.000	0.000

Internal Colour of RoPMFS, Day 14

Treatment	L*	a*	b*
0%RoPMFS(Control)	55.877	7.917ab	13.477^{c}
5%RoPMFS	56.650	8.540a	15.513^{bc}
10%RoPMFS	57.340	8.210a	17.357^{ab}
15%RoPMFS	60.003	7.107b	18.250^{a}
P-value	0.146	0.012	0.001

Internal Colour of RoPMFS, Day 21

Treatment	L*	a*	b*
0%RoPMFS(Control)	57.310	8.427a	14.680^{b}
5%RoPMFS	57.463	8.977a	16.930^{a}
10%RoPMFS	57.157	8.323ab	17.520^{a}
15%RoPMFS	58.520	7.380b	18.240^{a}
P-value	0.843	0.005	0.000

Surface Colour of SoPMFS, Day 0

Treatment	L*	a*	b*
0%SoPMFS(Control)	53.693	7.990	20.533
5%SoPMFS	56.967	8.153	19.860
10%SoPMFS	59.677	7.527	20.293
15%SoPMFS	56.743	8.203	23.200
P-value	0.061	0.371	0.081

Surface Colour of SoPMFS, Day 7

Treatment	L*	a*	b*
0%SoPMFS(Control)	53.483[b]	8.500[a]	18.907[b]
5%SoPMFS	55.103[b]	8.347[ab]	21.107[ab]
10%SoPMFS	56.760[ab]	7.580b[c]	21.523[a]
15%SoPMFS	59.183[a]	7.387[c]	19.667[ab]
P-value	0.004	0.006	0.027

Surface Colour of SoPMFS, Day 14

Treatment	L*	a*	b*
0%SoPMFS(Control)	52.830[b]	8.337	18.313
5%SoPMFS	57.060[a]	8.257	18.683
10%SoPMFS	58.230[a]	7.463	19.593
15%SoPMFS	58.263[a]	7.707	21.750
P-value	0.045	0.263	0.128

Surface Colour of SoPMFS, Day 21

Treatment	L*	a*	b*
0%SoPMFS(Control)	53.113c	8.093	18.167b
5%SoPMFS	56.397b	8.133	18.290b
10%SoPMFS	59.170a	7.547	19.583a
15%SoPMFS	58.787ab	7.777	21.650a
P-value	0.000	0.685	0.048

Internal Colour of SoPMFS, Day 0

Treatment	L*	a*	b*
0%SoPMFS(Control)	61.113[b]	8.723	14.617[b]
5%SoPMFS	62.330a[b]	9.600	15.670[ab]
10%SoPMFS	64.480[a]	9.173	15.813[a]
15%SoPMFS	63.423[ab]	8.363	16.357[a]
P-value	0.043	0.258	0.010

Internal Colour of SoPMFS, Day 7

Treatment	L*	a*	b*
0%SoPMFS(Control)	58.577[b]	8.523[ab]	14.870[b]
5%SoPMFS	60.123[ab]	9.253[a]	16.853[a]
10%SoPMFS	61.487[a]	7.943[b]	17.240[a]
15%SoPMFS	62.300[a]	7.780[b]	16.873[a]
P-value	0.006	0.002	0.000

Internal Colour of SoPMFS, Day 14

Treatment	L*	a*	b*
0%SoPMFS(Control)	55.877[b]	7.917[ab]	13.477[b]
5%SoPMFS	57.227[b]	9.397[a]	16.787[a]
10%SoPMFS	62.170[a]	7.390[b]	16.957[a]
15%SoPMFS	61.920[a]	7.953[ab]	17.920[a]
P-value	0.001	0.018	0.009

Internal Colour of SoPMFS, Day 21

Treatment	L*	a*	b*
0%SoPMFS(Control)	57.310[b]	8.427[a]	14.680[c]
5%SoPMFS	57.677[b]	9.080[a]	16.107[bc]
10%SoPMFS	62.400[a]	7.307[b]	17.617[ab]
15%SoPMFS	61.873[a]	7.640[b]	18.273[a]
P-value	0.005	0.000	0.001

APPENDIX II

Appendix II : Analysed Data on Peroxide Values

Peroxide Value of RaPMFS

Treatment	Week 1	Week 2	Week 3
0%RaPMFS(Control)	3.542	3.305	3.175
5%RPMFS	3.155	3.405	3.271
10%RPMFS	3.289	3.369	3.202
15%RPMFS	3.855	2.188	1.917
P-value	0.911	0.397	0.346

Peroxide Value of RoPMFS

Treatment	Week1	Week2	Week3
0%RoPMFS(Control)	3.542	3.305	3.175
5%RoPMFS	3.432	2.949	2.748
10%RoPMFS	3.593	2.410	2.214
15%RoPMFS	2.837	3.800	3.467
P-value	0.854	0.438	0.477

Peroxide Value of SoPMFS

Treatment	Week1	Week2	Week3
0%SoPMFS(Control)	3.542	3.305	3.175
5%SoPMFS	4.800	3.214	3.013
10%SoPMFS	4.180	2.586	2.353
15%SoPMFS	2.984	3.678	3.311
P- value	0.696	0.801	0.819