**UNIVERSITY FOR DEVELOPMENT STUDIES, TAMALE**

**FACULTY OF AGRICULTURE**

**DEPARTMENT OF ANIMAL SCIENCE**

# SENSORY AND NUTRITIONAL QUALITIES OF BEEF AND FRANKFURTER SAUSAGES USING SWEET POTATO PUREE AS EXTENDER



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# DECLARATION

I hereby declare that this research is my own work towards MPhil in Animal Science, that to the best of my knowledge, it contains no material previously published by another person or material which has been accepted for the award of any other degree in the University, except where due acknowledgment has been made in the text.

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



Supervisors

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

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**ABSTRACT**

The high cost of sausage production coupled with the need to impede rancidity without the use of artificial ingredients is a major concern. Of all the various processed meats, sausage is the most appetizing and widely consumed. This study investigated the effects of three varieties of sweet potatoe: orange, purple and white-fleshed sweet potato purees on the sensory, nutritional and oxidation rate of beef and frankfurter sausages. A complete randomized design was used for the experiment. The sweet potato purees were added to 2 kg meat at 0%, 10% (100g) and 15% (150g) each. There were no significant differences (P>0.05) in sensory attributes for beef sausages except tenderness which was significantly improved (P<0.05). In the frankfurter sausages, there were no significant differences (P>0.05) in the sensory attributes except general acceptability which was significantly influenced (P<0.05). The peroxide values of beef sausages were different on day 1 but became stable 7 and went significantly higher on day 14 of storage. There were significant differences (P<0.05) among treatments and control which went high from day 1 and increased on day 14 in peroxide values of frankfurter sausages. The pH of the sweet potato beef sausages varied significantly (P<0.05) among formulations. It was observed that whole beef sausages had the lowest value of pH and the pH values increased as inclusion level of potato puree also increased. The pH of sweet potato frankfurter sausages varied significantly (P<0.05) among treatments which products with higher inclusion level of puree had higher pH values. There were significant differences (P<0.05) in the moisture content of the sweet potato beef sausages with high values in products with low inclusion level of sweet potato puree. There were significant differences in moisture content for all samples of beef and frankfurter sausages with high moisture content in samples with low inclusion of sweet potato

puree. There were no significant differences (P>0.05) in fat for both beef and frankfurter sausages. However significant differences (P<0.05) were realized in the mineral content of both beef and frankfurter sausages. The inclusion of sweet potato puree as an extender did not negatively affect the sensory and nutritional qualities of both beef and frankfurter sausages. Sweet potato puree can be included in both beef and frankfurter sausages by meat processors up to 10%. Combining sweet potato varieties and meat rich in beta-carotene, iron, and zinc would be valuable in combating micronutrient deficiencies in the country.

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# DEDICATION

This work is dedicated to my parents: Mr. Emmanuel K. Nartey and Mrs. Dorothy Mamle Nartey.

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# CHAPTER ONE: INTRODUCTION

## 1.1 Background

Meat refers to the flesh of a slaughtered animal that is eaten as food and this may include skeletal muscle, fats and other tissues (Lawrie and Ledward, 2006). Meat is a primary source of quality protein required by man for growth and repair of worn out tissues (Lawrie and Ledward, 2006).

In the meat processing industry, the inclusion of non-meat ingredients are considered an important strategy for reducing overall production costs while maintaining nutritional and sensory qualities of end products (McWatters, 1990). Processing of raw meat into finished products adds value, increases the yield, extends the shelf life and also serves as a source of income generation (Smith and Hui, 2004). To reduce spoilage, meat is processed by the addition of ingredients and/ or mechanical action to convert it into specific products which may include sausages and burgers to meet the desires of consumers (Teye, 2007).

Extenders are used in meat products to improve meat particles cohesion, increase processing yield and increase dietary fiber to improve texture and reduce cost (FAO, 2013). Cassava flour, Anchovy, yam flour, and soy protein are among the common fillers or extenders used in Ghana (Anang, 1993; Annor-Frempong, Anan-Prah and Wiredu, 1996; Anang *et al*,1999). One of potential extenders yet to be explore is sweet potato which is readily available and relatively cheaper than meat can serve as an extender in sausages.

As in the quest of reducing cost of production, sweet potato which is readily available and relatively cheaper than meat can serve as an extender in sausages. Several varieties of potato exist with various phenotypic appearances ranging from white, cream, yellow, orange and purple fleshed (Woolfe, 1992). Sweet potato varies in carotenoid concentration. The primary vitamin A-forming carotenoid in sweet potatoes is beta-carotene (Bengntson *et al*., 2008). The concentration of beta-carotene depends largely on the variety of sweet potato (Hangenimana *et al*., 1999). Sweet potaoes are rich source of energy, antioxidants and vitamins which is of a high value to humans (Woolfe, 1992). Effah-Manu *et al*. (2013) and Chukwu *et al*. (2012), reported that, sweet potatoes are excellent source of fibre and minerals which are important in reducing blood cholesterol and aiding digestion. Sweet potatoes have a percentage of insoluble fibre which is capable of preventing colon cancer, diverticular disease and constipation (Bingham *et al*., 2003). The short shelf life of sweet potatoes and high cost of meat are among the major challenges of food processing even though they both have major nutrients for human development and maintenance. This research sought to address reduction in high cost of production and improvement of nutrients by combining sweet potato puree as an extender and meat to produce frankfurter and beef sausages to increase the shelf life of the sausages.

### 1. 2 Main Objective

The aim of this study was to use three varieties of sweet potato puree as an extender in beef and frankfurter sausages.

### 1.3 Specific Objectives

1. To determine sensory characteristics of sausages prepared with sweet potato puree as an extender.
2. To determine the nutritional qualities (protein, fat and mineral) of sausages.
3. To determine the pH and perioxide value of the products.

# CHAPTER TWO: LITERATURE REVIEW

## 2.1 Meat and it's Consumption Trend in the World

Meat can be defined as the whole or part of the carcass of any animal slaughtered, but does not include eggs, or fetuses (Williams, 2007). High amounts of proteins and other amino acids that play a vital role in growth and development of bodies are contained in meat, therefore the need to obtain good quality meat in diets (Teye, 2007). According to Warris (2010) red and white meat add a high amount of essential amino acids to the diets of humans with source from sheep, goat, cattle, pig and poultry (Soniran and Okunbanjo, 2002).

According to FAO (2007), there was an estimated increase in meat production from 267 million tonnes in 2006 to nearly 320 million tonnes in 2018. It is anticipated that demand for food from animal origin in developing countries will double by the year 2020, thereby creating markets for animal products (Juma *et al.,* 2005). Moreover, Obi (2000) explained that global demand for meat production will increase by 58% in 2020 and the consumption of meat will increase remarkably in the same year. Levels of meat consumption in developed countries have been high and growing steadily for several decades, aided by an ever greater array of products for consumption in or out of the home, and in real terms at lower prices (Delgado, 2003).

Earlier reports outlined factors that affected the consumption of meat as economic, social and cultural (Koppertt and Hladik, 1990; Burton and Young, 1992). Ojewola and Onwuka (2001) specifically highlighted religion, age, sex, socio-economic factors, individual variation and income as major factors in the world which brings variation of meat consumption among countries or continents. For instance, pork is unpopular in the Muslim communities across the world, likewise other meats too (Ikeme, 1990).

In developing countries, where almost all world population increases take place, consumption of meat has been growing at 5-6 percent per annum (de Haan *et al*., 1998). However, the past five decades have witnessed a marked '*meatification*' of the human diet, spreading from long-established high-consumption societies to the 'emerging market economies' of Asia and Latin America which have been undergoing a 'nutrition transition' (Weis, 2007; Popkin, 2005). As most states, "eating large quantities of meat has become a cultural imperative throughout much of the world, having become a sign of affluence and modernity, and a 'right' of consumer choice (Carolan, 2011). In the great majority of countries, failing to participate in the upsurge of the livestock products consumption, the reason has simply been lack of development and non-increasing of income (including failures to develop agriculture and production of these products (Delgado *et al*., 1999).

One of the factors limiting the growth of world meat consumption is the fact that consumption is heavily and disproportionately concentrated in the industrial countries. These characteristics of the industrial countries have meant that a good part of world demand has been growing only slowly. This slow growth in the industrialized countries has partly offset the accelerating growth in several developing countries that have been rapidly emerging as major meat consumers, such as China, Brazil and the Republic of Korea (Bruinsma, 2017).

Meat production has tripled in volume worldwide since the 1970s; it has grown by more than one-fifth since 2000; and it is expected to double by 2050 (FAO, 2009). Per capita meat consumption now averages 41.2 kg per year, up from 30 kg in 1980 (Sage, 2014). However, there is a considerable disparity across the world: in India just 5.8kg of meat are eaten per person per year whereas the USA accounts for almost 127 kg per person (Sage, 2014). Consumption of animal products, including milk and eggs, has grown most quickly in China where around 60 kg of meat are consumed annually per capita, a rate that has grown by four times since 1980 and by 50 percent since 1995 (FAO, 2009). Moreover, some countries are known for consumption of particular kind of meat example is china being known for high quantity of pork intake. The major backbone of all these are farmed animals, principally cattle, pigs and chickens that together account for 88 percent of all animal flesh by volume (Weis, 2007). For the high-income countries, the reasons include the near saturation of consumption (e.g. in the EU and Australia), policies of high domestic meat prices and/or preference for fish (Japan and Norway), and health and food safety reasons everywhere (Bruinsma, 2003). In 2005, more than 55 billion farm animals were slaughtered a more than fivefold increase in four decades (Weis, 2007). Today more than 40 percent of all meat production worldwide is produced by factory farms, a production model that illustrates the almost complete globalization of the industrial livestock complex (Weis, 2007). However, by far the most important reasons have been mentioned below, failure of many low-income countries to raise incomes and create effective demand, as well as the cultural and religious factors affecting the growth of meat consumption in some major countries (Bruinsma, 2003).



## 2.2 Meat Composition and its Nutrients Value

Meat as it is known provide essential nutrients to the body. Meat proteins contain all the essential amino acids making it highly nutritious (Xiong, 2004). Recent analyses have shown that there has been a significant trend to leaner cuts of meat over the past two decades (Williams *et al.*, 2002). While the nutritional composition will vary somewhat according to breed, feeding regime, season and meat cut, in general lean red meat has a low fat content, is moderate in cholesterol, rich in protein and many essential vitamins and minerals (William, 2007).

Broadly, the composition of meat, after rigor mortis can be approximated to 75% water, 19% protein, 3.5% soluble non-protein substances and 2.5% fat (Lawrie and Ledward, 2006). The proteins in muscle can be largely divided into soluble in water or dilute salt solutions (the sarcoplasmic proteins), those which are soluble in concentrated salt solutions (the myofibrillar proteins) and insoluble in the latter (Lawrie and Ledward, 2006). The sarcoplasmic proteins are a mixture of several hundred molecular species. Several of the sarcoplasmic proteins are enzymes of the glycolytic pathway and may be present in more than one form of isozymes (Lawrie and Ledward, 2006).

Protein from meat provides all essential amino acids (lysine, threonine, methionine, phenylalanine, tryptophan, leucine, isoleucine, valine, cysteine, arginine and histidine) and has no limiting amino acids (William, 2007). Meats like beef have a score of protein approximately 0.9 g/dl, compared to values of 0.5-0.7 g/dl for most plant foods (Schaafsma, 2000). Amino acids are important for maintenance and repair of body tissues in human (Lawrie and Ledward, 2006).

Among the four red meats (beef, mutton, chevon and pork), mutton is particularly nutrient dense, and the richest source of thiamin, vitamins B6 and B12, phosphorus, iron and copper (William, 2007). A daily intake of 100 g of meat and liver can supply up to 50% of the recommended daily allowance for iron, zinc, selenium, vitamins B1, B2, B6, B12 and 100% of vitamin A (Biesalski and Nohr, 2009). Raw red muscle meat contains around 20-25g protein/100g (William, 2007). Cooked red meat contains 28-36g/100g, because the water content decreases and nutrients become more concentrated during cooking (William, 2007).

Meat is also a better source of various micronutrients: low-fat pork contains 1.8 mg iron, 2.6 mg zinc; and pigs' liver contains 360 mg magnesium, 20 mg iron and 60µg selenium per 100 g (Biesalski, 2005). The importance of meat as an essential source of some micronutrients is due to the fact that it is either they are the only source, or they have a higher bioavailability. Vitamins A and B12 occur exclusively in meat and can hardly be compensated for by plant-derived provitamins (Biesalski, 2005). Iron has a higher bioavailability from meat than from plants, as has folic acid which is nearly 10-fold more, especially from liver or eggs, compared to vegetables (Biesalski and Nohr, 2009). Vitamin A is responsible for lung development and maturation, and for the development of other tissues. But the control of these processes seems to be dependent on the expression of Retinoic Acid (RA receptors) (Biesalski and Nohr, 2009).



## 2.3 Meat Processing

Processing of meat offers the opportunity to add value, reduce prices, improve food safety and extend the shelf-life. This can result in increased household income and improved nutrition. While the per capita consumption of meat in some industrialized countries is high, per capita consumption is below 10 kg in developing countries, this is considered insufficient and often leads to under-nourishment and malnutrition (FAO, 1995). Meat processing is aimed at bridging the gap in cost of meat products, increase sizes and extension of storage time of meat products.

Products from meat processing industries are widely accepted by meat consumers due to the increasing demand for fast and convenient meals (Biesalski, 2005). The after role is of particular importance because all the functional properties exhibited by meat proteins cannot be reproduced or compared by any other food protein (Xiong, 2004). It has been estimated that 800 million malnourished people exist in the least-developed countries such as Benin, Ghana, Togo and others (Myers, 2002). In this regard providing safe, nutritious, and wholesome food for poor and undernourished populations has been a major challenge for the developing world. More specifically, protein-energy malnutrition is among the most serious problems faced by developing countries today (Bhat and Karim 2009; Boye *et al*., 2010).

Meat is prepared for consumption in many ways such as smoked, cooked and dried meat examples are beef jerky, steaks in stews, Ham and hot dog (Lawrie and Ledward, 2006). Some meats are preferred to be prepared in a way such as cured by smoking, salting, or drying to prolong its shelf life. Others are also spiced up with ingredients such as garlic, cinnamon and ginger (Angioni *et al.*, 2004). Other forms of processing of meat is comminution which is defined as the process of reducing whole muscle to small particles (FAO, 1991). The level of comminution varies among various processed products. It ranges from coarsely to finely comminuted, to form an emulsion or paste for easy addition of spices (FAO, 2010). Meat trimmings, meat pieces and fatty tissues that could otherwise not be utilized are comminuted and spiced to form high quality meat products (FAO, 2010). Typical examples of comminuted meat products include; sausages, meat loaves, burgers and liver patties.



### 2.3.1 Sausage

Among various processed meats, sausage is the most appetizing and widely utilized (Trosnky, 2004). The word "sausage" is derived from the Latin word *salsus*, which means salted (Trosnky and Ehr, 2004). Several factors contributed to the production of sausage and climate is the major important factor for the development of region-specific fresh and dry sausages (Trosnky and Ehr, 2004). Regions with distinct seasons used different techniques to preserve meat. In the cold seasons, fresh sausage was able to keep for short periods of time without refrigeration (Trosnky and Ehr, 2004). The smoking process was developed to preserve sausages during the warmer seasons (Trosnky and Ehr, 2004). Dry sausage, which does not require any refrigeration, was created in warmer regions (Trosnky and Ehr, 2004). Some sausages became associated with their country or city of origin. A good example is Bologna, which originated in the town of Bologna in Northern Italy (All About Sausage, 2004). Almost every culture has created its own characteristic type of sausage. Even the Native Americans created sausages made from a wide variety of meats and berries (Basic Sausage-Making, 2004).

According to Boyle (1994), there are six basic categories of sausage namely:

1) Fresh Sausages - made from ground meat which are seasoned and stuffed into casings, or left in bulk form. Fresh sausage is not cured or smoked; and must be fully cooked before eating. Examples include: pork breakfast and bulk pork sausages.

2) Cooked Sausages - made from ground meat which are ground, seasoned, often cured without the use of smoke, stuffed into casings, and cooked. Cooked sausages are often served cold and examples include braunschweiger, liverwurst and liver cheese.

3) Cooked, Smoked Sausages - made from ground meat seasoned, stuffed into casings, smoked and cooked. These can be eaten cold or reheated and Examples include bologna, cotto-salami and frankfurters.

4) Uncooked, Smoked Sausages - made from ground meat seasoned, stuffed into casings, and smoked. These must be fully cooked before eating with examples such as some kielbasas, mettwurst, teawurst and smoked country-style pork sausage.

5) Dry and Semi-dry Sausages - made from minced meat seasoned, cured, stuffed into casings, fermented, often smoked and carefully air-dried. True dry sausages are not cooked. These sausages have a distinctive tangy flavour due to the presence of lactic

acid that is produced by fermentation. The meat is stuffed into casings and allowed to ferment. In this type of sausage bacteria metabolize sugars and produce acids and other compounds as byproducts. In meat fermentation, bacteria which produce lactic acid are utilized to produce the tangy flavor of dry sausages. They are sometimes referred to as "summer sausages" and eaten cold with pepperoni, German salami, Lebanon bologna, Genoa salami, thuringer and cervelat as examples.

6) Specialty Sausages: - this is a diverse category that may contain cured, uncured, smoked and non-smoked meats that do not readily "fit" into the other categories. They are seasoned and often formed into loaves with examples such as olive loaf, head cheese, jellied corned beef, scrapple and souse.

**2.3 Non Meat Ingredients, Additives and Casing**

An ingredient is a component of a recipe that is added in a specific quantity. Most ingredients may be purchased at local supermarkets or meat markets. Certain cuts of meat, generally has lower economic value and are suggested for sausage making which makes it more appealing to consumers (FAO, 1991).

Non-meat ingredients are used to impart flavour, slow bacterial growth and increase the yield of the sausage (FAO, 2010). These ingredients include water, salt, sugar, nonfat dry milk, extenders and binders, and spices (Tronsky *et al*., 2004)

**2.3.1 Water and Ice**

Water and ice are added to provide moisture and keep the sausage temperature low during its preparation. Cold temperature during sausage preparation delays microbial growth and also ensures a better final product texture when consumed (Tronsky *et al*., 2004). Ice and water can also be added to increase the yield of sausage. Water also aids in dissolving salt to facilitate its even distribution within the meat. Texture and tenderness of the finished sausages are affected greatly by the water content (Pearson and Gillet, 1996). The major component of the meat emulsion is ice or water. In the emulsion, water performs several functions such as: i) functioning as a curing solution; ii) regulating the temperature of the batter; iii) saving on production costs; and iv) having an impact on the texture and juiciness of the product (Ockerman and Basu, 2004).



**2.3.2 Salt**

Salt is an ingredient that is always used in most foods. Technically, it is the only non-meat substance required for a product to be considered a sausage (FAO, 2007). Salt has many functions but the major purpose for its inclusion in sausages is to lowers the amount of available water (which allows for preservation or shelf-life extension), extracts the meat myofibrillar proteins needed to make the product bind and to emulsify fat, and for flavor enhancement (FAO, 2007). In general, salt is added at a concentration of 1% to 2% (w/w) of the total sausage batter weight. Salt occupy an important place in human nutrition, especially in the diets of low-income earners of developing countries (Oboh *et al*., 2009). Studies have shown that meat products are responsible for approximately 20–30% of daily sodium consumption, which is a main ingredient used in processed meat, responsible for flavour, preservation and textural properties (Petracci *et al.*, 2013). The salt soluble meat proteins are responsible for the water-holding capacity, emulsification and fat-binding properties in the batter and gel-forming stability during the cooking stage which makes the products appealing to consumers (Totosaus and Pérez-Chabela, 2009).

**2.3.3 Sugar**

Sugar is used to balance the slight bitter taste of salt and to improve upon the flavour. It is also added as a medium (food) for the microbial fermentation process used to reduce the pH of dry and semi-dry sausages (e.g. pepperoni) (Trosnky, 2004). The lactic acid produced by fermentation of the sugar (usually dextrose) reduces the meat pH and gives these sausages their characteristic tangy flavour (Meat Board, 1991; Zhou *et al.*, 2010).

**2.3.4 Additives in Sausages**

Additives can be included in sausage products but under strict conditions and legally bound. Additives are used to impact the colour, minimize rancidity and effective in inhibiting microbal growth on meat carcasses under a variety of storage conditions. Lactic acid inhibits *Enterobacteriaceae* and *Pseudomonas* (Doores, 1993). Examples of additives are sodium nitrite, phosphates, sodium ascorbate, and sodium erythorbate (Feiner, 2006).

**2.3.4.1 Sodium Nitrite**

Sodium nitrite is used for curing meat. It inhibits the growth of a number of pathogenic and spoilage microorganisms, most importantly *Clostridium botulinum* (Tronsky *et al*., 2004). It is also used to retard the development of rancidity, stabilize colour of lean meat and to contribute to the flavour of cured meat. It is usually manufactured as a pink coloured salt (to distinguish it from normal sodium chloride) that can be purchased from ingredient suppliers as “Quick Cure” or “Rapid Cure.” It is highly undesirable to add too little or too much nitrite to sausage (Tronsky *et al*., 2004).

**2.3.5 Casings**

Chopped or ground meat are formed into patties are placed in casing to hold and to give shape. Traditional sausage casings are made from parts of the alimentary canal of various animals such as bovine equine, sheep, pig etc. These natural casings are largely made up of collagen which has the unique characteristic of variable permeability. Natural casings are strong enough to handle pressure during stuffing, permeable to water vapour, gases and smoke (Heinz and Hautzinger, 2007). Moisture and heat make casings more porous and tend to soften them (INSCA, 2003). Natural casings readily permit smoke penetration into it content but does not contribute any undesirable flavour and aroma. Sausage made from natural casings have a "snap" when bitten into and is considered a desirable sensory characteristic (A Brief History of Natural Casings, 2003). When stuffed, natural casing sausages have a characteristic curved shape with rounded ends where the sausage is linked giving the sausage visual appeal. Removing layers increase permeability and flexibility or elasticity, but at the same time decreases mechanical resistance of casings (Heinz and Hautzinger, 2007).



Casing production processes are completed by measuring, washing with salt water, drying and dry salting at the end and storage. Natural casings are not frozen, because in this way, they lose their elasticity and firmness (Heinz and Hautzinger, 2007). The use of natural casings can be a risk for human health because of different biological hazards such as infections from the following prions, *Salmonella* spp., *Clostridium* spp (Bradley, 2002; MAF 2010). Natural casings are usually obtained from hogs, beef cattle and sheep (A Brief History of Natural Casings, 2003).

There are five classifications of hog casings: bungs, middles, smalls, stomachs, bladders. Bungs and middles are generally used for liver sausage (Trosnky and Ehr, 2004). Hog casings are suited for the manufacture of frankfurters and other sausages similar in size, but due to the toughness of hog casings, they cannot be successfully used in the manufacture of fresh pork sausage and may be used only in the manufacture of frankfurters because the casing is objectionable to the consumer (INSCA, 2003). Middles are used for dry sausage. Small casings are used for fresh sausage, bockwurst, Polish sausage, frankfurters, and chorizos. Small hog casings from the small intestine are probably the most widely used and easiest to find at a local meat shop in developed countries (Tronsky and Ehr 2004). Similar to the hog, almost the entire beef gastrointestinal tract can be used. Beef rounds are the most common of all beef casings (Tronsky and Ehr 2004). An appropriate method is being sought to tenderize this casing in consideration of the low price for its mass production.

High pressure and organic acid treatment conducted individually or in conjunction was clearly shown to tenderize tough hog casing, the latter proving most effective (Nishiumi *et al*., 2005). Rounds are used for ring bologna, holsteiner, and mettwurst. Commercial sausage makers often use "sewed-casings." Sewed casings are obtained from two natural casings that are slit, matched up, and stitched together (Tronsky and Ehr 2004). This increases the uniformity and strength of the casings. The intestines of sheep are used mainly for frankfurters and pork breakfast sausage.

Each type of casing can be stored for a reasonable length of time if salted in a controlled, refrigerated environment. All natural casings need to be prepared before use. The casings should be rinsed thoroughly in lukewarm water to remove salt before being used. Dried middles, bladders and similar casings should be softened by soaking in warm water (Tronsky and Ehr 2004).

The alternatives to natural casings are synthetic casings made from edible or inedible materials. The three most common types of synthetic casings are collagen, cellulose, and artificial casings (All About Sausage, 2004).

Collagen casings are made from the gelatinous substance found in the connective tissue, bones and cartilage of all mammals (Tronsky and Ehr 2004). The substance is harvested from the animals and reconstructed in the form of a paper-like edible casing (Tronsky and Ehr 2004).

Cellulose casings are made from solubilized cotton linters, the short fibers that adhere to cottonseed (All About Sausage, 2004). The interior surface of the cellulose casings can contain a water soluble dye which colors the sausage surface during heat processing (Bridgeford and Rahman, 1988). Briefly submerging cellulose casings in room temperature water (e.g. 30 minutes) can facilitate the stuffing process. They are uniform, very strong, and generally used for slicing-sausages such as salami. Skinless hotdogs are made with this form of inedible casing; the casing is removed after smoke processing and before consumption (Tronsky and Ehr 2004).

Artificial, inedible casings are made from plastics and do not require refrigeration. Artificial casings are used by commercial producers and can be made in different colours. For example, some manufacturers use red casings for bologna, clear casings for some salami and white casings for liverwurst (All About Sausage, 2004). Artificial casings' strength and uniformity are similar to cellulose (Tronsky and Ehr 2004).

Synthetic casings are more consistent in diameter throughout their length, have a higher tensile strength than natural casings and are cost effective for large manufacturers (All About Sausage, 2004). They can be stored for longer periods of time and require less preparation prior to use.



### 2.4 Types and Sources of Meat

Types of meat available include beef, mutton and poultry. Beef from cattle is one of the most popular meat consumed across the world, and is also classified as red meat. Another meat consumed globally is the chicken; it is considered a healthy meat since it is a source of indispensable ingredients (Tan *et al.*, 2018). According to Lawrie (1991) pork is also another type of meat obtained from pigs and classified as red meat. Mutton from sheep and chevon from goat are consumed across the globe.

### 2.5 Meat Extenders (Non-meat Additives)

Meat extenders are added to reduce the cost of production and affordable for all consumers (Annor-Frimpong *et al*., 1996; Anang *et al*., 1999). Legumes are considered the poor man's meat which binds and emulsify fat for flavour enhancement which soyabeans is an example (Serdaroglu *et al*., 2005). The world faces the problem of shortage of food supply, which results in malnutrition problem and its consequences are more felt in the undeveloped countries (Sheehy *et al*., 2005). In the last few years, concern has grown regarding adequate supply of food for the current and growing world population of nearly 7 billion (Boye *et al*., 2010). It has been estimated that 800 million malnourished people exist in the least-developed countries such as Benin, Ghana and Togo (Myers, 2002).

Extenders have binding properties depending on their ability to form irreversible gel on mild heating, which serve to hold together the small pieces of meat. Egg albumen was reported to consist mainly of protein, with negligible fat content, and forms a gel when heated, thus enabling it to serve as a binding agent in reformed meat product (Chen and Lu, 1999). Legumes are also known to have a binding agent which act as extender (Sun *et al.*, 2008, Kang *et al.*, 2007). Because of the nutrition problem and cost of living which soars each and every year is making a demand for food producers to adjust to the trend and make life simple for each and every consumer by producing highly nutritious and affordable meat products. For this many products have been developed to substitute the whole or part of meat to reduce cost for all to be able to meet individual daily nutrient requirements.

Meat extenders are available in flaked form (>2 mm), in minced form (>2 mm), and in chunk form (15 to 20 mm), and can absorb 2.5 to 5 times water per initial weight (Riaz, 2004). If too little water is used to hydrate the product, the extended meat product will be dry so to curb this, Nonmeat proteins are often used as alternative gelling agents in comminuted meat products to enhance the yield and texture by improving water-binding properties (Pietrasik *et al.*, 2007). Soy protein ingredients are widely used in meat products as extenders as well as other promising extenders like wheat, yam and cassava flours. Soy can extend meat products while providing an economical, high-quality protein source to consumers (Egbert and Borders, 2006). Soy isolates are also used in meatballs, ground meat, bolognas, and frankfurters for improving the texture and quality (Hettiarachchy and Kalapathy, 1997). Soy-extended beef is used to achieve significant cost savings for low income consumers (Singh *et al.*, 2008). Wheat gluten can be used alone or in combination with soy flour or soy concentrate to produce meat extenders. Vegetable protein ingredients, including vital wheat gluten, functional soy concentrates, and isolates are being used to bind meat cuts and trimmings to make pressed loaves and poultry rolls (Singh *et al.*, 2008). Meat extenders have been extruded from cottonseed proteins, peanut proteins, sesame proteins, sunflower proteins, pea proteins, and bean proteins as shown in Table.1. Legume flours, such as blackeye beans, chickpeas, and lentils, slightly increased the toughness of meatballs and can be successfully used in meatball formulations as extenders (Serdaroglu *et al.*, 2005).

**Some extender groups and their nutrients used with meat (Non meat protein sources)**

**Table 1: Non meat protein sources**

| **Type of protein** | **Sources** | **References** |
|---|---|---|
| $\beta$-conglycinin | Soybean | Sun *et al.* (2008) |
| Glycinin<br>Vicilin | Legumes | Kang *et al.* (2007)<br>Duranti and Gius (1997) |
| Legumin<br>Albumins<br>Globulins<br>Glutelins | Oil seeds (soy and groundnut) | Marcone (1999) |
| Gluten<br>Gliadins<br>Glutenins | Wheat, rye, and barley | Green and Cellier (2007) |
| Mycoprotein | Filamentous fungus | Denny *et al.* (2008)<br>Rodger (2001) |

### 2.5.1 Types of Non-meat Additives

Non-meat additives can be classified as plant protein, animal protein and textured plant protein.

#### 2.5.1.1 Animal Protein Non-meat Additives

Animal protein are proteins gotten from animal sources. Example are fish, meat, egg and diary. Blood plasma proteins demonstrated very acceptable emulsifying properties (high emulsifying and stabilizing capacities and others), similar to those of the meat. The important functional property of blood plasma proteins is their excellent gel forming ability induced by meat (Anang, 1993). The use of blood plasma in meat products have also become increasingly popular (Anang, 1993). Anang (1993), also indicated that slaughter house by-product such as blood meal, blood plasma proteins and a whole blood protein powders could be used. Albumen from egg and gelatin has also been used as meat extenders. Animal proteins that have been considered for use as meat extenders include dried skim milk, coagulated lactalbumen from cheese whey and casein (by-product of certain cheese types). Hung and Zayas (1992) reported the use of 3.5% whey protein in beef frankfurters containing 3.5% whey protein concentrate



#### 2.5.1.2 Textured Plant Protein as Non-meat Additives

Textured proteins are fabricated palatable food ingredients processed from and edible protein source including soy grits, soy protein isolates which can be added to meat as extenders (Riaz, 2011). Recently there has been improvement in human nutrition in which texturized vegetable proteins is a contributing factor. Texturized vegetable protein is recognized as one of the hot list ingredients for its ability to contribute to 2 top food trends including the continued quest for high-quality, low-fat foods and the thriving field of functional and nutraceutical foods (Riaz, 2004). The products are produced in a variety of shapes and sizes. The most popular shapes are chunks, granules, and flakes. The generic term, “texturized soy protein” (TSP), typically means defatted soy flours or concentrates that are mechanically processed by extruders to obtain meat-like chewy textures when hydrated and cooked (Singh *et al*., 2008). Texturized vegetable proteins are accepted as halal foods (Lusas, 1996). They are often regarded as a healthy food option because they are cholesterol free, low in fat, and low in calories. An additional reason for using texturized vegetable proteins is because they have a lower price as compared to muscle proteins and, consequently, can reduce the cost of the meat product. Approximately 1 million metric tons of functional soy proteins are produced annually, with 55% of that used in processed muscle foods including meat, poultry, and seafood (Hoogenkamp, 2007).



#### 2.5.1.3 Cereal Proteins

Cereal protein are mostly obtained from cereals which constitute about 10% of grain dry weight and are an important source of protein. In addition, they play an important role in the processing properties of cereal flour namely the ability of wheat to be baked into leavened bread (Cauvain, 2012). Wheat gluten is a protein that has unique properties. In bread formulations, gluten addition can help compensate for low-protein flours. Products comprised of wheat gluten provide an endless array of textured vegetable protein ingredients that are utilized as meat extenders and meat analog products (Orcutt *et al*., 2006). Wheat gluten can be used in combination with soy flour or soy concentrate to produce meat extenders (Riaz, 2004). Gluten can be used as an extender in ground meat patties and as a binder for sausage products. Wheat gluten can bind chunks or trimmings to create restructured meat or meat analog. In poultry rolls, the binding ability of gluten can reduce cooking losses during processing and preparation and improve slicing characteristics. Hydrated gluten may be extruded, texturized, or spun into fibers to produce a variety of meat analogs. The International

Grains Council (IGC) forecasts world wheat production to reach 645 million metric tons in the 2008 to 2009 season, which is up from 604 million metric tons in 2007 to 2008 (Launois, 2008). Wheat gluten is a protein that has unique properties. Wheat gluten has been used to produce texturized products in the extrusion process (Riaz, 2004). Wheat gluten represents approximately 72% of wheat protein (Kong *et al*., 2007). The acceptance of textured vegetable proteins that contain wheat protein is rapidly increasing (Joshi and Satish, 2015). Texturized vegetable protein can be imparted into meat as an extender or it can be consumed directly as a meat analog (Joshi and Satish, 2015). The difference between meat extenders and meat analogs is the dependence on texturization of raw materials by extruders (Riaz, 2004).



## 2.6 Organoleptic Evaluation of Sausages (Meat Quality)

Organoleptic refers to evaluation by means of the organs of sense and includes the microscopic appearance of the sausage. Organoleptic evaluation consists of describing the attributes of sausages, in the special case, of meat and meat products, which can be perceived by the sense organs. The attributes to be evaluated are appearance, colour, texture, consistency, flavour and taste.

### 2.6.1 Appearance of Sausages

The appearance of meat, in the form of carcass or as boneless meat cuts, has great impact on its evaluation by consumers. The way consumers or processors assess the appearance of meat is subjective. Differences will be registered in relation of lean meat and fat including the degree of marbling or in the relation of bones and lean meat. More so, unfavourable influences can be detected such as unhygienic meat surfaces, surfaces too wet or too dry, or unattractive blood splashes on muscle tissue. Special product treatments like control atmosphere (chilling, freezing, cooking, curing, smoking and drying) or the kind and quality of packaging the product (casings, plastic bags, and cans) will be recognized by evaluating the appearance (Heinz *et al*., 1990). The ultimate goal of the meat industry is to place a product on the consumer's table that will result in a high degree of eating satisfaction and that will be available at a reasonable cost being appreciated by customers (Heinz *et al*., 1990).

### 2.6.2 Colour of Sausages

In processing, colour has been identified as the single most important factor of meat products that influences consumer buying decision and affects their perception of the freshness of the product (Boles and Pegg, 2005). Among all sensory attributes of meat, color is considered one of the most important physical traits/properties because once colour is deemed unacceptable, all other sensory attributes lose relevance to consumers (Bekhit *et al*., 2005; Mancicni and Hunt, 2005) and purchasing decisions are negatively influenced by what is seen (McKenna *et al*., 2005). Colour is an important indicator of freshness and is one important criterion to attract customers as consumers tend to reject products which have different colours from accustomed colours (Mancini and Hunt, 2005). Colour change is closely associated with spontaneous autoxidation of myoglobin (Trout, 2003) since myoglobin (Mb) is the primary pigment associated with meat colour. In fresh meat Mb occurs in several forms: the most important is deoximioglo-bin (DMb), oximyoglobin (OMb) and metmyoglobin (MMb). The oxygenated form of Mb (OMb) is responsible for the bright-red colour while the oxidised form (MMb) is responsible for browning (Bekhit *et al*., 2001). Myoglobin is the primary pigment responsible for fresh meat colour and during cooking myoglobin is denatured to varying degrees thereby influencing appearance of meat colour to humans (Garcia-Segovia *et al*., 2007). DMb is the form of Mb in which ferrous iron (Fe+) has no related ligands. In this case, flesh colour is purple-red (purple-pink) and this is the color of fresh meat immediately after cutting fresh meat surface open. Meat colour is synonymous with freshness and consumers consider it attractive (Renerre, 1990). The colour of meat can be controlled by changing the composition of the atmosphere in the packaging and applying adequate high barrier films (Šuput *et al*., 2012), thus improving the attractiveness of the product. Because of this fact, modified atmosphere packaging (MAP) has been popular technique for the past three decades (McMillin, 2008). A lot of studies have been carried out in order to study the effectiveness of vacuum, different gas composition and packaging material on the preservation of fresh meat (Sorheim *et al*., 1999; Buys *et al*., 2000; Houben *et al*., 2000).



### 2.6.3 Texture and Consistency (Tenderness and Juiciness) of Sausages

Texture is a complex attribute as evidenced by the large number of characteristics used to describe it, and it depends on diverse factors, such as chemical composition, structure, physical properties, processing methods, shape, and many others (Szczesniak, 2002). Meat tenderness has been recognized as the most important quality attribute of whole meat (Hertzman *et al*., 1993). Tenderness has been identified as the most important palatability attribute of meat, and the primary determinant of meat quality (Miller *et al*., 1995) and consumer acceptability (Brewer and Novakofski, 2008). The two primary determinants of meat tenderness are maturity of the connective tissue and myofibrillar toughness. Results of the most recent beef tenderness survey showed that over 94% of beef from the rib and loin in foodservice and at the retail level were classified as tender or very tender (Guelker, 2013). Tenderness is influenced by various factors including postmortem proteolysis, intramuscular fat/marbling, connective tissue, and the contractile state of the muscle (Belew *et al*., 2003).

Texture of meat remains the most important aspect of eating quality in the world (Brooks *et al*., 2000). Meat juiciness is also an attribute valued by most consumers. Although consumers routinely pay more for cuts of meat that are typically more tender, but there is some expectation that the meat will also be juicy to a consumer who purchases meat (Thompson, 2002). Properties of samples that have a greater amount of intramuscular fat include reduced resistance needed to disrupt myofibrils; this creates a more tender meat product because less force is needed to chew, or break apart the product (Corbin *et al*., 2014). Van Wezemael *et al*. (2014) suggested that meat with greater lubrication due to increased marbling can maintain quality attributes more sufficiently when exposed to extreme cooking methods, or when cooked to a more severe degree of doneness. Thus, intramuscular fat, mostly in the form of marbling, has been found to contribute to the juiciness of meat (Thompson, 2004), although little is really known of the mechanism by which this occurs.

### 2.6.4 Aroma and Flavor of Sausages

Meat flavour, like aroma, is very difficult to evaluate and describe. There is considerable variability among humans in intensity and quality of response to a given flavour or odour stimulus, with some individuals preferring meat that is essentially bland and others desiring meat that is very intense. Many restaurants try to get best of flavour before serving it to customers, based on the perception of improved flavour and tenderness (Warren and Kastner, 1992; Campbell *et al*., 2001). Numerous studies have evaluated the contribution and importance of flavour to meat eating satisfaction (Brooks *et al*., 2012; Miller and Kerth, 2012; O'Quinn *et al*., 2012).

More recent consumer studies have shown flavour to be more highly related to consumer acceptance of beef than tenderness (Killinger *et al*., 2004; O'Quinn *et al*., 2012; Corbin *et al*., 2014), as flavour has become a relatively important in meat production. In Europe, USA, Africa and Asia flavour was studied and was found to be the most important factor affecting consumers' meat buying habits and preferences when tenderness was held constant (Sitz *et al.*, 2005). Because of the relationship between flavour and meat eating quality, it is important to gain a better understanding of factors that influence flavour in order to produce the most flavour and consistent product possible for the satisfaction of customers (Calkins and Hodgen, 2007).

On the other hand, the influence of aroma on flavour perception is a result of olfactory stimulation from volatile compounds that work with receptors on the roof of the nasal cavity (Idolo and Spanier, 1994). Although the basic meaty flavour is non-lipid in origin, some quantity of fat is undoubtedly necessary to make beef, for example, taste rich, full, and "beefy" and to assure that flavours are species-specific.

As animals increase in age, flavour precursors or odouriferous compounds may be concentrated in the fat depots and intense flavours or odours may result. In the latter case, increased deposition of fat could serve to dilute these precursors or compounds and to make the flavour or aroma less pronounced. Depot fats serve either as the source of flavour and aroma precursors or as the storage medium for odouriferous compounds that are volatilized and released from fat during cooking. It is these volatiles, rather than taste, that allow consumers to identify meat originating from different species (Resconi *et al*., 2013). According to Miller *et al*. (2001), many compounds contributing to beef flavour are water soluble. However, the ability to differentiate meat from varying species is predominantly attributed to lipid degraded compounds that give off various "fatty" aromas (Van Ba *et al*., 2012).

## 2.7 History of Sweet Potato and its Consumption

Sweet potato (*Ipomoea batatas*), is considered the only species of economic significance within the genus *Ipomoea* (Sossah *et al.*, 2014; Zhang *et al.*, 2000). Sweet potato (*Ipomoea batatas*) was originally domesticated in tropical America (Roulier, *et al.,* 2013). The exact center of origin and domestication of the sweet potato has not been well defined, neither has the wild ancestor of this species been found (Denham, 2011). Sweet potato is generally cultivated for its tuberous roots and leaves, which is useful for human consumption, animal feed and for industrial purposes to generate income (Lebot, 2009). Sweet potato is a dicotyledonous starchy, sweet tasting, tuberous roots that are used as vegetable which belongs to the morning glory family (John, 1998; Huaman, 1992; Reddy *et al*., 2007; Troung *et al.,* 2011). Sweet potato is majorly grown for its storage roots for food security and income generation (Diaz *et al*., 1996; Tairo *et al.*, 2004). The young leaves and shoots are also eaten as vegetables in most part of the world at large. Sweet potato is an old food to the tropical regions in American (Woolfe, 1992). Sweet potato was also grown before western exploration in Polynesia. Sweet potato has been radio carbonated in the Cook Islands to 1000AD, and current thinking is that it was brought to the central poiynesia around 700AD (Ladefoged, *et al.,* 2005). Potatoes were then spread to European countries, including Spain and England, in the late 1500s (Center for disease control and prevention, 1999).

### 2.7.1 Utilisation of Sweet Potato

In addition to roots being used as food during the last 20 years, a significant industry based on extraction of starch has developed in several regions of China (Li *et al*., 1991) and especially in Shandong and Sichuan provinces (Zhang, 1995). The starch is used mainly for the production of traditional noodles. The fundamental driving force behind the growth in potato production in many developing countries of Asia such as China, Korea and Japan has been the diversion in consumption patterns away from strictly cereal-based diets (Pingali, 2006; Scott and Suarez, 2011a, 2011b). As incomes increased in subsequent decades, per capita consumption of potatoes surge sharply in a number of major potato-producing countries including Bangladesh, China, India, and Iran (Fuglie *et al.*, 2003; Liu and Chern, 2003; Scott and Suarez, 2011b). Furthermore, except in Central Asia where potato often serves more as a staple food, a progressively higher percentage of output was utilized for food over the last three decades and particularly since 1991-1993 (FAO, 2009). The emergence of potato consumption in the form of snacks or French fries has been a noteworthy phenomenon given the explosive growth (Pingali, 2006) and apparent potential for continued expansion (Scott and Suarez, 2011b). Although the data provided are skeptical because such use is overwhelmingly on farm, it appears that as the livestock sector in China converts to industrial inputs and processes to meet increased demand for meat and dairy products (Rae, 2008), the effective cost of potato became increasingly expensive in comparison to other local feed sources such as cassava, maize, and sweetpotato (Scott, 2002; Fuglie, 2003, 2004) or imported soybean cake (Alexandratos, 2008).



### 2.7.2 Antioxidant Activity of Sweet Potato

Sweet potatoes have several secondary constituents with antioxidant activity, which contributes to the physiological ability (defence) against oxidative and free-radical-mediated reactions. The quantity of antioxidants vary with the flesh colour (e.g., orange flesh, purple, dark yellow or blue) of potatoes (Brown *et al.*, 2005; Reyes *et* *al*., 2005; Brown *et al*., 2007; Van Eck *et al*., 2007; Brown *et al*., 2008; Navarre *et al*.,2011). Potatoes are known to contain water-soluble antioxidants that act as free radical acceptors, e.g. glutathione, ascorbic acid, quercetin and chlorogenic acid (Ezekiel *et al*., 2013). Greater antioxidant activity was observed in skin tissue as compared to flesh (Cevallos-Casals and Cisneros-Zevallos, 2003). Sweet potato varieties with yellow, orange and white flesh were found to have greater antioxidant activity which indicated that carotenoid pigments were probably not responsible for much of the antioxidant activity (Van Jaarsveld *et al*., 2006; Bengtssona *et al*., 2008). Carotenoids insoluble in water also serve as effective antioxidants (Byers and Perry, 1992). Sweet potatoes and processed sweet products such as French fries and chips were reported to be good sources of glutathione, a water-soluble antioxidant and anti-carcinogen that helped maintain functional levels of other antioxidants such as vitamins C and E, and β-carotene (Al-saikhan *et al*., 1995). Water soluble anthocyanins, are potent antioxidants and antioxidant activity is not associated only with coloured flesh of potatoes. The colourless compounds, probably either flavonoids or phenolic acids are potentially potent antioxidants (Brown, 2005). Cyanidin has been found to be three times more effective than pelargonidin as an antioxidant (Pietta, 2000), while another study found malvidin as the most potent antioxidant of the anthocyanidins (Kahkonen and Heionan, 2003). It has been shown that flavonoids also differ significantly in their antioxidant capacity (Pietta, 2000). Quercetin was found to be three times more effective as an antioxidant than kaempferol and eridictyol and was thrice as effective as catechin (Ezekiel *et al*., 2013). Chu *et al*. (2000) reported that the flavonoids and flavones extracts from potatoes showed high scavenging activities toward oxygen radicals. Though potatoes contain relatively low amount of total phenolic acids, they have high antioxidant activities compared to other fruits and vegetables (Velioglu *et al*., 1998). Reyes *et al*. (2005) observed a high positive correlation between antioxidant capacity and, anthocyanin and phenolic content, and concluded that these compounds are mainly responsible for the antioxidant capacity. Potatoes can play an important role in increasing the intake of antioxidants which is the reason for its inclusion as an extender in sausage.



### 2.7.3 Health Benefits of Sweet Potato

Consumers are becoming increasingly interested concerned about foods that provide health benefits besides the basic nutrients because of the current disease trends emanating in the world at large. Potato peel is a good source of natural antioxidants, which has been studied in various food systems (Singh and Rajini, 2004). Potato peel extract provide protection against acute liver injury (Singh *et al.*, 2008) and oxidative damage to erythrocytes (Singh and Rajini, 2008). Thompson *et al*. (2009) reported that the phytochemicals of freeze-dried potato powder caused a 23% reduction in induced breast cancer in rats. Several other health promoting (longevity, heart and eye health) and therapeutic (antibacterial, anti-inflammatory, antiallergic, antimutagenic, antiviral, antineoplastic, antithrombotic, and vasodilatory activity) of phenolics in sweet potato has been reported (Alan and Miller, 1996; Manach *et al*., 2004). Many of these effects result from powerful antioxidant and free radical scavenging properties of phenolic compounds (Rice-Evans *et al*., 1997; Amakura *et al*., 2000).

Chlorogenic acid is also well known for health promoting effects such as protection against degenerative diseases, cancer and heart disease which is present in sweet potato (Nogueira and do Lago, 2007), hypertension, viral and bacterial diseases (Yamaguchi *et al*., 2007). Chlorogenic acid has been found to be a strong and selective inhibitor of matrix metalloproteinase (MMP)-9, an angiogenic enzyme responsible for tumor invasion and metastasis (Jin *et al.*, 2005). Chlorogenic acid slows down the release of glucose into the blood-stream (Bassoli *et al.*, 2008), hence could be helpful in lowering the glycaemic index (GI) of potatoes. Therefore, potatoes with lower glycaemic index GI are good for diabetic patients and may even decrease the risk of type II diabetes (Legrand and Scheen, 2007). Chlorogenic acid has strong antioxidant activity and potatoes are an excellent source of it (Brown, 2005). It has been reported that chlorogenic acid blocks nitrosamine formation through competitive reaction with nitrite and to bind the carcinogen benzo (a) pyrene in a cellulose model system (Friedman, 1997). Chlorogenic acid has been demonstrated to exhibit several desirable anticarcinogenic properties including inhibition of A549 human lung cancer cells (Feng *et al.*, 2005).

Anthocyanins function as antioxidants and are known to prevent diseases such as cardiovascular diseases, cancer and diabetes which is present in cloured sweet potato (Konczak and Zhang, 2004; Reddivari *et al.*, 2007). Coloured potato extracts and an anthocyanin rich fraction have been reported to suppress lymph-node carcinoma of the prostate and prostate cancer-3 prostate cancer cell proliferation (Reddivari *et al.*, 2010). Polyphenol and anthocyanin rich purple potato flakes were found to play an important role in the protection against adverse effects related to oxidative damage in rats fed a high-cholesterol diet (Han *et al.*, 2007). Because of their high carotenoids content potatoes are particularly beneficial for eye health (Wang *et al.*, 1999; Tan *et al.*, 2008).



### 2.7.4 Effect of Processing and Storage on Antioxidant Content of Sweet Potato

Many other food roots and tubers are rarely eaten raw. They normally undergo some form of processing and cooking before consumption. The methods of processing affect the nutritional content of sweet potato whiles cooking vary from simple boiling to elaborate drying, slicing, fermentation and sun drying of roots as practiced in countries like Ghana, Togo, Nigeria and Kenya (Woolfe, 1999). In the recent years, interest in the study of antioxidant activity of plant extracts and isolation from plants has grown due to the fact that free radicals have been related to degenerative diseases (Willcox *et al*., 2004). Sweet potato has a high percentage of antioxidant content and recent studies have placed sweet potato under the perspective of an antioxidant-rich crop. More precisely, potatoes contain phenolic compounds including hydroxycinnamic acids, the predominant being chlorogenic acid and flavonoids (André *et al*., 2007*;* Brown, 2005).

Potatoes are also known as rich sources of antioxidant compounds, including polyphenols, carotenoids and vitamins, pointing to their relevance not only as a starchy food, but also as a vegetable. Anthocyanins are widely distributed among flowers, fruits, and vegetables contribute to colour pigment (Hou, 2003). Carotenoid plays a function in plants as accessory pigments, photosynthesis and protect against photosensitization in plants and animals. In humans, carotenoids are thought to have a variety of functions including antioxidant activity, immune-enhancement and perhaps protection against some forms of cancer (Monsen, 2000). Many of the compounds present in potato are important because of their beneficial effects on health, therefore, are highly desirable in the human diet (Katan and De Roos, 2004). Vitamins and minerals are known to be contained in sweet potato. Sweet potatoes also contain an assortment of phytochemicals with antioxidant potential, including carotenoids and anthocyanins (Brown *et al*., 2004). Anthocyanins are found in the greatest quantities mostly in purple and red sweet potatoes while carotenoids are found largely in yellow and red sweet potatoes (Brown *et al*., 2004). Pigmented potatoes contain a variety of substances with antioxidant potential (Stushnoff *et al*., 2007).

Free radical attacks biological molecules such as lipids, proteins, enzymes, DNA and RNA leading to cell or tissue injury associated with many diseases including ageing, atherosclerosis, heart diseases and carcinogenesis (Halliwell, 1994). Antioxidants are compounds which act as radical scavengers when added or present in the material being used for the food products. The ability of phenolic substances including flavonoids and phenolic acids acting as antioxidants has been reported (Liu *et al*., 2003). Tannins have been reported to have strong antioxidant activity (Cai *et a*l., 2006). There is also growing interest both in industry and in scientific research in spices and medicinal herbs because of their antimicrobial and antioxidant activity (Eyob *et al*., 2008).



**2.7.5 Benefits of Sweet Potato Storage**

The storage root is the main organ used for human consumption and feed examples are carrot, beets and sweet potato. The swollen root normally contains the food and is generally called a 'storage root' (Hill *et al*., 1992) and by classical botanical definition is an enlarged true root (Kays *et al*., 1992). Storage generally increases some nutrient contents such as total phenols content in sweet potatoes but little change or a decrease in phenols content after storage. Rosenthal and Jansky (2008) observed that stored tubers had higher levels of antioxidant activity than fresh tubers. Jansen and Flamme (2006) determined the anthocyanin content of tubers in 14 cultivars/ clones immediately after harvest and after 135 days of storage at 4 °C and 86% relative humidity, but did not find any significant change in anthocyanin content of tubers.

The fact that cold storage had no significant effect on the anthocyanin content of sweet potatoes indicates that there is no risk of degradation of these compounds during storage of sweet potatoes over a longer period. Sweet potatoes are stored at 4 °C in cold storage in countries such as India (Gottschalk and Ezekiel, 2006). Although sugar accumulation is favoured by low temperature (4 °C), which could be helpful in anthocyanin retention in stored potatoes.



### 2.7.6 Nutritional Composition of Sweet Potato

Many of the compounds present in potato are important because of the beneficial effects on health are highly desirable in the human diet (Katan and De Roos, 2004). Most foods are eaten because of their important peculiar nutritional content including vitamins and minerals, such as thiamin, riboflavin, folate, potassium, magnesium, phosphorous, iron, selenium and zinc. The potato has been widely accepted throughout the world as a staple food and is available in many forms yet many consumers are unaware of the healthful attributes of the tubers. The potato has greater dry matter and protein per unit growing area compared with the cereals (Bamberg and del Rio, 2005). Consumers tend to believe that potatoes are high in calories and in fat compared with other carbohydrate sources such as rice or pasta; which is a wrong perception since potato has negligible fat and a low energy density similar to legumes (Priestley, 2006). Research on the use of potatoes or potato products as a replacement for cereals or cereal products in cooked and processed food items (Buckenhuskes, 2005). Enhancing the nutritional value of sweet potato tubers depends mostly on how it is processed for consumption (Ou *et al.*, 2002). Sweet potatoes are usually eaten cooked, and most often eaten boiled and unpeeled in many regions of the world with nutritional content such as vitamin, mineral and carbohydrate not to mention a few.

#### 2.7.6.1 Vitamins in Sweet Potato

Vitamin C is often lacking in the diet of individuals without access to fresh produce such as fruits and green leaves. Potato had a role in prevention of scurvy from its first contact with Europeans (Camire *et al*., 2009). Despite destruction of ascorbic acid during cooking and a moderate content compared with some other fruits and vegetables, potato plays a critical nutritional role as the primary source of vitamin C in many countries. The importance of potato in contributing vitamin C is partly because sweet potato can be stored, allowing sweet potatoes to be a regular ingredient in the diet. It is estimated that potatoes provide, on average, over 50% of the daily ascorbic acid requirement when consumed and about 20% of the dietary intake in some part of the world (Love and Pavek, 2008).

In developing countries, seasonal variations in plasma ascorbate have been related to deterioration in ascorbic acid content of potatoes in locations where refrigeration is relatively unavailable (FAO, 2002). Potatoes provide 27 mg of vitamin C, which can contribute to total daily requirements (Golaszewska and Zalewski, 2001). The water-soluble vitamin acts as an antioxidant, stabilizing or eliminating free radicals, thus helping to prevent cellular damage (Butt and Sultan, 2011). Vitamin C also aids in collagen production, a process that helps to maintain healthy gums and is important in healing wounds (Iqbal *et al*., 2004). Finally, vitamin C assists with the absorption of iron and may help support the body's immune system (Gropper and Smith, 2013). Although sweet potatoes do not compete in vitamin C content of citrus fruits, they do contribute significantly to daily vitamin C requirements. In fact, data indicates potatoes rank 5th in terms of dietary sources of vitamin C (Cotton *et al*., 2004; O'neil *et al*., 2012).

Potatoes are a good source of vitamin B6, a water-soluble vitamin often low in the diets of certain groups of people (Dietary Reference Intakes, 1997).

Vitamin B6 plays important roles in carbohydrate and protein metabolism. It helps the body make nonessential amino acids needed to make various body proteins. It is also a cofactor for several enzymes involved in energy metabolism, and it is required for the synthesis of hemoglobin an essential component of red blood cells (Dietary Reference Intakes, 1997). Carotenoids and their derivative xanthophylls are diverse lipid-soluble pigments (Carle and Schweiggert, 2016). Two of these pigments, present in low concentration in cultivated potato ($\beta$-carotene and lutein), have an important role to play in eye health (Mozaffarieh *et al.*, 2003). Vitamin A deficiency is widespread; more than 124 million children around the globe are deficient in vitamin A leading to various ailments, including blindness and resulting in premature death (Humphrey *et al.*, 1992). The most potent dietary source of vitamin A (pro-vitamin A) is $\beta$-carotene (Grune *et al.*, 2010). The orange-fleshed potatoes contain zeaxanthin in addition to lutein (Brown *et al.*, 2003).

#### 2.7.6.2 Minerals in Sweet Potato

The minerals present in greatest concentrations in raw potato include (mg/g): potassium (564), phosphorus (30–60) and calcium (6–18) (Buckenhuskes, 2005). The percentage recommended dietary allowance (RDA) for these minerals is 22, 6, and 6, respectively (White and Broadley, 2005). Potatoes provide one of the most concentrated and affordable sources of potassium significantly even more than those foods commonly associated with being high in potassium content, such as bananas, oranges, mushrooms, etc. (Drewnowski, 2013). Research suggests diets rich in potassium and low in sodium reduce the risk of hypertension and stroke (Zhang *et al.*, 2013; Adrogue and Madias, 2014; Seth *et al.*, 2014). The health benefits of potassium, surpasses cardiovascular health. Research indicates that diets high in potassium-rich fruits and vegetables may help maintain lean body mass and bone mineral density as human age (Tucker *et al*., 1999; Dawson-Hughes *et al.*, 2008). Magnesium is the fourth most abundant mineral found in the body and serves as a co-enzyme for over 300 metabolic reactions that are important for such functions as protein synthesis, energy production, nerve transmission, blood pressure regulation and muscle contraction (Gröber *et al*., 2015). Low levels of magnesium have been associated with a number of chronic diseases including migraine headaches, Alzheimer's disease, cerebrovascular accident (stroke), hypertension, cardiovascular disease and type 2 diabetes mellitus (Volpe, 2013). A medium size sweet potato with the skin provides 48 mg of magnesium and research indicates potatoes contribute 5% of the total magnesium intake in the diets of consumers (Freedman and Keast, 2012).



**2.7.6.3 Carbohydrates in Sweet Potato**

Cooked potatoes are a good dietary source of carbohydrates, which make up about 70% -75% of the total dry matter of the tuber (Marecek *et al*., 2013). Starch is the predominant carbohydrate in potatoes and serves as an energy reserve for the plant. The potato has protein per unit growing area compared with cereals (Bamberg and del Rio, 2005). Despite this, consumers tend to believe that sweet potatoes are high in calories and in fat compared with other carbohydrate sources such as rice or pasta; an incorrect assumption since potato has negligible fat and a low energy density similar to legumes (Priestley, 2006). There is a substantial resistance of raw potato starch to digestion and so it acts physiologically as a "resistant starch" (Birt *et al*., 2013). Nutritionally, a greater proportion of resistant starch (or more slowly digested starch) is considered advantageous as it provides similar health benefits to fermentable fiber

(Gunnars, 2014). Resistant starch refers to the summation of starch and starch degradation products that are not absorbed in the small intestine. Resistant starch is found naturally in foods such as legumes, fruits (especially under-ripe, slightly green bananas), sweet potatoes and some unprocessed whole grains. Natural resistant starch is insoluble, fermented in the large intestine and a prebiotic fiber (it may stimulate the growth of beneficial bacteria in the colon) (Bird *et al*., 2010). Other types of resistant starch may be soluble or insoluble, and may or may not have prebiotic properties (Higgins, 2004). Resistant starch appears to exert beneficial effects within the colon as well as body wide. Health benefits in the colon include enhanced laxation, vigorous fermentation and the production of important short chain fatty acids and increased synthesis of a variety of "good" bacteria (Nofrarias *et al*., 2007; Murphy *et al*., 2008; Higgins and Brown, 2013) all of which are believed to protect the colon from harmful microorganisms and even cancer (Hylla *et al*., 1998). Systemic effects include improvement in glucose tolerance and insulin sensitivity, reduction in blood lipid levels, increases satiety and potential uses in weight management (Higgins, 2004; Bodinham *et al*., 2010). The amount of resistant starch found in potatoes is highly dependent upon processing and preparation methods. For example, cooked and cooled sweet potatoes leads to nearly a two-fold increase in resistant starch (Englyst *et al*., 1992; Murphy *et al*., 2008).

# CHAPTER THREE: MATERIALS AND METHODS

The study was conducted at University for Development Studies (UDS), Tamale. The products formulations took place at the Meat processing unit of UDS, while chemical and microbiological analyses were carried out at laboratories of University for Development Studies, Nyankpala Campus and Kwame Nkrumah Science and Technology, Kumasi.

## 3.1 Experimental Design and Sample Preparations

Completely randomized design was used in all the experiment. The purees were randomly assigned to the minced meat and each treatment was replicated three times. Treatment means of the various levels of ingredients were compared against their respective controls.

### 3.1.1 Processing of Sweet Potato Puree

The orange, white and purple fleshed sweet potato as shown in Plate 1, 2 and 3 used for the experiment were purchased from farmers in Kumbugu. They were peeled chopped into smaller sizes (4mm) and cooked for 15mins as shown in Picture 4 and 5. Chopped sweet potato with stock were then allowed to cool down mashed/blended into puree as shown in Plate 6 and 7 then stored frozen at -2 $^{o}$C. Code names were given to formulations as follows.

Control: whole beef, WFP1: white flesh sweet potato, WFP2 15% white flesh sweet potato, OFP1: orange flesh sweet potato OFP2 15%: orange flesh sweet potato, PFP1 10%: purple flesh sweet potato and PFP2 15%: purple flesh sweet potato.

F: Control frankfurter, WFP1: white flesh sweet potato, WFP2 15%: white flesh sweet potato, OFP1: orange flesh sweet potato OFP2 15%: orange flesh sweet potato, PFP1 10%: purple flesh sweet potato PFP2 15%: and purple flesh sweet potato.



**Plate 1: Orange fleshed sweet potato**

Picture 2: Purple fleshed sweet potato

.

**Picture 3: White fleshed sweet potato**

**Plate 4: Chop and cooked purple sweet potato**



**Plate 5: Chopped orange flesh sweet potato**

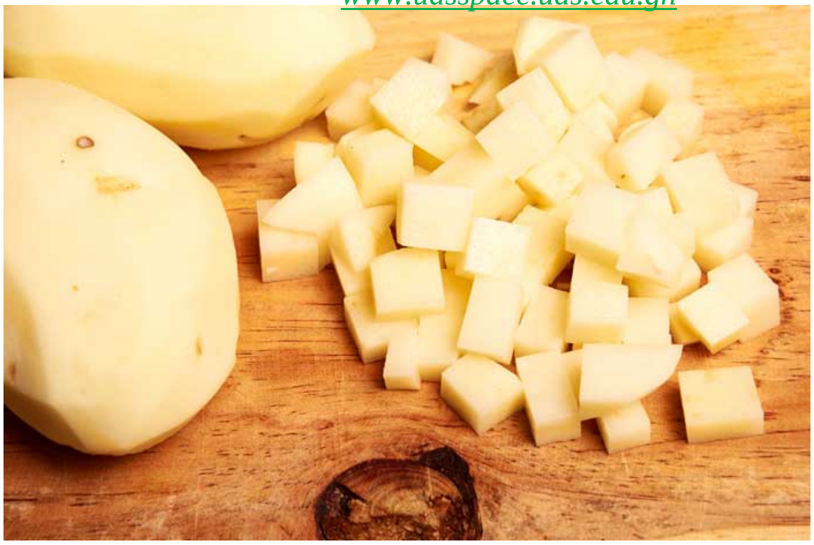

**Plate 6: Chopped white flesh sweet potato**

**Plate 7: Orange sweet potato puree**

**Plate 8: Purple sweet potato puree**

**Plate 9: white flesh sweet potato puree**

### 3.2 Sausage Formulations

Muscles from the bull and castrate (castrated pig); were obtained from the UDS Meat Processing Unit, thawed overnight at a temperature of 1°C, cut into smaller sizes and minced using a 5mm-sieve table top mincer (Taller Ramon, Spain). Two kilograms of meat was used for each treatment which comprises of 1kg beef and pork. Ingredients were added in the stated amounts (g/kg) to the various sausage formulations.

**Table 2: Spices used in the formulation of products**

| Ingredient (spices) | quantities added(g/kgmeat) |
| --- | --- |

| | |
|---|---|
| Curing salt | 15.0 |
| Red chillies | 0.5 |
| White pepper | 1.0 |
| Black pepper | 1.0 |
| "Adobo'' | 2.0 |
| Polyphosphate | 5.0 |



### 3.2.1 Comminution of Meat

Potato purees were included at 100 and 150 (g/kg) to the various sausage. The minced meat was comminuted in a 3-knife, 30 litres- capacity bowl chopper (Talleres Ramon, Spain) into a meat butter at temperature of 16°C.

Crushed ice was added to each set of products during comminution to obtain the desired consistency and temperature of meat butter, and to minimise the risk of fat separation from the muscles. The meat butter was immediately stuffed into natural casings, using a hydraulic stuffer (Talleres Rammon, Spain) and manually linked into equal length of 10cm. Frankfurter sausages were prepared using the same method as the beef sausages but the sausage formulation contained 50% beef and 50% pork.

The sausages were hung on smoking racks and smoked for 45 minutes and subsequently scalded to a core temperature of 70°C. They were then cooled in cold water and hung on racks for adhering water to drain before packaging.

### 3.3 Packaging of Sampled Products

The products were bagged in transparent polythene bags, vacuum sealed using electronic vacuum sealer (Busch, Rammon, Spain), labeled and stored in a refrigerator at 2 °C for sensory, chemical and microbial anlyses.

## 3.4 Sensory Evaluation of the Sampled Products

A total of 12 panelists were selected from the students and staff of UDS Nyankpala Campus and trained according to the British Standard Institution guidelines (BSI, 1993) for panel selection and training to form the sensory panel for the evaluation of the products. The panelists were made up of 6 females and 6 males. Sensory analysis according to the British Standard Institution (BSI, 1993) was conducted by panelist to determine the attributes which include colour, aroma, flavour liking, juiciness, texture, taste and overall acceptability of the sausages. A 9-point hedonic scale (*1= Extremely dislike to 9 = Extremely like*).

Prospective candidates were trained for their tasting acuity. The selected panelists were trained for a period of 2 hours to detect differences in aroma, flavour, colour and texture. The stored products were removed from the refrigerator and allowed to thaw for three hours under normal room temperature. They were then grilled in an electric oven (Turbonfan, Blue seal, UK), sliced into 2cm thickness and wrapped with coded aluminium foil.

### 3.4.1 Sensory Evaluation of Products

Sensory evaluation was carried out on the day 1, 7 and 14 of storage to determine the effect of storage period on the sensory characteristics of the products. The grilled products were presented to the panelist under conditions of controlled lightening. Panelists were provided with water and pieces of bread to serve as neutralizers in between products. The panelists were provided with content validated questionnaires to indicate their impression of the products offered to them. Nine hedonic scale was used to rate the sensory characteristics of the products per colour, aroma, favour liking, tenderness, texture, taste, and overall liking using the scale indicated.

### 3.5 Laboratory Analyses

The crude protein, crude fat, moisture, pH, mineral and peroxide values of the products were determined according to AOAC (1999) methods as follows:

#### 3.5.1 Determination of Moisture Content of the Products

Empty glass crucibles were labeled according to treatment and weighed. Then 10g of the sample was weighed into the crucible and placed in an electric oven at a temperature of 105°C for three hours. Samples were taken from the oven and placed in the desiccator to cool and reweighed. The moisture content was calculated using the formula:

$$\text{Moisture content}=\frac{(W1-W2)}{Wfs}\text{x}100$$

Where:

W1- weight of crucible+ fresh sample

W2- weight of crucible+ dried sample

Wfs-weight of fresh sample



#### 3.5.2 Crude Protein Determination

A gram of sausage was weighed on filter paper and placed on kjeldhal digestion tube, 15ml concentrated $H_2SO_4$ and three tablets of kjeldhal tabs were added. The flask was placed in kjeldhal digestion blocks and heated at 420°C for 30 minutes. The setup was allowed to cool and 75ml of distilled water was added and distilled with an automated distillation unit. The distillate was collected and titrated against 0.2N hydrochloric acid. The same procedure was followed without sausage sample to obtain the blank titre. The titre value was used to calculate the nitrogen and crude protein percentage using the formular:

$$\text{Nitrogen} = \frac{(T - B) \times N \times 14.007x100\%}{Weight\ of\ sample\ (mg)}$$

% protein = % Nitrogen × 6.25

Where: T-Titre value, B-Blank value, N-Normality of hydrochloric acid (0.2N)



### 3.5.3 Fat Content Determination

Empty thimbles were weighed together with the holders. The samples (3g) each were weighed with an analytical scale into each of the empty thimbles and plugged with cotton wools. Extraction cups were weighed and weight recorded, 50mls of petroleum ether was measured into each of the extraction cups. With the help of thimble holders thimbles were inserted into the condenser of the soxtec apparatus. The extraction cups were then placed into the soxtec apparatus. It was allowed to boil for 45minutes at 150°C. The air button on the unit was pressed to open the evaporation valve on the soxtec apparatus to evaporate traces of solvent from the extraction beaker in 20 minutes. The oil was then allowed to cool for about 30 minutes in the service unit after which the extraction cups with the oil were weighed. Percentage fat and oil was calculated using the formula:

$$\text{Fat} = \frac{\text{weight of fat}}{\text{Weight of sample}} \times 100\%$$

Weight of fat = W2-W1, where

W1-Weight of the beaker

W2-Weight of beaker + oil

#### 3.5.4 Peroxide Value Determination

Samples of each beef sausage and frankfurter (3g) were weighed into 250-ml Erlenmeyer flasks and heated in water bath at 60$^{o}$C for 3mins to melt the fat, then thoroughly agitated for 3mins with 30ml acetic acid – chloroform solution to dissolve the fat. The samples were then be filtered using a filter paper to remove meat particles. Saturated potassium iodide solution (0.5ml) was added to the filtrates in each of the flask. They were then titrated against standard solution of sodium thiosulphate (25g/l) with 1% starch solution as indicator. Peroxide value was calculated as:

POV = $TxN/W$

Where:

T-Titre value

N-Normality of sodium thiosulphate solution

W-The sample weight (kg)

POV- Peroxide Value

#### 3.5.5 pH Determination

Samples of 10g each were ground using a laboratory mortar and pestle and homogenized with 50ml distilled water. The pH value of the products was measured with digital pH meter (Crison, Basic 20, Spain).

#### 3.5.6 Determination of ash Content

Dried samples from moisture determination were used. The dried material was ignited in the dish left after the determination of moisture with the flame of a burner till charred. It was then transferred into a muffle furnace at a temperature of between 550 – 600°C until grey ash was obtained. It was cooled in a dessicator and reweighed. The process of heating was repeated, cooled and weighed at half hour intervals till the difference in weight in two consecutive weighings were constant and calculated as:

Formula for ash calculation

$$\text{Total ash on Dm}(\%\text{ by weight}) = \frac{\text{W2} - \text{W}}{W1 - W2} x100$$

Where,

W2 = Weight in g of the crucible with the ash

W = Weight in g of empty crucible

W1 = Weight in g of the crucible with the dried material taken for test

**3.5.7 Determination of Mineral**
**Preparation of Reagents**

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

**3.5.8 Digestion Procedure of Sausage Samples**

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

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

### 3.5.9 Mineral Content Determination Using Atomic Absorption Spectrometer (AAS)

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

Concentrations were determined using the equation: $y = a + bx$. Where y is the absorbance (Abs) and x is the concentration. The values for a and b are constants and always given after each reading by the machine. Make x the subject that is y - a /b = x. Then input the absorbance readings each to get each of the three concentrations respectively. That is check from (Abs) values; #1, #2, #3.

With #1 as the 1st concentration and the rest follow accordingly as; Using the results from iron, UDS 100, Abs reading; #1 = 1.0847, #2 = 1.0900, #3 = 1.0889, a = 0.0028759 and b = 0.0329169

Formula (X= y - a /b )

# CHAPTER FOUR: RESULTS

## 4.1 Sensory Characteristics of Sweet Potato Beef Sausages

There were no significant differences (P>0.05) in the sensory characteristics of sweet potato beef sausage throughout the storage period except tenderness which was significantly different (P<0.05) on the 14th day of storage as shown in Table 3, 4 and 5 respectively.

**Table 3: Sensory characteristics of sweet potato beef sausages on day 1**

| Parameters | TO 0% | WFP1 10% | WFP2 15% | OFP1 10% | OFP2 15% | PFP1 10% | PFP2 15% | S.e.d | P value |
|---|---|---|---|---|---|---|---|---|---|
| Colour | 5.25 | 5.42 | 5.33 | 4.67 | 5.25 | 5.17 | 5.75 | 0.854 | 0.941 |
| Aroma | 6.17 | 6.50 | 6.50 | 7.00 | 6.58 | 6.25 | 6.50 | 0.717 | 0.945 |
| Flavour liking | 6.00 | 5.83 | 6.67 | 7.08 | 7.08 | 7.08 | 6.92 | 0.648 | 0.239 |
| Tenderness | 5.00 | 5.83 | 6.33 | 5.58 | 6.33 | 5.83 | 5.92 | 0.838 | 0.730 |
| Texture | 5.42 | 6.08 | 5.83 | 6.17 | 6.00 | 6.17 | 6.58 | 0.744 | 0.837 |
| Taste | 6.67 | 6.67 | 7.17 | 6.75 | 6.83 | 7.33 | 6.92 | 0.502 | 0.790 |
| Overall liking | 7.08 | 7.00 | 7.00 | 7.08 | 7.00 | 7.00 | 7.00 | 0.513 | 1.000 |

**Sed = standard error of difference. Means on the same row are not significantly different (P>0.05). TO: whole beef, WFP: white flesh sweet potato, OFP: orange flesh sweet potato and PFP: purple flesh sweet potato**

**Table 4: Sensory characteristics of sweet potato beef sausages on day 7**

| Parameters | TO 0% | WFP1 10% | WFP2 15% | OFP1 10% | OFP2 15% | PFP1 10% | PFP2 15% | S.e.d | P value |
|---|---|---|---|---|---|---|---|---|---|
| Colour | 6.53 | 6.13 | 5.93 | 5.60 | 5.80 | 6.20 | 5.40 | 0.586 | 0.529 |
| Aroma | 5.60 | 5.93 | 6.40 | 5.73 | 6.27 | 7.00 | 6.60 | 0.653 | 0.331 |
| Flavour liking | 6.27 | 7.20 | 6.93 | 6.60 | 6.33 | 6.87 | 7.00 | 0.580 | 0.622 |
| Tenderness | 5.53 | 6.47 | 6.40 | 5.47 | 6.13 | 6.67 | 6.53 | 0.594 | 0.246 |
| Texture | 5.60 | 6.13 | 5.93 | 5.87 | 6.07 | 6.80 | 7.07 | 0.604 | 0.176 |
| Taste | 6.93 | 7.40 | 7.00 | 6.73 | 6.80 | 7.40 | 7.00 | 0.454 | 0.660 |
| Overall liking | 7.13 | 7.27 | 6.53 | 6.33 | 6.40 | 7.00 | 6.87 | 0.605 | 0.612 |

**Sed = standard error of difference. Means on the same row are not significantly different (P>0.05). TO: whole beef, WFP: white flesh sweet potato, OFP: orange flesh sweet potato and PFP: purple flesh sweet potato.**

**Table 5: Sensory characteristics of sweet potato beef sausages on day 14**

| Parameters | TO 0% | WFP1 10% | WFP2 15% | OFP1 10% | OFP2 15% | PFP1 10% | PFP2 15% | S.e.d | P value |
|---|---|---|---|---|---|---|---|---|---|
| Colour | 6.91 | 5.82 | 4.91 | 5.73 | 6.18 | 6.27 | 5.73 | 0.691 | 0.163 |
| Aroma | 4.91 | 5.00 | 5.45 | 5.18 | 5.82 | 5.27 | 5.91 | 0.664 | 0.671 |
| Flavour liking | 6.00 | 5.55 | 6.55 | 6.09 | 5.91 | 6.09 | 6.64 | 0.743 | 0.802 |
| Tenderness | 3.27[a] | 4.55[ab] | 5.00[ab] | 4.91[ab] | 5.64[b] | 5.36[b] | 5.18[ab] | 0.689 | 0.028 |
| Texture | 5.82 | 6.00 | 6.09 | 6.18 | 6.82 | 6.27 | 6.27 | 0.692 | 0.869 |
| Taste | 6.00 | 6.18 | 6.82 | 6.27 | 6.55 | 6.82 | 7.00 | 0.529 | 0.421 |
| Overall liking | 5.91 | 6.00 | 6.55 | 6.18 | 6.36 | 6.91 | 6.73 | 0.556 | 0.500 |

**Sed = standard error of difference. Means on the same row with the same superscript are not significantly different (P>0.05).TO: whole beef, WFP: white flesh sweet potato, OFP: orange flesh sweet potato and PFP: purple flesh sweet potato**

### 4.2 The pH of Sweet Potato Beef Sausages

Fig. 1 shows the pH of the sweet potato beef sausages varied remarkably ($P < 0.001$) among formulations. Control, $OFP_1$ 10%, $WFP_1$ 10% and $PFP_1$ 10% had the lower pH as compared to the treatments with high puree products.

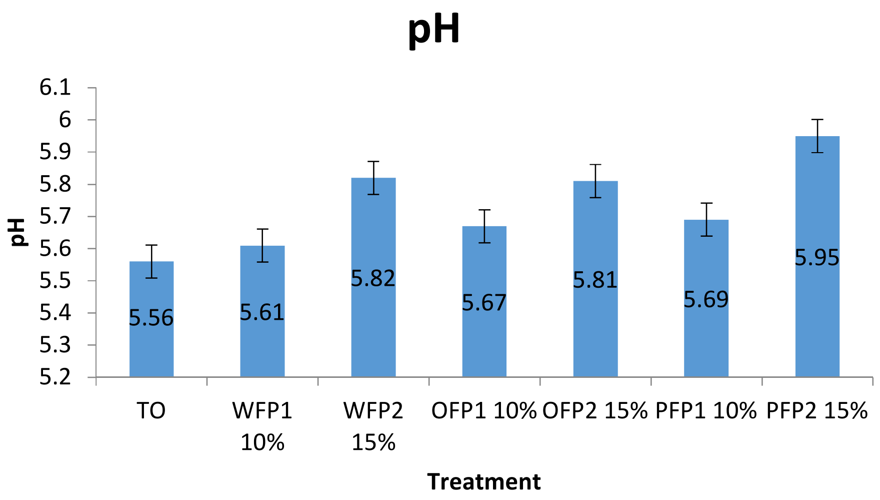


**Fig. 1: pH of sweet potato beef sausages**

### 4.3 Proximate Composition of Sweet Potato Beef Sausages

The results on proximate composition of sweet potato beef sausages are presented in Table 6. All proximate parameters considered were significantly different ($P < 0.05$) among the various formulations except for the crude fat content. The moisture content of the sweet potato beef sausage ranged from 63.60-69.10. The protein content also ranged from 18.35-19.21% while the fat and ash content ranged from 14.71-16.18% and 6.74-8.71% respectively.

### 4.4 Cooking Loss of Sweet Potato Beef Sausages

There were significant differences ($P<0.05$) in cooking loss for beef sausage with sweet potato puree. PFP2 and WFP2 had the highest and the lowest value of cooking lost (25.0 and 8.0) respectively as shown in Table 7.

**Table 6: Proximate composition of sweet potato beef sausages**

| Parameter | TO 0% | WFP1 10% | WFP2 15% | OFP1 10% | OFP2 15% | PFP1 10% | PFP2 15% | P value |
|---|---|---|---|---|---|---|---|---|
| Mo | : $0.42^{b}$ | $69.10 \pm 0.42^{a}$ | $65.50 \pm 0.42^{bc}$ | $66.30 \pm 0.42^{b}$ | $64.50 \pm 0.42^{bc}$ | $64.90 \pm 0.42^{bc}$ | $63.60 \pm 0.42^{c}$ | 0.001 |
| Pro | $\pm 0.24^{a}$ | $18.94 \pm 0.24^{ab}$ | $19.18 \pm 0.24^{ab}$ | $19.07 \pm 0.24^{ab}$ | $17.98 \pm 0.24^{b}$ | $19.21 \pm 0.24^{ab}$ | $18.35 \pm 0.24^{b}$ | 0.014 |
| Fat | $\pm 0.47$ | $15.88 \pm 0.47$ | $15.29 \pm 0.47$ | $16.18 \pm 0.47$ | $14.71 \pm 0.47$ | $16.18 \pm 0.47$ | $15.88 \pm 0.47$ | 0.264 |
| Ash | $0.18^{bc}$ | $8.71 \pm 0.18^{a}$ | $8.21 \pm 0.18^{ab}$ | $6.75 \pm 0.18^{c}$ | $6.83 \pm 0.18^{c}$ | $7.70 \pm 0.18^{bc}$ | $6.74 \pm 0.18^{c}$ | 0.000 |

**Val ± standard error of means; Means in the same row with the same superscript are not significantly different (P › ıole beef, WFP: white flesh sweet potato, OFP: orange flesh sweet potato and PFP: purple flesh sweet potato**

**Tal loss of sweet potato beef sausages**

| Tre | | WFP1 10% | WFP2 15% | OFP1 10% | OFP2 15% | PFP1 10% | PFP2 15% | P value |
|---|---|---|---|---|---|---|---|---|
| Me | $1.0^{ab}$ | $11.5 \pm 3.50^{ab}$ | $8.0 \pm 4.0^{b}$ | $13.0 \pm 1.0^{ab}$ | $15.0 \pm 3.0^{ab}$ | $25.0 \pm 13.0^{a}$ | $12.0 \pm 0^{ab}$ | 0.043 |

**Me d deviation); Means in the same row with the same superscript are not significantly different ($P < 0.05$). TO: wh white flesh sweet potato, OFP: orange flesh sweet potato and PFP: purple flesh sweet potato**

### 4.5 Peroxide Value of Sweet Potato Beef Sausages

The peroxide value in whole beef was significantly ($p < 0.001$) higher than to the other formulations but on day 7 products were stable in the storage period (Fig 2). The peroxide values ranged from 4.16 to 8.833meq/kg of product throughout the storage period.

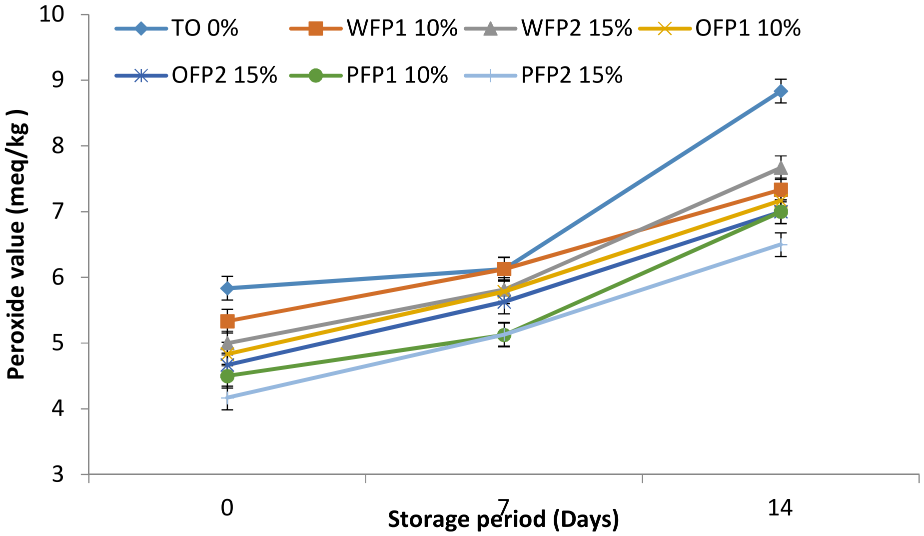


**Fig. 2: Peroxide value of beef sweet potato sausages**

### 4.6 Mineral Composition of Sweet Potato Beef Sausages

Table 8 shows the results of the mineral content of beef sausages as affected by sweet potato puree. Among the formulations all minerals considered were significantly different ($P<0.0001$) from each other except OFP1 10% and PFP1 10% which were not different from each other in iron.

**Table 8: Mineral composition of sweet potato beef sausages**

| Treatments | Iron | Zinc | Selenium |
|---|---|---|---|
| TO | $0.2637^{c}$ | $0.0670^{a}$ | $0.0784^{b}$ |
| WFP1 10% | $0.3181^{a}$ | $0.0349^{c}$ | $0.1088^{a}$ |
| WFP2 15% | $0.1949^{f}$ | $0.0017^{e}$ | $0.0427^{e}$ |
| OFP1 10% | $0.2205^{e}$ | $0.0573^{b}$ | $0.0571^{c}$ |
| OFP2 15% | $0.2370^{d}$ | $0.0350^{c}$ | $0.0305^{f}$ |
| PFP1 10% | $0.2205^{e}$ | $0.0542^{b}$ | $0.0565^{c}$ |
| PFP2 15% | $0.3009^{b}$ | $0.0117^{d}$ | $0.0438^{d}$ |
| Pooled standard error of means | 0.00 | 0.00 | 0.00 |
| P value | 0.0001 | 0.0001 | 0.0001 |

**Means (± standard error) Means in the same column with different superscript are significantly different (P<0.0001). TO: Frankfurter, WFP: white flesh sweet potato, OFP: orange flesh sweet potato and PFP: purple flesh sweet potato**

## 4.7 Sensory Characteristics of Sweet Potato Frankfurter Sausages During Storage Period

Sensory attributes of products did not differ significantly (P>0.05) when puree was incorporated in frankfurter sausages except overall liking which was significantly higher (P<0.05) on the first day of production as shown in Table 9, 10 and 11 respectively.

**Table 9: Sensory characteristics of sweet potato frankfurter sausages on day 1**

| Parameters | TO 0% | WFP1 10% | WFP2 15% | OFP1 10% | OFP2 15% | PFP1 10% | PFP2 15% | S.e.d | P value |
|---|---|---|---|---|---|---|---|---|---|
| Colour | 6.45 | 6.36 | 6.64 | 7.18 | 6.45 | 6.00 | 5.91 | 0.737 | 0.685 |
| Aroma | 5.73 | 7.09 | 6.00 | 6.36 | 6.27 | 7.27 | 6.73 | 0.777 | 0.396 |
| Flovour liking | 6.42 | 6.92 | 6.17 | 6.33 | 6.75 | 6.75 | 6.08 | 0.588 | 0.733 |
| Tenderness | 7.18 | 6.18 | 7.36 | 6.36 | 6.91 | 6.27 | 7.09 | 0.874 | 0.720 |
| Texture | 6.73 | 6.09 | 6.45 | 6.73 | 6.27 | 6.64 | 6.00 | 0.904 | 0.969 |
| Taste | 5.55 | 6.18 | 7.09 | 6.64 | 7.18 | 6.82 | 5.82 | 0.784 | 0.267 |
| Overall liking | 5.27[a] | 7.45[b] | 7.09[ab] | 7.27[ab] | 7.27[ab] | 7.36[ab] | 7.36[ab] | 0.712 | 0.038 |

**Sed = standard error of difference. Means on the same row with the same superscript are not significantly different (P>0.05). Frankfurter: whole beef, WFP: white flesh sweet potato, OFP: orange flesh sweet potato and PFP: purple flesh sweet potato.**

**Table 10: Sensory characteristics of sweet potato frankfurter sausages on day 7**

| Parameters | TO 0% | WFP1 10% | WFP2 15% | OFP1 10% | OFP2 15% | PFP1 10% | PFP2 15% | S.e.d | P value |
|---|---|---|---|---|---|---|---|---|---|
| Colour | 5.92 | 6.08 | 7.25 | 6.17 | 6.58 | 5.58 | 5.17 | 0.732 | 0.132 |
| Aroma | 6.83 | 6.92 | 7.00 | 6.50 | 6.75 | 6.67 | 6.17 | 0.607 | 0.852 |
| Flovour liking | 6.42 | 6.92 | 6.17 | 6.33 | 6.75 | 6.75 | 6.08 | 0.588 | 0.733 |
| Tenderness | 6.17 | 5.75 | 6.33 | 5.33 | 5.17 | 5.00 | 5.67 | 0.850 | 0.657 |
| Texture | 4.92 | 5.33 | 6.25 | 5.75 | 6.25 | 5.25 | 5.83 | 0.727 | 0.442 |
| Taste | 6.67 | 7.17 | 6.75 | 6.33 | 7.42 | 6.83 | 6.83 | 0.553 | 0.575 |
| Overall liking | 7.08 | 7.08 | 6.92 | 6.42 | 7.17 | 6.92 | 6.33 | 0.619 | 0.741 |

**Sed = standard error of difference. Means on the same row are not significantly different (P>0.05). TO: Frankfurter, WFP: white flesh sweet potato, OFP: orange flesh sweet potato and PFP: purple flesh sweet potato**

**Table 11: Sensory characteristics of sweet potato frankfurter sausages on day 14**

| Parameters | TO 0% | WFP1 10% | WFP2 15% | OFP1 10% | OFP2 15% | PFP1 10% | PFP2 15% | S.e.d | P value |
|---|---|---|---|---|---|---|---|---|---|
| Colour | 5.55 | 5.82 | 6.91 | 6.27 | 5.73 | 5.00 | 5.09 | 0.767 | 0.189 |
| Aroma | 6.00 | 6.00 | 6.27 | 6.27 | 5.82 | 5.91 | 5.45 | 0.713 | 0.928 |
| Flovour liking | 6.18 | 6.27 | 6.18 | 6.18 | 6.09 | 5.18 | 5.18 | 0.679 | 0.403 |
| Tenderness | 6.00 | 5.64 | 5.09 | 4.73 | 4.82 | 4.91 | 6.09 | 0.765 | 0.354 |
| Texture | 4.91 | 5.45 | 4.82 | 5.27 | 5.18 | 5.00 | 5.45 | 0.735 | 0.961 |
| Taste | 6.18 | 6.64 | 6.00 | 6.45 | 5.73 | 5.91 | 5.45 | 0.638 | 0.555 |
| Overall liking | 6.27 | 6.82 | 6.00 | 6.45 | 6.18 | 6.09 | 5.82 | 0.700 | 0.852 |

**Sed = standard error of difference. Means on the same row with the same superscript are not significantly different (P>0.05) TO: Frankfurter, WFP: white flesh sweet potato, OFP: orange flesh sweet potato and PFP: purple flesh sweet potato.**



### 4.8 The pH of Sweet Potato Frankfurter Sausages

The pH of sweet potato frankfurter sausages varied remarkably ($p < 0.000$) among formulations (Fig. 3). The control sausages, $OFP_1$ 10% and $WFP_1$ 10% had the lowest value whiles $OFP_2$ 15% had the highest value (6.06).

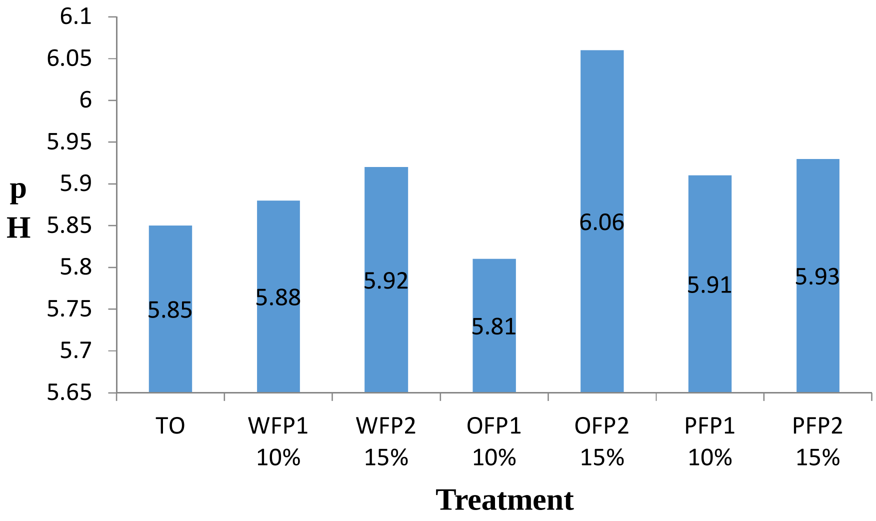


**Fig. 3: pH of sweet potato frankfurter sausages**

### 4.9 Proximate Composition of Sweet Potato Frankfurter Sausages

The proximate composition of sweet potato frankfurter sausages is shown in Table 12. Except for crude fat content all proximate parameters taken into accounts were significantly affected ($p < 0.05$) the various formulations. The protein content ranged from 18.52-20.78% whiles ash and fat ranged from 5.15-6.80% and 15.62-17.50% respectively. The moisture content of sweet potato frankfurter sausage ranged from 56.15-66.45%.

### 4.10 Cooking Loss of Sweet Potato Frankfurter Sausages

Table 13 show the cooking loss of sweet potato frankfurter sausages. There were significant differences ($P<0.05$) among treatments. Most formulations were not significantly different ($P>0.05$) from each other but PFP2 lost most water while OFP1 lost the least water.

**Table 12: Proximate composition of sweet potato frankfurter sausage**

| Parameter | TO | WFP1 10% | WFP2 15% | OFP1 10% | OFP2 15% | PFP1 10% | PFP2 15% | P value |
|---|---|---|---|---|---|---|---|---|
| Mo[illegible] | [illegible] ± 0.14$^{e}$ | 60.30 ± 0.14$^{d}$ | 61.30 ± 0.14$^{c}$ | 61.05 ± 0.14$^{cd}$ | 63.20 ± 0.14$^{b}$ | 63.25 ± 0.14$^{b}$ | 66.45 ± 0.14$^{a}$ | 0.000 |
| Pro[illegible] | [illegible] 0.10$^{a}$ | 19.69±0.10$^{b}$ | 18.52± 0.10$^{c}$ | 19.76±0.10$^{b}$ | 18.81± 0.10$^{c}$ | 19.91±0.10$^{b}$ | 18.89$^{c}$±0.10$^{c}$ | 0.000 |
| Fat | [illegible] ± 0.54 | 17.50 ± 0.54 | 17.19 ± 0.54 | 16.88 ± 0.54 | 16.88 ± 0.54 | 16.88 ± 0.54 | 15.62 ± 0.54 | 0.420 |
| Ash[illegible] | [illegible]0.06$^{a}$ | 6.80± 0.06$^{a}$ | 5.15± 0.06$^{c}$ | 5.79± 0.06$^{b}$ | 6.92± 0.06$^{a}$ | 6.78± 0.06$^{a}$ | 5.84± 0.06$^{b}$ | 0.000 |

**Me[illegible]d error) Means in the same row with the same superscript are not significantly different (P < 0.05).**
**TO[illegible] WFP: white flesh sweet potato, OFP: orange flesh sweet potato and PFP: purple flesh sweet potato**

**Tal[illegible] loss of sweet potato frankfurter sausages**

| Tre[illegible] | [illegible] | WFP1 10% | WFP2 15% | OFP1 10% | OFP2 15% | PFP1 10% | PFP2 15% | **P value** |
|---|---|---|---|---|---|---|---|---|
| Me[illegible] | [illegible] 1.0$^{a}$ | 10.0 ± 4.0$^{ab}$ | 5.0 ± 0$^{bc}$ | 3.50 ± 0.5$^{c}$ | 10.0 ± 0$^{ab}$ | 7.0 ± 3.0$^{abc}$ | 11.50 ± 1.0$^{a}$ | 0.001 |

**Me[illegible]d deviation); Means in the same row with the same superscript are not significantly different (P < 0.05). TO:**
**Fra[illegible]: white flesh sweet potato, OFP: orange flesh sweet potato and PFP: purple flesh sweet potato**

### 4.11 Peroxide Value of Sweet Potato Frankfurter Sausages

The Fig. 4 shows the trend of lipid peroxidation of frankfurters prepared with sweet potato. The peroxide value in TO was significantly ($P<0.05$) higher throughout the period of storage compared to the other formulations. The peroxide value of the products ranged from 4.00 to 4.833meq/kg.

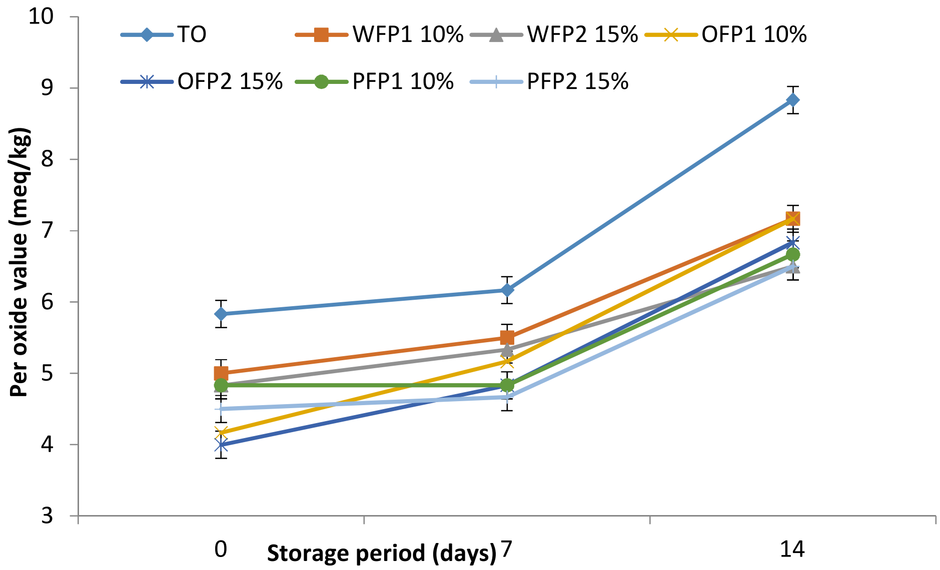


**Fig. 4: Peroxide value of Frankfurter Sweet Potato Sausage**

### 4.12 Mineral Composition of Sweet Potato Frankfurter Sausages

Significant differences ($P<0.0001$) were observed among treatments for all minerals studied (Table 14). Iron and zinc contents among formulations were all significantly different ($P<0.0001$) from each other. PFP2 15% had the highest content of iron whiles PFP1 10% had the lowest value of iron. Also among zinc and selenium TO has the highest value respectively whiles OFP2 15% and PFP1 10% had the lowest value.

**Table 14: Mineral composition of sweet potato frankfurter sausages**

| Parameters | Iron | Zinc | Selenium |
|---|---|---|---|
| TO | 0.1974$^{f}$ | 0.0686$^{a}$ | 0.5731$^{a}$ |
| WFP1 10% | 0.2379$^{d}$ | 0.0251$^{e}$ | 0.0862$^{b}$ |
| WFP2 15% | 0.3019$^{b}$ | 0.0312$^{c}$ | 0.0713$^{c}$ |
| OFP1 10% | 0.2112$^{e}$ | 0.0208$^{f}$ | 0.0552$^{d}$ |
| OFP2 15% | 0.2889$^{c}$ | 0.0191$^{g}$ | 0.0569$^{d}$ |
| PFP1 10% | 0.1589$^{g}$ | 0.0271$^{d}$ | BDL |
| PFP2 15% | 0.3214$^{a}$ | 0.0377$^{b}$ | 0.0560$^{d}$ |
| Pooled standard error of means | 0.00 | 0.00 | 0.00 |
| P value | 0.0001 | 0.0001 | 0.0001 |

**Means (± standard error) Means in the same column with different superscript are significantly different (P<0.000). BDL- Below detection limit. TO: Frankfurter, WFP: white flesh sweet potato, OFP: orange flesh sweet potato and PFP: purple flesh sweet potato**

# CHAPTER FIVE: DISCUSSION

## 5.1 Sensory Characteristics of Sweet Potato Beef Sausages

The addition of sweet potato puree had positive impact on the beef sausages. The colour of sweet potatoes was expected to have impacted on the final product and consumer's preference but that was not the case. The puree did not change colour of sausages when puree was incorporated into sausages. The inclusion of sweet potato puree in the products did not cause any repulsion by consumers.

The level of inclusion could not have any significant impact on the beef sausages. There was a trend of improving tenderness in the test products which became significant on day 14 in the beef sausage. This can be attributed to the high moisture content of the products from the addition of the sweet potato puree. Lorenzen *et al*. (2003), demonstrated that 51% of consumers think that tenderness is the most important sensory trait consumers looked for in meat and meat products. This insignificant difference among the various treatments for most sensory attributes indicates that beef sausages prepared by the addition of sweet potato puree would equally be preferred as the control by consumers.

## 5.2 Proximate Composition of Sweet Potato Beef Sausages

### 5.2.1 Moisture Content of Sweet Potato Beef Sausages

The moisture content of beef sausages with and without sweet potato puree ranged from 69.10-63.60. Agnihotri and Pal, (2000) stated that the moisture content of sausage is about (66.7%). A significant amount of moisture content that was found in test materials with low inclusion level of sweet potato puree shows that products with 10% inclusion level has high water holding capacity than products with 15% inclusion level.

### 5.2.2 Protein Content of Sweet Potato Beef Sausages

It was realized that higher inclusion level of sweet potato ($OFP_1$15% and $PFP_2$ 15%) puree significantly ($P<0.05$) lowered the protein content of the products which agrees with the findings of Tamakloe (2017) who also had lower protein values when potato puree was included at 5%. It was reported by Nurul *et al*. (2010) that adding substances which are low in protein will result in low protein content of which sweet potato is one of such. Proteins are required in higher levels in growing children and also for reproductive functions such as pregnancy and lactation (Pond *et al*., 1995). Therefore, the sausages can be consumed by this group of people to make up for the high protein requirements. The protein content of meat and meat products also indicates their biological value (Lawrie and Ledward, 2006).

### 5.2.3 Fat Content of Sweet Potato Beef Sausages

The addition of sweet potato did not affect the fat content of the sweet potato beef sausage which agrees with Tamakloe (2017) who found that potato puree/starch did not affect the fat content of sausages. It is generally known that sweet potatoes have very low fat content. The consumption of fat from meat products is associated with health problems (Muguerza *et al*., 2004), which has led to the reformulation of products with reduced fat content. This implies that inclusion of sweet potato puree in beef sausages would reduce the fat content and not have any negative effect on the health of consumers.

### 5.2.4 Ash Content of Sweet Potato Beef Sausages

Ash content represents the total mineral content in foods. Significant amount of ash was found in sweet potato sausages which indicates the presence of mineral in products. Ash is the portion of the food or any organic material that remains after it is burned at very high temperatures.

## 5.3 pH of Sweet Potato Beef Sausages

It was observed that whole beef sausages, had the lowest pH which is more acidic as compared to the treatments. The role of lower pH in meat and meat products on the inhibition of bacterial growth and development was realized as far back in 1964 (Lawrie and Ledward, 2006). Lower pH of meat products creates an acidic medium, making it inappropriate for bacterial growth and reproduction (Jamilah *et al*., 2008, Warris, 2010). This implies that the inclusion of sweet potato purees up to 10% would enhance storability of the products.

## 5.4 Cooking Loss of Sweet Potato Beef Sausages

The inclusion of sweet potato puree in beef sausages significantly affected the cooking loss of the products. There was no trend that can be attributed to the effect of the addition of the puree on cooking loss. However, inclusion of the various treatments up to 10% inclusion level did not negatively affect the cooking yield of the products. This finding agrees with Tamakloe (2017) who included sweet potato puree up to 20% in beef sausage.

### 5.5 Peroxide Value of Sweet Potato Beef Sausages

The values (4.16 to 8.833meq/kg) obtained throughout the storage period were below the maximum permissible limit of 25meq/kg of active oxygen/kg of product (Evranus, 1993). The test products had significantly lower values and could be attributed to the presence of sweet potato as extender which served the role of antioxidant to halt lipid oxidation. Pigmented potatoes contain a variety of substances with antioxidant potential (Stushnoff *et al*., 2007). Potatoes are known to contain water-soluble antioxidants that act as free radical acceptors, e.g. glutathione, ascorbic acid, quercetin and chlorogenic acid (Ezekiel *et al*., 2013). Diets rich in antioxidants, such as carotenoids, have been associated with lower risk of stomach, kidney and breast cancers (Hu *et al*., 2012). Orange flesh sweet potato is also known to contain β-caraotene which has antioxidant properties.



### 5.6 Mineral Content of Sweet Potato Beef Sausages

The products with sweet potato puree had the highest value of iron content than the control. Infants and toddlers are at increased risk for Iron deficiency (ID) and Vitamin A deficiency (VAD) when complementary foods, which are usually cereal-based are fed (Khan and Bhutta, 2010). Therefore, sweet potato sausage can be given alongside the cereals to curb the deficiency of iron. This product can be recommended to people with low or deficient in iron (anemic) levels.

All minerals considered were significantly different among treatments. The sweet potato products were significantly lower in zinc than the control. Zinc is known to stabilize the molecular structure of cellular components and membranes and in this way contributes to the maintenance of cell and organ integrity. Furthermore, zinc has an essential role in polynucleotide transcription and thus in the process of genetic expression (FAO and WHO, 2004). Fundamental activities probably account for the essentiality of zinc for all life forms. It recommended that an individual must take in 3.6mg of zinc per day (FAO and WHO, 2004). The significant lower zinc content of the treatments could be as a result of the incorporation of potato puree.

The selenium content of the sweet potato products was highly improved than the control. Selenium works with vitamin E in production of glutathione to protect cells from damage that may lead to cancer, heart related disease and other health problems (Nutrition Reference Guide, 2013). Sweet potato sausage can be eaten by all ages of human because of the improved selenium content. It has the ability to stimulate the formation of antibodies which help to fight infections in the body (Meschy, 2010).

**5.7 Sensory Characteristics of Sweet Potato Frankfurter Sausages**

There was significant improvement in terms of general acceptability of the products with the inclusion of potato puree on day 1. Non-significant differences among treatment means in terms of sensory characteristics of the product which indicates that frankfurter prepared with the addition of sweet potato puree would equally be preferred by consumers as the control.

## 5.8 Proximate Composition of Sweet Potato Frankfurter Sausages

### 5.8.1 Moisture Content of Sweet Potato Frankfurter Sausages

The values of moisture content of sweet potato frankfurter sausage ranged from 56.15-66.45. Less moisture makes meat dryer in the mouth while high moisture content in meat makes it juicier (Colmenero, 2000). This means the juiciness of products were different from each other. This is as a result of the high moisture content of sweet potato puree incorporated in the sausage at different levels. Statistically, there was a trend in products per the percentage inclusion of puree which shows the correlation in the moisture content. The inclusion level of 15% was found to have higher values to 10% inclusion level. However, high moisture content enhances microbial growth and vice versa (Lawrie, and Ledward, 2006).



### 5.8.2 Protein Content of Sweet Potato Frankfurter Sausages

There was a significant reduction in protein content as sweet potato inclusion increased from (0%, 10% and 15%). The difference in protein content was due to the addition of the potato. It was reported by Nurul *et al*. (2010) that adding substances which are low in protein will result in low protein content.

### 5.8.3 Fat Content of Sweet Potato Frankfurter Sausages

The fat content of the sweet potato frankfurter sausage was not negatively affected. Sweet potato is known to have low amount of fat. Consumers tend to believe that potatoes are high in calories and in fat compared with other carbohydrate sources such as rice or pasta; an incorrect assumption since potato has negligible fat and a low energy density similar to legumes (Priestley, 2006). The insignificant difference in the fat content of the products indicated that consumers would not be at risk for health reasons when sweet potato puree is included in frankfurter sausages formulation.

### 5.8.4 Ash Content of Sweet Potato Frankfurter Sausages

The ash content of sweet potato frankfurter sausage was significantly different. This indicates the presence of minerals in the sausage. Ash or mineral content is the portion of the food or any organic material that remains after it is burned at very high temperatures. Ash content of a product indicates the level of mineral available if consumed. Lucarini *et al.* (2013) recorded ash content of meat which values are in the same range as this study which was sweet potato as extender in sausages.

### 5.9 pH of Sweet Potato Frankfurter Sausages

The shelf life of meat is mostly based on its pH. It was observed that frankfurter sausages, had similar pH as the control except the 15% treatment. Lower pH of meat products creates an acidic medium, making it inappropriate for bacterial growth and reproduction (Warris, 2010). pH plays an important role in preservation of foods. Generally high acidic foods are less prone to bacterial spoilage. This implies that the inclusion of sweet potato purees up to 10% would not change the shelf life of frankfurter sausages.

### 5.10 Cooking Loss of Sweet Potato Frankfurter Sausages

The inclusion of sweet potato puree in frankfurter sausages significantly affected the cooking loss of the products. However, inclusion of the various extenders up to 10% inclusion level did not negatively affect the cooking yield of products. High moisture loss could have negative effect on tenderness which is an important attribute of eating quality. This could affect the eating quality of the various sausages. Tenderness has been identified as the most important palatability attribute of meat, and the primary determinant of meat quality (Miller *et al*., 1995) and consumer acceptability (Brewer and Novakofski, 2008).

### 5.11 Peroxide Value of Sweet Potato Frankfurter Sausages

The treatments had lower peroxide values than the control frankfurter sausage which was significantly higher from day one to the 14$^{th}$ day (Fig. 4). The peroxide value of the products ranged from 4.00 to 4.833meq/kg throughout the storage period. Although the control was significantly higher from day one to day 14 but was still liked by consumers. This was because peroxide values were within the recommended value of rancidity. Carotenoids are found largely in orange and red sweet potatoes (Brown *et al*., 2004). Products with sweet potato puree were not different from each other because of the antioxidant content which is known to halt or slow oxidation of lipids. In addition to the coloured flavonoids, sweet potatoes with skins contain a variety of colourless phytochemicals with antioxidant potential, most notably vitamin C (Barnes *et al*., 2013). These could be the major cause of stabilization of the peroxide values of the test products.

### 5.12 Mineral Content of Sweet Potato Frankfurter Sausages

The iron content was significantly higher in the sweet potato product than the control frankfurter sausage with FP2 15% being the highest. The treatment values ranged from 0.1974 -0.3214 mg. The average daily iron intake from foods and supplements is 13.7–15.1 mg/day in children aged 2–11 years, 16.3 mg/day in children and teens aged 12–19 years, and 19.3–20.5 mg/day in men and 17.0–18.9 mg/day in women older than 19. The median dietary iron intake in pregnant women is 14.7 mg/day (Institute of Medicine and Food and Nutrition Board, 2001). Iron deficiency may affect three billion people worldwide (Long *et al*., 2004). Iron deficiency (ID) and Vitamin A deficiency (VAD) are prevalent in the developing world, especially in vulnerable groups such as infants and young children (WHO, 2015). VAD and ID often co-exist in low-income countries due to long-term poverty and plant-based monotonous diets (WHO, 2015), thus sustainable strategies, particularly specific nutritional food-based approaches, which will lead to high intake of dietary vitamin A and bioavailable iron (sweet potato sausage) are desirable. This shows sweet potato sausage can provide some iron needed by human. Therefore, it would be predicted that sweet potato-based complementary foods (sweet potato sausage), with cereal-based infant foods, would have better iron bioavailability (Lung'aho and Glahn, 2009).

Significant amount of Zinc was recorded in the treatments though the control was significantly higher than the treatments. Courtney (2007) found that genotypic variation of iron and zinc concentration exists in sweet potato storage roots. Health problems caused by zinc deficiency include anorexia, dwarfism, and weak immune system (Solomons, 2003). In Africa, it is estimated that 500-600 million people are at risk for low zinc intake (HarvestPlus, 2007).

Higher ($P<0.001$) selenium content was recorded in the control compared to the test products though all had appreciable amount of selenium. Selenium has been implicated in the protection of body tissues against oxidative stress, maintenance of defenses against infection, and modulation of growth and development (FAO and WHO, 2004). Selenium works with vitamin E to protect cells from damage that may lead to cancer, heart related disease and other health problems (Nutrition Reference Guide, 2013). Meta-analytic studies of the epidemiological literature showed that selenium deficiency was a cancer promoting factor. Therefore, the consumption of sweet potato frankfurter can be a cancer prevention and reducing dietary supplement. Selenium also has a role, besides vitamin E, in muscle function by improving endurance, recovery and slowing the ageing process (Cabaraux, 2007; Suttle, 2010).

# CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

The inclusion of sweet potato puree as an extender did not negatively affect the sensory characteristics of both beef and frankfurter sausages. It improved on the tenderness and texture of both beef and frankfurter sausages. The beef and frankfurter sausages were not influenced negatively in terms of their proximate compositions. Lipid per oxidation process was slowed by the sweet potato puree inclusion in the sausages. The three sweet potato varieties prove to have rich sources of micro minerals (zinc, iron and selenium) contents.

**RECOMMENDATIONS**

1. Sweet potato puree can be included in both beef and frankfurter sausages by meat processors up to 10%.
2. Combining sweet potato varieties and meat rich in beta-carotene, iron, and zinc would be valuable in combating micronutrient deficiencies in the country.

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