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NUTRITIONAL QUALITY OF SAUSAGE MADE WITH EDIBLE MEAT WASTE AND THE PERCEPTION OF CONSUMERS ON OFFAL PRODUCT IN EASTERN CAPE PROVINCE, SOUTH AFRICA

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BY

ALAO BABATUNDE OLUWASEGUN

A THESIS SUBMITTED IN FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF
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CO-SUPERVISORS: DR. AMANDA CHULAYO
DR. ANDREW BAMIDELE FALOWO

JUNE, 2018

DEDICATION

I dedicate this piece of work to my wife Oluwatoyin Opeyemi and to my children Oluwapemi Goodness and Oluwapetan David who endured my absence at home during the course of this study. I also dedicate this work to my Lord and Saviour Jesus Christ who has blessed me beyond anything I could ever have imagined and who has loved me beyond my comprehension.

DECLARATION

I, ALAO Babatunde Oluwasegun, declared that this thesis, submitted to the University of Fort Hare for the degree of Doctor of Philosophy in the Department of Livestock and Pasture Science in the Faculty of Science and Agriculture, is my own work; and that this work has not been submitted to any other institution for the award of any academic degree.

I declare that I followed the rules and conventions concerning referencing and citation in scientific writing.

I also declare that all sources of materials used for this thesis have been duly acknowledged and accurately referenced.

Again, I declare that I am fully aware of the University of Fort Hare policy on plagiarism and I have taken every precaution to comply with the regulations of the University.

Name: Babatunde Oluwasegun Alao **Signature**

Institution: University of Fort Hare **Date:** 01/06 2018

We confirm that the work reported here was carried out by the above named candidate under our supervision.

Prof Voster Muchenje

Signature: Date: 01/06 2018

Dr Amanda Chulayo

Signature: Date: 01/06 2018

Dr Andrew Bamidele Falowo

Signature: Date: 01/06 2018

ETHICAL APPROVAL FOR THE STUDY

The portion of this study involving the survey on the perception of offal meat consumption in Amathole District and Sensory evaluation of the sausage made with edible meat waste for data collection was carried out following the approval of the University of Fort Hare's Ethics Committee, with ethical clearance number MUC341SBAB01.

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I thank the Almighty for giving me the strength and patience to work through all these years so that today I can stand proudly with my head held high. Now unto the king eternal, invisible, the only wise God, be honour and glory forever and ever. Amen.

TABLE OF CONTENTS	PAGES

GENERAL ABSTRACT

Meat processing at the abattoir provides meat by product and waste while, the major part of the muscle which constitutes a third is edible. The edible by products (EBP) of meat have a notable position in our day-to-day life and are used in diverse forms. However, the quality of offal meat may differ according to intrinsic and extrinsic attributes that may occasionally be shaped by the attitude of consumers towards the products.

Therefore, the first objective of this thesis focused on features that might influence consumer preferences and their perception of offal meat. A total of 202 consumers from three Municipalities in Amathole District were randomly sampled using exponential non-discriminative snowball sampling. Data were gathered through a structured questionnaire containing open ended and closed ended questions. The study showed that consumers were more influenced by the freshness, price and availability of the product and these factors are used to determine the purchase outlet. Differences were observed in the offal meat consumption between the age groups. Age groups 25-34 (29.7%) and 35-44 (27.4%) showed the highest offal meat consumption, while the decline was observed in age groups of 55-64 (11.9%), 65-74 (5.9%) and 75-85 (0.01%) respectively.

The most preferred purchase point for offal meat in this study was in butcheries. However, it was observed that the factors influencing offal consumption in Amathole District were similar to meat consumption except that, offals were mainly purchased at butcher shops.

The second objective in this study was to determine the sensory characteristics and consumer acceptance of sausages with 10% fat, 30% edible meat waste and 50% edible meat waste. Sensory descriptive attributes such as appearance, texture, colour, taste, flavour and overall acceptance of the sausage were evaluated by sensory panel (*n* = 60). The sensory panel comprised of students from undergraduates, post-graduates, post-doctoral fellows and lecturers at the University of Fort Hare. The findings of the study indicated that 50% replacement of

edible meat waste was similar to the commercial 10% fat with regard to several sensory attributes and pooled liking. Therefore, the utilization of the edible meat waste in production of sausages has the potential to increase profitability in meat industry and minimise meat waste in the industry.

However, the cooking method that was more acceptable to consumers in this study was using the microwave as compared to oven-grilling. Furthermore, the effects of different cooking methods (microwave and oven-grilling) on proximate and mineral composition of the formulated sausages were determined. However, the cooking process appeared to have a significant effect on most of the minerals in the sausage. The cooking methods had a significant effect at $P < 0.01$ on the nutrients composition of the formulated sausage. It was observed that the nutritional values of the sausage was better preserved after the cooking process due to higher mean values obtained after cooking. The mean values for calcium (173.1, 221.76, 231.29), potassium (444.57, 158.58, 156.67), magnesium (84.43, 257.97, 127.27), zinc (52.94, 35.27, 27.13), copper (8.8, 7.07, 4.44), manganese (8.74, 0.65, 0.08), sodium (589.42, 604.45, 529.79) and iron (63.3, 85.38, 74.81) in cooked. And the mean values for calcium (286.18, 132.18, 114.79), potassium (206.64, 113.83, 207.81), magnesium (189.89, 33.97, 48.11), zinc (61.05, 28.09, 26.44), copper (2.92, 2.73, 3.89), manganese (1.42, 0.11, 0.35), sodium (566.47, 530.79, 527.35) and iron (77.56, 58.68, 45.42) in uncooked sausage varied greatly among the treatments. Although, the disparities in the mineral content may be attributed to the different edible meat waste from different parts of the cattle which are either from feedlot or pastured based. In regard to the results obtained from proximate and mineral composition, microwave cooking method was found to be the best cooking technique for healthy eating.

Finally, the effect of frying with two different oils (sunflower oil and olive oil) on the fatty acid composition of sausage made with edible meat waste was examined. The results revealed that beef sausage containing 70% edible meat wastes and 30% beef (T1) had a higher fat content

(25.7%±0.83%) than other treatments. On the other hand, beef sausage fortified with 10% fat and 90% beef (T3) had the lowest fat content but highest FFDM (55.85±0.57%) and moisture content (69.15±0.62) than other treatments. Despite the increase in omega-3: omega-6 fatty acid ratio in the sausage treatments after cooking, the mean value of omega-3: omega-6 fatty acid ratio was greater than 1:5 (0.2) which is within the FAO/WHO recommended range. The omega-3: omega-6 association is well-known for its importance in the diet because it is a key factor for balanced eicosanoid production in the living organism. The significant reduction in saturated fatty acids after cooking showed that there could also be a positive influence on the human health if consumed. Therefore, it may be concluded from the findings of the study that sausage made with edible meat waste as fat replacer is safe for human consumption.

CHAPTER ONE

1.1 Background Study

The world meat production is estimated to increase by 16% by 2025 while, livestock production is likely to improve to compensate for the downturn in quantity of slaughtered animals (OECD-FAO. 2016). As the world population continues to rise, more slaughtered animals will provide more meat and edible by-products to meet up with the demand for animal protein (Umaraw *et al.,* 2015). As a result, sustainable livestock production will play a role in fighting impending food insecurity around the world. In South Africa, 69% of land surface is suitable for pasture and livestock farming. Livestock production is a major agricultural sector in most of the provinces in the country (Goldblatt. 2010). Over 6 million cattle head is maintained for the public by the national government of South Africa since 1970s and now stands at near 14 million (Palmer and Ainslie, 2006). Past reports have showed that 25% of cattle were slaughtered and 11% consumed as red meat between 2014 and 2015 (DAFF, 2016). In the interim, the desirability of livestock products is expected to increase and grow until 2025 before the law of diminishing returns sets in (Thornton *et al.,* 2010).

Livestock production is the world's most prevalent end user of land resources. Research also shows that Southern African region is not immune to this because livestock production has also been on the increase since 2008 with 61.8 million cattle and 75% found in the communal areas (Blignaut *et al.,* 2014; Muchenje et al. not dated). In South Africa, roughly 84% of the land is obtainable for agricultural practices. For instance, 13% of the smaller part of this land is suitable for arable farming while 70% is suitable for increasing livestock productivity (RMRD SA, 2012; Scholtz *et al.,* 2013). The communal farmers in South Africa keep livestock for many reasons such as meeting up with the well-being of their families. Thus, communal farmers depend on livestock products such as milk, meat, and hides as the source of revenue (Dovie *et al.*, 2006). Initially, the foremost growth in domestic animal production was expected to come from communal peasants. But, communal farmers lacked adequate facilities to manage an intensive cattle production hence, this was better managed by the large-scale farmers. Reason being, high throughput abattoir which are normally managed by large scale livestock farmers that are capable of boosting meat and meat products supplies through better management and production of hygienic products.

In South Africa, many people prefer to consume grounded meat products which are marketed in butcher shops, supermarkets or abattoirs. Thus, meat is perceived as an important source of protein which contributes to human diet for adequate growth (Gerber et al., 2009; Asmaa et al., 2015). The presence of fat in the meat, serves not only as nutrient in the human body, but also as reservoir of fatty acid (Pearson et al., 1987). Dietary fat in meat and meat products is responsible for its juiciness, taste, flavour and texture in meat and meat products. However, excessive fat consumption has deleterious effect on human health and it is recommended that, consumers reduce their dietary fat intake. This infers that, fat replacers in meat products especially grounded meat are necessary to satisfy the need of consumers, especially for those consumers who are willing to cut down the amount of fat being consumed in their daily diet (Chin et al., 2004; Gerber et al., 2009). Although several studies h

ave evaluated the effects of fat replacers on sausages (Yılmaz, and Dağlıoğlu, 2003; Cengiz, and Gokoglu, 2007; Choe et al., 2013) however, research of edible meat waste as fat in sausage production is yet to be explored.

Research indicates that sausage production utilises edible meat cut from beef, pork, lamb and meats from chicken, though deboned meat (Mohan, 2014). There is a noticeable heterogeneity in sausage production around the continent as a result of tastes and the ingredient found in a particular place. Nevertheless, the consumption of sausage continues to spread in respect to flavour from meat varieties and ingredients that are unique to a particular region (Essien, 2003). Flavour is attributed to intramuscular fat and influences consumers' decision, while application of heat to meat products induces palatability (Tornberg, 2005; Sitz *et al.*, 2005; Resconi *et al.*, 2013). Brugiapaglia and Destafanis. (2012), concurs with the foregoing scholars who reported that cooking methods and cooking conditions such as cooking duration, heating phase, and temperature interval can influence chemical composition with a consequential transformation in nutritional value. However, there has been little research on fat replaced with edible meat waste in sausage production, where the physiochemical properties are compared with the normal sausage. Hence, the acceptability of the sausage made from meat wastes with the effect of the cooking oil and cooking methods needs to be investigated with resultant fatty acid composition.

1.2 Problem Statement

In South Africa little is known about consumer and traders perception on offal consumption. Although, the freshness of meat is frequently reported as the most important factor in the assessment of consumer to purchase fresh meat (Glitsch, 2000). However, limited study has been conducted on consumers' perception on offal meat consumption. The evaluation of offal quality before purchase may show a notable role in consumer's decision on intrinsic features of the edible by-product. Therefore, understanding consumers and meat traders' perceptions on offal consumption will be helpful in the cultural background for promotion and encouraging the consumption of offals. This will help remove any negative beliefs towards offal consumption, thereby assist in fighting protein deficiency and enhancement of food security particularly, at municipality level.

Effective abattoir monitoring system have been adopted and valuable information is provided at national and provincial level in South Africa (Humblet *et al.,* 2009). The responsibility of abattoirs in record keeping is expected to accommodate the amount of offal produced at the abattoirs, consumed, sold, purchased, imported and exported (Bekker *et al.,* 2011). However, observations have been made that such records are presently lacking at the Department of Agriculture Fishery and Forestry (DAFF). The awareness of offal consumption at municipality level is therefore imperative in regard to the number of low and high throughput abattoirs that are well pronounced in South African provinces. These abattoirs are governed by strict regulations and saddled with the responsibility to produce animal proteins that are safe for human consumption. Thus, understanding consumer and meat traders' perceptions on offal consumption will give insight on perception of offal consumption and its acceptability in Amathole District of Eastern Cape Province.

Today processed meat products remain an excellent source of protein for a number of people. Meat products are now considered as delicacies used as basic modern dishes in many countries. In this regard, meat products has been incorporated as constituents of modern diet. Hence, the creative utilization of meat by-products is important for productivity of the meat industry. While the utilization of edible meat waste, by conversion into useful products of higher value can satisfy the needs for fat replacement in sausage production. Although, comprehensive researches have been implemented on fat replacement to improve quality of many products (Tokusoglu, and Ünal, 2003; Yılmaz, 2004; Viana *et al.,* 2005; Choi *et al.,* 2009; Hygreeva *et al.,* 2014; Keenan *et al.,* 2014). As such, there is the necessity for more efforts to be focused toward using this valuable edible meat waste in sausage and to ensure that maximum benefits are derived. Thus, improving the nutritional profile of sausages through the addition of edible meat waste might have cognitive impact on sensory characteristics and acceptably depending on mixing ratio. Hence the pre-objective of the present study was designed to address substituting the fat content in sausage with edible meat waste (tendons, connective tissues, trimmed off meat, trimmed-off fat) obtained during the deboning and trimming process at the abattoir.

1.3 Justification

In South Africa little is known about consumer and traders perception on offal consumption. Although, the freshness of meat is frequently reported as the most important factor in the assessment of consumer to purchase fresh meat (Glitsch, 2000). However, little or no study has been conducted on consumers' perception on offal meat consumption. The evaluation of offal quality before purchase may show a notable role in consumers' decision on intrinsic features of the edible by-product. Hence, understanding consumers and meat traders' perceptions on offal consumption will be helpful in the cultural background for promotion and encouraging the consumption of offal. This will help remove any negative belief towards offal consumption, thereby assist in fighting protein deficiency and enhancement of food security at municipality level.

A number of studies have shown that, apart from intrinsic features referring to those of the physical product, extrinsic meat features and perceived meat features, such as the perception, products, person, place, or environmental aspects, have a tendency to become important to consumers and traders (Ophuis and Van Trijp, 1995; Grunert, 2005; Chamhuri and Batt., 2015). Intrinsic indicator describes the physical features of the product such as colour, freshness, size, packaging, and physical outlook which cannot be removed without altering the product itself (Grunert, 2005; Chamhuri and Batt., 2015). The extrinsic indicators are features that the consumer used to compare between products with comparable appearance but not related to physical features such as price

(Ophuis and Van Trijp, 1995; Chamhuri and Batt., 2015). It is therefore, imperative to meet the consumers' demands based on their expectations from the meat traders. For this reason, it is required that meat traders should display important quality features that are appealing when such products are displayed in their outlets. When consumers and traders perception are well synchronized, it could bring satisfaction to the two parties. This is due to the fact that, consumers are influenced by certain indicators for their desired quality attributes (Glitsch *et al.*, 2000). These indicators play a conclusive role on the demand for offal and meat product. Furthermore, these indicators are not limited to price, accessibility, and freshness alone but it also extends to other factors such as packaging, flavour, colour, tenderness, and price (Owusu-Sekyere, 2014).

Currently, with the increased concerns over human health, nutritional skill has been developed to allow efficient utilization of meat by-products (Walker *et al.*, 2005; Wolk, 2017). This is imperative, because increase of revenues and lower costs of production are essential for sustainability of the meat industry. The utilization of edible meat waste, by conversion into useful products of higher value can satisfy the needs for fat replacement in sausage production. However, comprehensive researches have been implemented on fat replacement to improve quality of numerous meat products. As such, there is necessity for more efforts to be focused toward using valuable edible meat waste in sausages and to ensure that maximum benefits are derived. Thus, improving the nutritional profile of sausages through the addition of edible meat waste might have cognitive impact on sensory characteristics and acceptably depending on mixing ratio.

The consumption of meat and meat products can be a good approach to understanding dietary form of macrominerals and microminerals. Essential minerals are categorized into two main groups namely microminerals (needed in large quantity) and microminerals (needed in smaller quantity). These minerals are found in meat and its consumption provide essential nutrients needed for growth and vitality (Littledike *et al.*, 1995; Cabrera *et al.*, 2010; Ramos *et al.*, 2012). Meat is of extreme significance in human nutrition as a result of its adequate nutritional quality however, the principal components found in meat are proteins, carbohydrates, fats, fatty acid and minerals (Miguel and Salvador, 2015). It is well known that, meat is one of the most important sources of macro and micro minerals such as iron, phosphorus, potassium, zinc and selenium. Essential minerals with well-defined physiological functions and higher bioavailability are more present in meat compared to other sources of minerals (Miguel and Salvador, 2015).

The bioavailability of these minerals in meat has been reported to be affected by the feeding regime, breed, geographical location of the farm, meat type and processing method (Hintze *et al.*, 2002; Purchas *et al.*, 2003; Purchas and Busboom, 2005; Revilla and Vivar-Quintana, 2006; Cabrera *et al.*, 2010). In this view, the amount and degree of macronutrients and micronutrients may change considerably, depending on variety and quality of meat product consumed. Therefore, the knowledge of essential minerals in sausage made with edible meat waste is very important to establish the dietary proficiency of the product to consumers.

1.4 Objectives of the study

The broad aim of the study was to investigate the nutritional quality of sausage made with edible meat waste and the perception of consumers on offal products in Eastern Cape Province, South Africa. Specific objectives were to:

- To determine consumers perception on offal consumption in Amathole District;
- To establish consumers acceptability on sausages made with edible meat waste under two different cooking methods;

- To determine and compare the proximate and mineral composition of sausages made with edible meat waste;
- To determine the fatty acid profiles of sausages made with edible animal waste and cooked with two different cooking oils.

1.5 Research Hypotheses

The null hypothesis tested was that the physiochemical properties, consumers' perception, acceptability and cooking methods does not have an effect on sausages made from edible meat waste.

- consumer perception on offal consumption in Amathole district is the same;
- there are no differences in acceptability of sausages made from edible animal waste with different cooking methods;
- there are no differences in the proximate and mineral analysis of sausages made with edible meat waste;
- there are no differences in the fatty acid profiles of sausages made with edible animal waste and cooked with two different cooking oils.

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CHAPTER TWO

LITERATURE REVIEW

(This section has been published under Sustainability Journal)

Abstract

The consumption of animal by-products has continued to witness tremendous growth over the last decade. This is due to its potential to combat protein malnutrition and food insecurity in many countries. Shortly after slaughter, animal by-products are separated into edible or inedible parts. The edible part accounts for 55% of the production while the remaining part is regarded as inedible by-products (IEBPs). These IEBPs can be re-processed into sustainable products for agricultural and industrial uses. The efficient utilization of animal by-products can alleviate the prevailing cost and scarcity of feed materials, which have high competition between animals and humans. This will also aid in reducing environmental pollution in the society. In this regard, proper utilization of animal by-products such as rumen digesta can result in cheaper feed, reduction in competition and lower cost of production. Over the years, the utilization of animal by-products such as rumen digesta as feed in livestock feed has been successfully carried out without any adverse effect on the animals. However, there are emerging gaps that need to be further addressed regarding the food security and sustainability of the products. Therefore, the objective of this review highlights the efficacy and effectiveness of using animal by-products as alternative sources of feed ingredients, and the constraints associated with their production to boost livestock performance in the industry at large.

Keywords: animal by-products; environmental pollution; feed; rumen digesta; utilization; food security; sustainability

2.1 Background of the study

Meat and meat products form an important segment of the human diet because they provide essential nutrients which cannot be easily obtained through vegetables and their derived products (Byers *et al.*, 2002). They provide a means for reducing malnutrition and increasing household food and food security (Chikwanha *et al.*, 2011). Over the last 20 years, the demand for meat and meat products has increased in many parts of the world (including Africa, Asia, Europe and United States of America) and this has led to rapid surge in livestock production for sustainable food security (Sans and Combris, 2015).

The process of converting livestock to meat in abattoirs usually generates a lot of by-products which can be further utilized by humans as food or reprocessed as secondary by-products for both agricultural and industrial uses (Liu *et al.*, 2002). The yield of these by-products has been reported to account for about 10% to 15% of the value of the live animal in developed countries, although animal by-products account for about two-third of the animal after slaughter (Irshad and Sharma, 2015). Basically, animal by-products include all parts of a live animal that are not part of the dressed carcass such as liver, heart, rumen contents, kidney, blood, fats, spleen and meat trimmings. In this sense, the production of these animal by-products can be grouped into non-carcass meat (EBPs) and non-meat products (IEBPs) as shown in Figure 1.

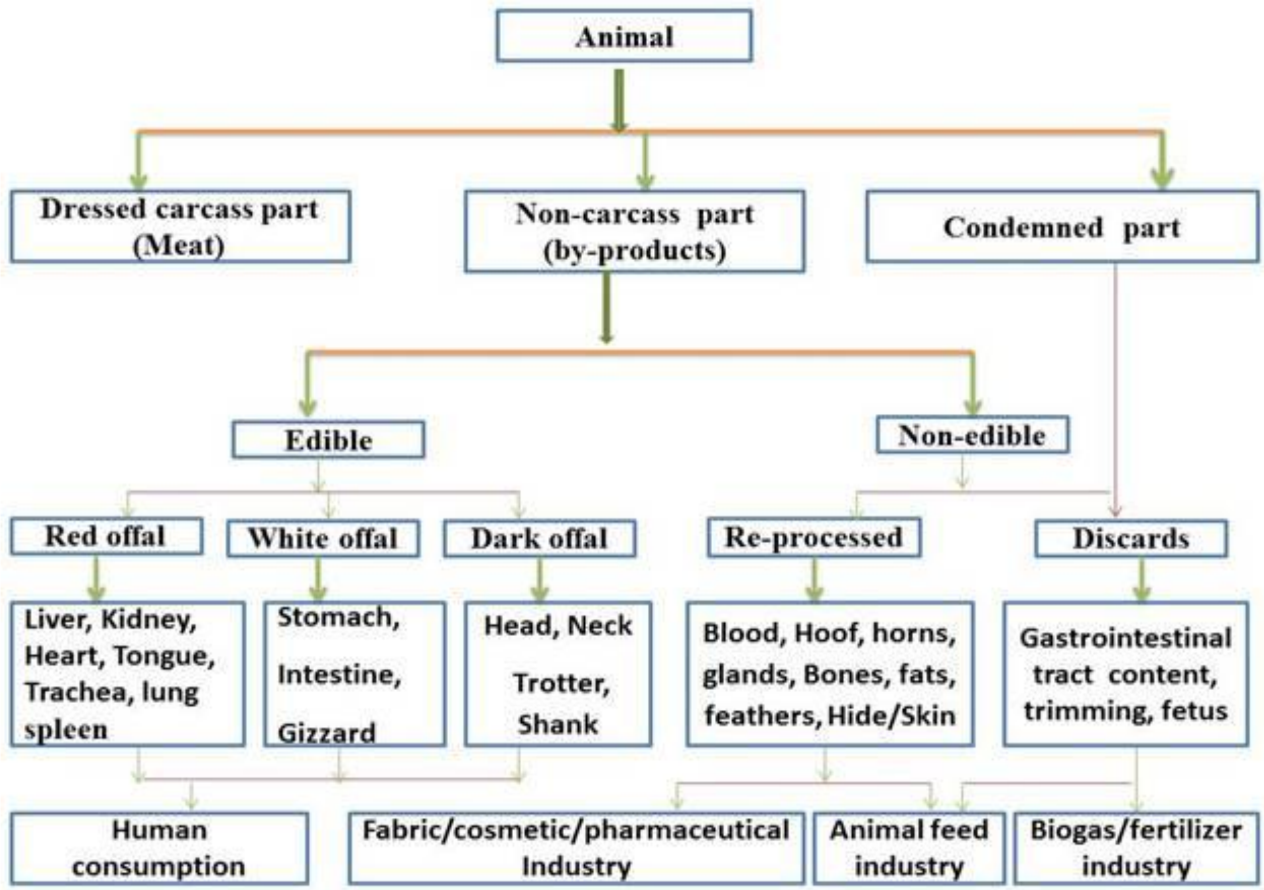

Figure 1: Classification of animal by-products.

EBPs are products that are approved by registered public health inspector and considered safe for human consumption after inspection in the abattoir. In contrast, IEBPs cannot be consumed by humans and are condemned as discards or re-processed and used as secondary by-products. Most EBPs, especially the liver, kidney, tongue and heart, have the potential to provide essential nutrients where meat and meat products are limited or insufficient to meet the nutritional requirements of people (Fayemi *et al.*, 2016). Today, the world is facing a huge problem on food insecurity and climate change, which has resulted to malnutrition especially in the developing countries (Sheely *et al.*, 2005). Over two billion people in the world, especially in developing countries, have been reported to be suffering from the deficiency of key food nutrients such as vitamins and minerals including vitamin A, iodine, iron and zinc (FAO, 2014). Meeting the nutritional needs of these people will require about 20 g of animal protein (meat, fish, egg and milk) per person per day or 7.3 kg per year (FAO, 2014). Therefore, protein sources such as EBPs could be employed to reduce the menace of malnutrition and food insecurity. It has been proposed that studies involving the use of EBPs as food ingredients should be promoted and evaluated (Rosa *et al.*, 2002). For this reason, Ockerman and Basu (2004) reported that EBPs contain essential nutrients such as vitamins (B1, B2, B6, and folic acid), proteins, minerals and fat, with important poly-unsaturated fatty and amino acids which comparable to those in muscular tissue.

On the other hand, IEBPs such as bones, hides and skin, feathers, hooves, horns, hair, bristles and rumen digesta (Figure 2) can be transformed into useful and valuable products for human and livestock consumption (Irshad and Sharma, 2015). It is widely accepted that bone can be re-processed into livestock feed (source of minerals) while skin/hide and feathers can be processed and utilized in the upholstery, leather and textile industry. However, the utilisation of rumen digesta could serve as an alternative feed source for the livestock industry since most developing countries are experiencing a shortage of feed ingredients due to extreme climate condition, increase in cost of feed and competition for cereal crops between humans and livestock (Elfaki *et al.*, 2014) Therefore, this review highlights the importance of animal by-products in food system as sources nutrient for humans and alternative feed ingredients for livestock industry.

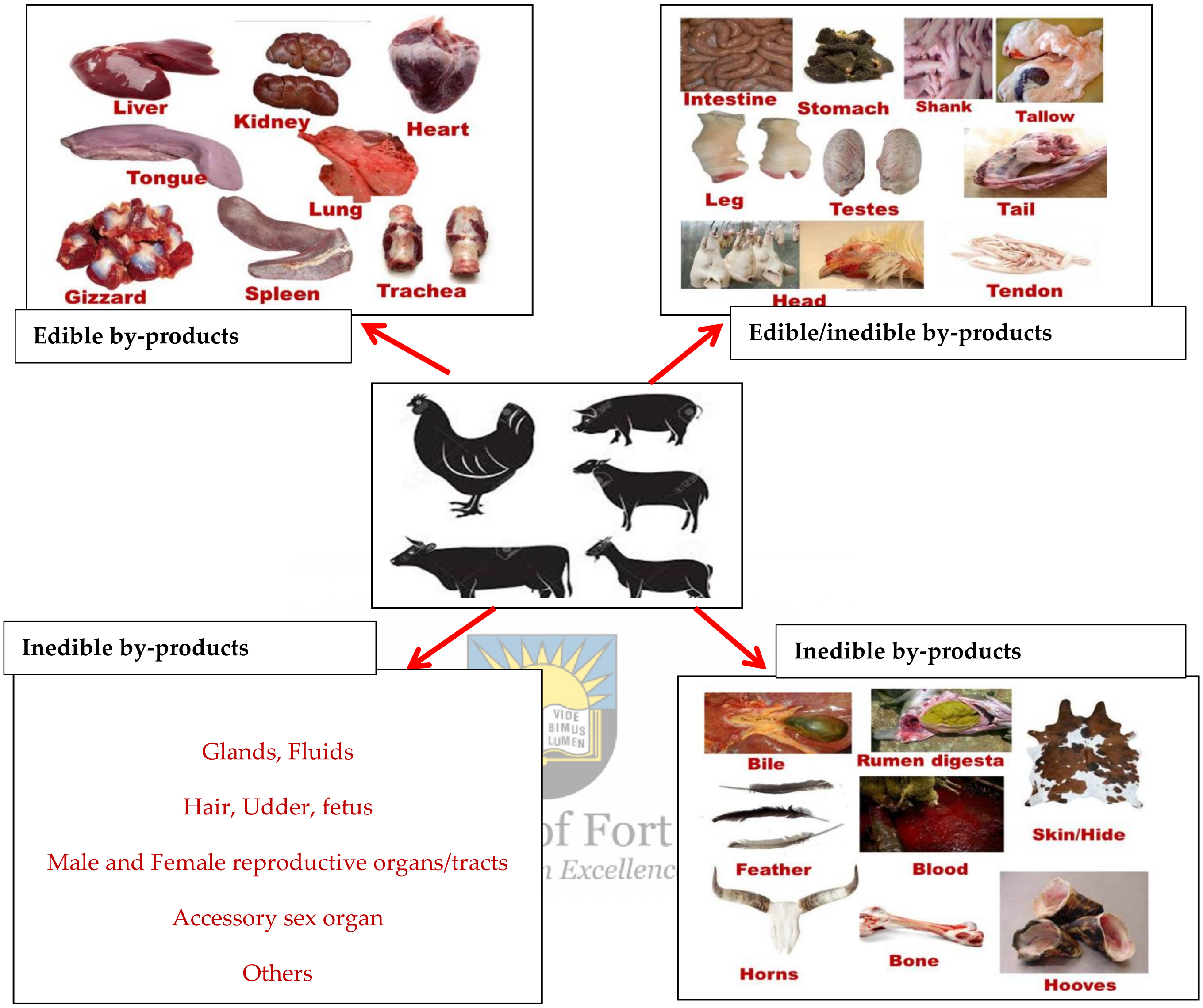

Figure 2: General descriptions of edible and inedible by-products.

It is widely known that, data attained through the amount of waste generated at abattoir may vary from animal species to the type of carcass being processed (Roupas *et al.*, 2007). In order for the meat industry to maximise their profit, meat waste such as connecting tissues, tendons, and other meat trimmings may be recycled into value-added products such as sausages. The increase in the consumption trend of processed meat products such as the sausage, burger, hot dog, meatballs, and patties are common among the young people (Analytics 2014; Ferreira *et al.*, 2016). This is attributed to the ease of cooking, time-saving and simple processing and cooking technique before consumption (Ferreira *et al.*, 2016). In 2012, Europe reported the sum of forty-seven billion euros of ready to eat easy and easy to prepare food (Kanzler *et al*., 2015; Ferreira *et al.*, 2016). South African, fast food sector generated 170 billion rands revenue in 2015 while the purchasing power of consumers in fast food shop increased from 66% to 80% (Murray, 2017). Consumption of processed meat has increased to about 46 percent. Therefore, as the global population increases the ability and desire to purchase more processed meat products will continue to increases across many regions in developing nations (Delgado, 2003).

2.2 Classification of Animal By-Products

The description and classification of animal by-products differ from country to country and according to different usages in the meat industry. They can be classified as EBPs and IEBPs (Figure 1), or organ and non-organ by-products (Marti *et al.*, 2012). They are also sometimes classified based on muscular structure, shape and colour (Pérez-Alvarez *et al.*, 2011). Regardless of this, the offal can be sub-grouped into red offal, white offal and dark offal (Alexandre *et al.*, 2010) as shown in Figure 3.

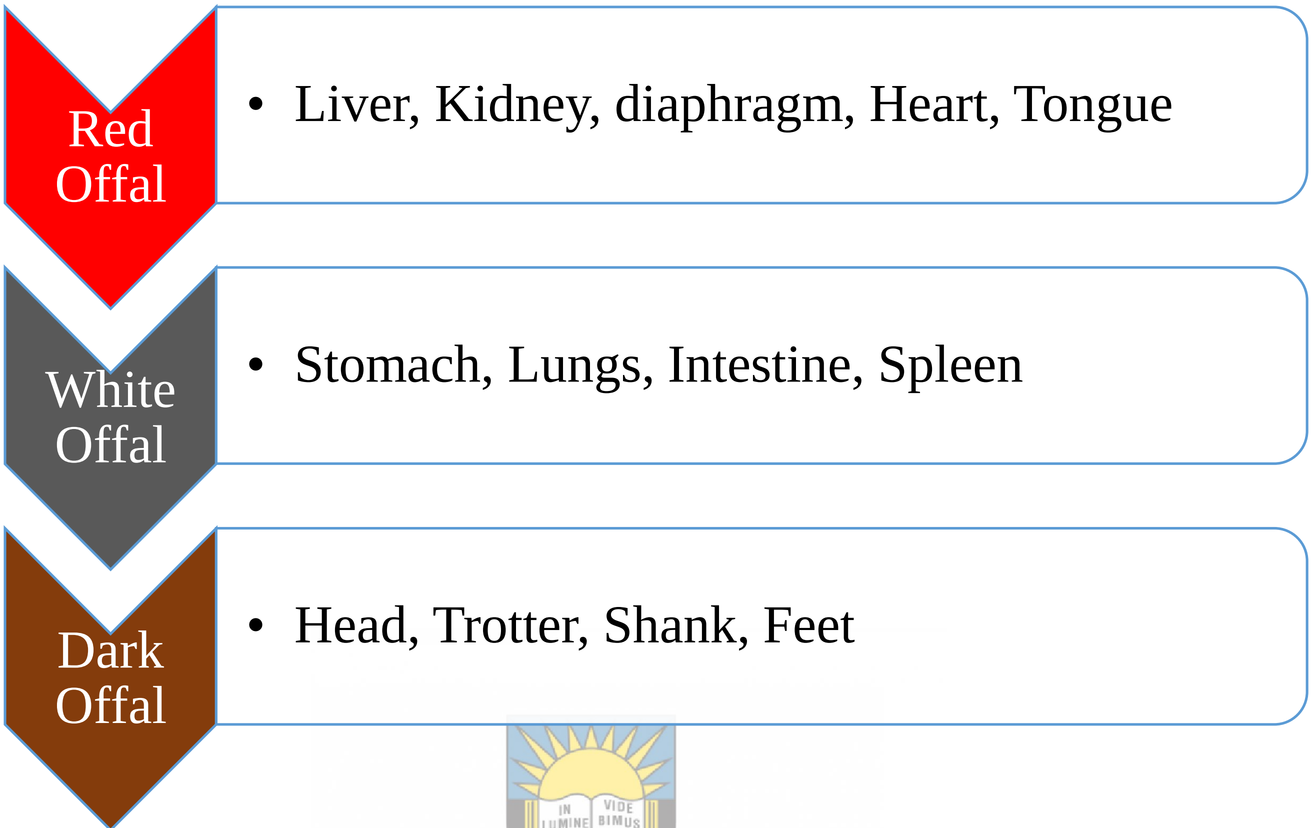

Figure 3; General classification of edible offal

2.3 Consumption and Nutritional Composition of Edible By-Products

As stated earlier, regulations require that EBPs be examined by a public health inspector immediately after slaughter and approved to be free from infections (such as fasciolosis, fibrosis, echinoccosis, tuberculosis, hydatidosis and abscess) and any physical abnormalities before processing for human consumption (Yibar *et al.*, 2015; Gonulalan *et al.*, 2004). If diseases and abnormalities such as bruises are found in any organs and carcasses, the affected parts or whole organs are usually condemned and discarded or declared unsafe for human consumption. Other by-products such as the intestine and stomach are thoroughly washed and heat-treated to remove any dirt and to also destroy any microbes present that might cause infection or pose a health risk to consumers (Nollet and Toldra, 2011). Products such as tongue are usually graded on surface integrity, colour and defects which include cuts on the membrane, warts and physical abnormalities or diseases (Gonulalan *et al.,* 2004).

The consumption of EBPs across the world is gradually increasing due to the discovery of their importance as a source of nutrients for human benefit. They are widely used in traditional culinary in Europe, South America, North America, Asia, Africa and Australia (Nollet and Toldra, 2011; Van Heerden and Morey, 2014). In Africa, all parts of EBPs are processed and commonly used as human food (Toldra *et al.,* 2012). In South Africa, EDP delicacies are enjoyed and accepted as one of the traditional norms shared collectively between white South Africans (especially Afrikaners) and black South Africans (Van Heerden and Morey, 2014). A study conducted in Somalia revealed that EBPs are culturally acceptable and consumed by people of all ages (Masese and Waweru, 2011). EBPs are usually eaten after frying, grilling, boiling or braising with vegetables and other ingredients. In some cultures, liver meat is processed and consumed in different forms such as liver pâté, foie gras and liver sausages (Abu-Salem *et al.,* 2010; Lorenzo and Pateiro, 2013; Xiong *et al.,* 2016). This is due to the richness of animal liver in protein, fat, iron, copper and vitamins which are important for normal development in humans.

In a recent survey conducted among 1030 United Kingdom public members, 43% of the respondents indicated that they eat chicken livers (Jones *et al.,* 2016). The study also revealed that chicken liver dishes are eaten by people of ages ranging from 18 years and above. On the nutritional basis, beef heart and liver have been reported as important dietary sources of Coenzyme Q10 (vitamin) compared to muscle tissue (Ercan and El, 2011). In addition to this, the digestibility of coenzyme Q10 in beef heart and liver was significantly higher than the digestibility of coenzyme

Q10 in muscle tissue. Coenzymes Q10 are produced mainly in mitochondria, which show that liver and heart muscle contain higher mitochondria than other parts of muscle tissue.

It is well known that the liver is a vital edible organ that forms 1–2% of the live weight of cattle and is richer in minerals and vitamins compared to other muscular tissue (Li *et al.,* 2014). Beef liver was reported to contain about 3.5% to 7.8% lipid at wet basis (Chan, 1995; Enser *et al.,* 1998). In general, lipids from ruminant liver appear to contain more longer-chain polyunsaturated fatty acids (PUFA), stearic acid (l8:0) and less palmitic acid (16:0) than the ruminant muscle (Enser et al., 1998). The concentration of PUFA in the liver has been reported to be ten times higher than that of muscles from the same animals (Enser *et al.,* 1998). Seong *et al.* (2014) also found that the fat content of pork liver was comparable to those of the muscle tissues of cattle. Fats serve as building blocks of membranes and play a key regulatory role in numerous biological functions.

Liver protein contains essential functional features that are associated with different protein portions and with physiochemical conditions such as pH, ionic strength, and high level of water soluble protein (Zouari *et al.,* 2011; Steen *et al.,* 2016). However, sheep liver was reported to contain a higher value of di-unsaturated (C18:2) and tri-unsaturated (C18:3) fatty acid than *longissimusdorsi muscle* (Enser *et al.,* 1998). Similarly, there was lower saturated (C16:0, C16:1) fatty acid values in liver compared to longissimus dorsimuscle. Purchas and Busboom (1993) reported that beef liver contains relatively higher iron content than beef muscle. Iron is needed for proper functioning of blood in the human system and its deficiency can result in anaemia, especially in pregnant women and children (Miller, 2013). The liver has also been found to contain a moderate amount of taurine, carnosine, and creatine (Purchas and Busboom, 1993) compared to other muscle tissues.

Heart muscles have been reported to contain a large amount of threonine, leucine, lysine and tryptophan and other amino acids (Gaudy and Landis, 1973). The proximate composition and amino acid profile of gizzard were reported to be similar to that of chicken meat (Arafa, 1977). Gizzards from poultry can be processed to produce fermented sausage or served fried or eaten with other food ingredients. Chicken gizzard is high in protein (26%), ash (1.3%) and low in fat (0.9%) (Daniel, 2015). Bovine intestine is commonly used as sausages casings (Byun et al., 2001; Nakyingise *et al.,* 2012). Blood and viscera organs from goat have been reported to be rich in protein, fat and mineral content (phosphorus and iron) in a measure similar to those of goat muscle tissue (Madruga *et al.,* 2007). The tongue is also known to provide quality protein, vitamins and minerals which could be beneficial nutritionally (Ranken, 2000; Gonulalan *et al.,* 2004). It is rich in iron, zinc, choline and vitamin B_{12}, its utilisation showed that each portion of cooked cow tongue can boost iron content in the body system to provide about 28% and 12% of the daily iron intakes set for men and women, respectively (Tremblay, 2011). In this sense, beef, pork, sheep, goat and veal tongues can be processed by curing, boiling, smoking and seasoned with onion and other spices before consumption. Cow tongue is consumed as special delicacies in North America, Africa, Europe and Asia as a nutritional food source (Ranken, 2000). However, research on textural and organoleptic properties of the cooked cow tongue is still limited.

A study on bovine and pig testicles has shown that they are relatively rich in lipid, iron, protein and poly-unsaturated acids (Holman and Hofstetter, 1965). Pork testicles are reported to contain 10.5% protein, 2.9% fat and 1.3% carbohydrate (Pucciarelli *et al.,* 2012). The concentration of the heme iron in pork testicles (2 mg/100 g, uncooked weight) has been specified to be at least 2.5 times higher than that in pork loin which can provide 25% of the United States Department of Agriculture (USDA) daily recommended intake for adult males (Pucciarelli *et al.,* 2012). The testicles and penis from livestock are customarily eaten in many parts of the world as a means to enhance male strength, virility, and prowess (Rotenberg, 2008). In the United Kingdom and the United States, spleens are broadly consumed in processed foods while, in Sicily, it is used for making the sandwich “pani ca meusa”, or “bread with spleen” and caciocavallo cheese (Nollet and Toldra, 2012). However, consumers may sometimes prefer offal to meat due to its availability, nutritional value, price difference, cultural background and religious belief. With the fast growing population, the demand for offal is likely to increase in regards to individual perception. In this regard, further research on consumer perception on consumption of EBPs should be carried out. This will give a comprehensive representation on factors influencing offal demand.

2.4 Factors Influencing the Yield and Quality of Edible and Inedible Animal By-Products

2.4.1. Edible By-Products

The yield and quality of edible animal by-products depend on multiple interactive factors of genotype (breed), sex, animal species, production system (feedlot or pasture-based system), physiological and health condition of the animal, age, weight, post-mortem handling and processing (Florek *et al.*, 2012). Florek *et al.* (2012) reported that variation in weight of the by-products is due to differences in animal weight at slaughter, indicating that animal of the same breed and species with high body weight gain will produce more kilogrammes of by-products than those with low body weight. Florek *et al.* (2012) reported that veal from calves has higher fat, energy, ash, minerals (Zn and Ca), fatty acids and oxidative stability than the liver, tongue, heart and kidney from suckling calves. Hoffman *et al.* (2013) in their study also found a significant breed effect on the proximate composition of all the organs meat, with Merino sheep having higher fat content in liver, and tongue than Dorper sheep. However, Dorper brain, heart, kidney, spleen and testicles had higher protein contents than those of the Merino. It was also found that Dorper liver had higher levels of valine, tyrosine, isoleucine, phenylalanine and leucine than Merino liver. Li *et al.* (2014) reported higher significant differences in the protein, fat, carbohydrate, total energy, mineral, amino acids, polyunsaturated fatty acids and glycogen values of liver meat from Wagyu × Qinchuan cattle than from Qinchuan cattle raised on the same pasture.

Furthermore, Puschner *et al.* (2004) found that mineral content (copper) of calves varied according to age, sex and production system while the amount of copper in liver was higher in dairy calves than beef calves. In addition, copper concentration in the liver for both dairy and beef calves increased initially for the first 2 months of age and then declined until about 9–10 months of age when concentrations began to increase slightly. Zawacka *et al.* (2016) in their study showed that capons chicken had higher liver and gizzard weight and lower heart weight than cockerels. In addition, Zawacka *et al.* (2016) has shown that the sex of green-legged partridge cockerels and capons could influence weight variation, and this is similar to the result obtained by Abdelmageed *et al.* (2014) that the gizzard weight of male broiler chickens was heavier than those from female chickens. On the other hand, buffalo had heavier hearts, lungs, kidney fat and spleens and lighter livers compared to cattle liver, heart and spleen (Purchas and Busboom, 1993).

2.4.2 Effect of Thermal Processing and Preservation Methods on Quality of Edible By-Products

It is well known that EBPs are highly perishable and must be stored under refrigerated conditions to control microbiological growth and other deteriorative changes. Shortly after slaughter, the EBPs are washed with clean running water, hung on hooks for cooling and drip drying and then chilled to reach a core temperature less than 7 °C within 16 h to prevent any deterioration or spoilage by microorganisms. To a certain degree, EBPs can be chilled at 0–2 °C for 7 days without negative impact on their quality. However, at frozen temperatures of −12, −18 and −24 °C, liver meat shelf life could be extended to 4, 12 and 18 months, respectively (Meatupdate, 2002). These preservative mechanisms are employed to ensure that EBPs are safe for consumption by the end-users, although some authors have reported the presence of different microorganisms such as *Escherichia coli*, *Staphylococcus aureus*, *Clostridium perfringens* in EBPs from cattle, pig and sheep (Cohen *et al.,* 2006; Brasil *et al.,* 2014; Lee *et al.,* 2015). Moreover, this has been attributed to poor hygienic quality of the products due to their uncontrolled processing, storage, and handling.

Studies on the impact of packaging on the quality of edible offal during cold storage are still limited. Moreover, it is required that these products are processed, wrapped, boxed and frozen for shipment in order to preserve quality and increase marketability. Traditionally, EBPs are prepared and cooked by boiling, roasting, smoking, frying and microwaving before eaten. Cooking is carried out to destroy microbial contamination and improve the palatability and quality of the products. Among the cooking processes, boiling seems to be the most common practice with all different recipes. Contaminants such as Campylobacter have been implicated on both the inside tissues and the outer surfaces of fresh liver meat, especially in poultry and lamb liver (Jones *et al.,* 2016). To ensure that meat and other EBPs are safe for eating, an appropriate cooking temperature is needed to reduce the risk of food-borne infection. Destruction of cyst in meat could be achieved when the internal temperature of the meat reaches a temperature of 67 °C but uneven heating from microwave may not destroy the microorgnism completely (Kijlstra and Jongert, 2008). Recent work on cooked liver revealed that application of heat at 60 and 80° C did not significantly affect the fatty acid and mineral composition of the liver meat from cattle raised on pasture-based diets (Falowo *et al.,* 2017). Apart from this report, no other scientific studies seem to be available on the effect of heat treatment on quality of EBPs.

2.5 Edible Meat Waste Recovery.

Food processing industry have inherent capacity to reduce pollution and waste production with the aim of generating more profit, reducing overall cost of production, improved workers health and safety (Klemeš and Perry, 2007; Roupas *et al.*, 2007). A typical example is the recovery of edible meat waste for sausage production and this can improve the profitability of the industry. Processing of animal carcass at the abattoir involves the production of substantial amount of wastes. Once the carcasses are cut and sorted according to the market demand, abattoirs either discard the meat wastes or sell them to sausage makers (Roupas *et al.*, 2007). The meat wastes that are discarded are oftentimes not edible while the edible products could be recycled back into the food chain inform of sausage. The processing of sausage involves the addition of different food components that could enhance human well-being. Processed meat products is a natural portion of sausages that is associated with other components of the meal which adds to its dietary attributes and enhance digestibility (Louis-Sylvestre *et al.*, 2010). Addition of these components also provide functional properties that improve the structure, nutritional and health qualities of the finished products (Fernández- Ginés *et al.*, 2005).

In the processing of edible animal products any edible parts can be used and blended with lean meat to make good sausages. The blending of lean meat with offal (liver, kidney, heart) and other meat products (edible meat waste) can also provide a cheaper animal protein with better flavor. Many studies have been successfully carried out on sausages by replacing the beef with other meat such as goat meat, pork, chicken, fish and rabbit meat and this enhances the juiciness, textural properties and fat reduction which have a positive health implication (Aleson-Carbonell *et al.*, 2005; Asmaa *et al.*, 2015; Santana *et al.*, 2015; Malekian *et al.*, 2016; Xue *et al*., 2017).

Sausages making is a good example of processed meat and it came into existence from Europe, United Kingdom, and Asia during the rule of Roman Empire (Kearney, 2010). The utilisation of sausage has a long traditional history aimed at economic satisfaction as it spread across the globe. In Italy, fermented sausages are produced without microbial starter which produces distinct sensory profiles and organoleptic properties (Comi *et al.*, 2005). Hence, production of sausages has become the products of human creativity across the globe. Sausages are secondary products produced from comminuted meat, made with other food ingredients and encased in a distinct unit (Cunningham *et al.*, 2015). Ready-to-use ingredients such as antioxidants, dietary fibre, and Omega 3 fatty acid are reported to improve the nutritional properties of sausage (Fernández- Ginés *et al.*, 2005). Sausages may show general meat quality features and provide vital nutrients (proteins, fats, vitamins, and minerals) needed for human support and sustenance (Akhtar *et al.*, 2013).

Fresh sausages are always available at the butcheries, abattoir, and supermarkets in large quantities. This is in high demand among South Africans because it serves as an excellent source of nutrients required for human development and growth (Quasem *et al*., 2009; Gerber *et al.*, 2009). Sausages are under normal condition wrapped and filled inside its natural or synthetic casings. Natural casing is made from large and small animal intestine but sausage can also be available with no casing in the grounded form. The traditional use of natural casings dates back to 4000BC when abdominal part of the goat was first used (Peggy, 2017). Quality casings are prepared from submucosa layer of sheep, pigs, cattle, and sheep intestine and this improves the sensory and organoleptic properties of the sausage (Oster, 2011; Peggy, 2017). Since the advent of the quality natural casing, acceptance of sausages around the globe has increased due to its natural outlook. Natural casings came from the digestive tracts of sheep, hog, and cattle intestines with the dimension ranging from 17mm to 38 mm in diameter and 300mm length (Essien, 2003; Guillén *et al.,* 2011). These natural casings come in different length arranged or spooled in a container and preserved with salt. An artificial casing is produced from collagen, a derivative of animal protein, purified and isolated from hides and manufactured into an edible casing (Gómez Guillén *et al.*, 2011). Artificial casings are not from collagen alone, they are made from cellulose and plastic materials to stimulate the sense of taste (Essien, 2003). However, limited study has been done on replacement of edible meat waste as a constituent in sausage for cross examination under different cooking methods and evaluation of its nutritional and physiochemical properties.

2.6 Utilization of Inedible By-Products

IEBPs as stated earlier represent discards that are unsuitable for human consumption and rejected as wastes (blood and stomach contents) or reprocessed into secondary products (gelatine and keratin extraction, belts, footwear, and pharmaceuticals) as shown in Figure 1. Most inedible animal by-products consist of hides, hair, horns, teeth, blood, fats, bone, ligaments and cartilage, feet, manure, trimmings, rumen contents and glands (Figure 2). IEBPs can be further separated into parts such as elementary and secondary by-products (Sharma, 2013). Elementary by-products are by-products which are described as being collected after slaughter and include blood, bones, pancreas, intestine, hides and skins, hoofs and horns (Figure 2). Secondary by-products are by-products which are obtained as derivatives from elementary by-products; this may include products like, buttons, bone meal, insulin, cutlery handles, tennis strips, fat and gelatine. Hides from abattoir are often exported to different parts of the world such as South America, Asia, North America and Europe for reprocessing, and later converted to leather through the use of tanning agents for the production of secondary by-products like shoes, clothing, car seats, and many other items (DAFF. 2012).

Other IEBPs such as glands are vital for the development of most superior quality and accessible modern human medicines (Aberle *et al.,* 2001; Costa-Neto. 2005). It has been reported that glands and organs harvested from slaughtered animals such as adrenal, parathyroid, pituitary, thyroid, ovaries, pancreas and testes are responsible for many of the hormones and enzymes used in the medical field sustainability nowadays (Aberle *et al.,* 2001). Medicinal products that can be procured from animal glands are epinephrine, oestrogens, progesterone, insulin, trypsin, parathyroid hormone, adrenocorticotropic hormone (ACTH), somatotropin, thyroid stimulating hormone, testosterone and thyroxin (Marti *et al.,* 2012). Under-utilization of these by-products could lead to loss of potential incomes and result in the additional cumulative rate of discarded products.

Blood is a red fluid comprising a mixture of cellular and plasma fraction (red blood cells, white blood cells and platelets). It represents about 4% of animal live weight or 6–7% of the lean meat content of the carcass (Wismer-Pedersen, 1988; Bah, 2013). Blood is rich in iron, proteins and bioactive compounds which are suitable for human and livestock use (Davidson, 2014). Blood proteins are easily accessible, edible and available in different forms, mainly as a liquid, frozen and dried. In the food industry, blood is used as binding agents, colour enhancers, emulsifiers, fat replacers and meat curing agents (Hseih and Ofori, 2011; Toldra *et al.,* 2012). Plasma product (spray dried plasma) has been well integrated into food industry due to its foaming and leavening properties (Hseih and Ofori, 2011). Besides, many cultures also consume blood as food or in combination with meat and other ingredients such as in blood sausage, black puddings and pancakes (Davidson, 2014). In feed industry, blood is used in the production of blood meal for feeding livestock and pets (Toldra *et al.,* 2012; Bah *et al.,* 2016). In medicine, blood is usually processed and used as a medium for the growth of probiotic bacteria (bovine plasma), the raw material for pharmaceutical porphyrin derivative production, a precursor to thrombin production and purification, the active ingredient in topical surgical hemostatic applications, and a reagent for routine blood clotting in serology laboratories (Bah *et al.,* 2013). When blood is collected from any animal, it is compulsory that such animal should be free from disease before the blood can be consumed or processed into food. However, blood or blood-related products are prohibited by a certain group of people who avoid blood-tainted foods due to religious, ethical, traditional and/or health reasons (Hseih and Ofori, 2011).

Animal horns contain keratin for the production of trophies, decorative objects, musical instruments and drinking vessels. The hooves and horns of animals have an abundant quantity of keratin, a protein used as hair care products. Likewise, collagen, gelatine and glue can be extracted from bone, hoof and horn. The extracted gelatine can be used for the treatment of digestive problems, ulcer, muscular disorders and nails growth (Irshad and Sharma, 2015). Meat and bone meal (MBM) in animal diet remains a protein source because of its available essential amino acids, minerals and vitamins. On the other hand, the use of MBM became restricted in countries that experienced mad cow disease epidemics due to health concerns (Moller, 2015). Like any other gland, bile is extracted either in liquid or dry form. Bile extracts contain proteins, prednisone, cortisone, acids and pigments that are important for medicinal and pharmaceutical purposes such as the treatment of constipation and indigestion (Jayathilakan *et al.,* 2012).

In the poultry industry, feathers are epidermal growths that form the outer covering on poultry animals. Feathers are commonly used to stuff mattresses, pillows, dusters and in the manufacturing of automobiles accessories. They are among the most complex integumentary structures that produce keratin proteins in vertebrates. "Keratins are insoluble proteins (scleroproteins) which are resistant to physical, chemical and biological actions due to the resistance of proteolytic degradation" (Deivasigamani and Alagappan, 2008). Thus, keratinase-producing microorganisms have been reported to degrade feathers into usable poultry feed and can be utilised for biogas production (Deivasigamani and Alagappan, 2008). More so, application of high-pressure heat and steam has been shown to hydrolyze feathers into usable cysteine-rich, high protein product which has 60% digestibility (Dios, 2001). These degraded feathers can be used to produce fertiliser because of its high protein and nitrogen content (Davidson, 2009). Furthermore, chicken feathers can be used for the production of strong thermoplastic products (such as polyethylene nylon, polyvinyl chloride and polystyrene) when processed with chemicals such as methyl acrylate (Sharma and Gupta, 2016).

2.7. Industrial Usage of IEBPs

2.7.1 Biogas Industry

Abattoirs generate an enormous quantity of waste products in the form of solid and liquid wastes which are responsible for severe environmental degradation if not well handled (Cuadros *et al.*, 2011). The usage of abattoir wastes as secondary fuel through thermal recycling in power plants has been reported to be achievable (Arvanitoyannis and Ladas, 2008). In spite of this, cattle manure, poultry litter and pig waste are also important for biogas and electric power production (Ur Rahman *et al.,* 2014) while solid waste generated from abattoirs and meat processing is used as fuel in the cyclonic combustor (Virmond *et al.,* 2011).

2.7.2 Cosmetic and Fabric Industry

After the removal of hides and skin from slaughtered animal in the abattoir, it is necessary to cure the skin to prevent microbial and enzymatic decomposition (Ur Rahman *et al.,* 2014). The by-product such as hide and skin provides raw materials for industrial processing and export in many countries around the world. Common products from hides and skin are cosmetics, shoes, belts, car seats, bags, keratin and gelatine (Benjakul *et al.*, 2009).

2.7.3 Pharmaceutical Industry

Chemical and biochemical extracts present in animal glands and organs which are contained as a portion in the syntheses of enzymes, hormones, pigments and vitamins are desirable and excellent products in the pharmaceutical, food and cosmetic industries (Irshad and Sharma, 2015). Some preliminary research suggests that the use of these extracts may be helpful in treating various medical conditions such as hepatitis, building healthy red blood cells, treating chronic liver diseases, preventing liver damage, regenerating liver tissue, and treating certain cancers and other viral infections (Liu,2002; Jayathilakan *et al.*, 2012). The liver extract contains vitamins and minerals such as calcium, copper, phosphorus and iron sold in either powdered or tablet form. Heparin extracted from the lungs and small intestine is a prescribed anticoagulant drug (Table 1) used to prevent blood clotting during surgery and in organ transplants (Jayathilakan *et al.*, 2012).The adrenal gland is for the production of steroid drugs, insulin from pancreas helps to treat diabetic patients while glucagon is important to treat overdose or low sugar (Jayathilakan *et al.*, 2012).

Table 1: Common uses of animal by-products.

Animal By-Products	**Reprocessed Products**	**Major Uses**	**References**
Hides and Skin	Cured hides & skin. Leather & Textiles	Leather clothes, belts, car and household upholsteries, bags, footwear, drums, luggage, wallets, sports goods, gelatine etc	Irshad & Sharma. 2015, Jayathilakan *et al.*, 2012, Ur Rahman *et al.*, 2012, Tesfaye *et al.*, 2015, Hekal. 2014 DAFF. 2011
Hoof and horns	Hoof & horn meal. Gelatin and keratin extraction	Combs, buttons, plates, souvenirs, Fertilizer, Collagen, glue, gelled food products, foaming in fire extinguishers	Jayathilakan *et al.*, 2012, Omole & Ogbiye. 2013 Karthikeyan *et al.*, 2007
Bone	Extraction of collagen. Bone meal	Cutlery handles, Shortening, bone gelatine, bone meal, Collagen	Irshad & Sharma. 2015, Ur Rahman *et al.*, 2012, Gue. 1998, Nhari *et al.*, 2012
Blood	Pharmaceutical products Blood meal	Catgut, tennis strips, blood sausages or pudding, fertilisers, animal feeds, emulsifier and stabilizer	Irshad & Sharma. 2015, Ur Rahman *et al.*, 2012 DAFF. 2011, QMS.2010, Hyun &Shin. 2000, Bah *et al.*, 2013
Intestine	Sausage casings Surgical sutures Musical instruments	Sports guts, musical strings, prosthetic materials, collagen sheets, burn dressing, strings for musical instruments, sausage casings, human food, pet food, meat meal, tallow, casings	Irshad & Sharma. 2015, QMS.2010, Marti, *et al.*, 2012, Toldrá *et al.*, 2012 Bhaskar *et al.*, 2007

Organs & Glands	Pharmaceuticals Medicinal Xenotransplantation	Heart stimulant, heparin, corticotrophins, enzymes, steroids, oestrogen, progesterone, insulin, trypsin, parathyroid hormone	Irshad & Sharma. 2015, Ur Rahman *et al.*, 2012, Marti, *et al.*, 2012, Aberle *et al.*, 2001, Jayathilakan *et al.*, 2012, Deveau *et al.*, 2004
Hair/Wool	Textiles Extraction of keratin	Cloths or woven fabrics, mattress, keratin, carpets, knitted apparels insulators	Scobie, *et al.*, 2015, Patrucco *et al.*, 2016, Phua *et al.*, 2015, Liu *et al.*, 2013

2.8 Utilization of Blood and Dried Rumen Digesta as Feed Ingredient

Rumen contents, which are commonly known as "digesta", are considered as waste, but when re-processed or utilised, can become a product of high significance and economic value for the livestock industry (Amata, 2014). The recovery of rumen digesta from ruminant animals in abattoirs offers a great opportunity as an alternate source of nutrients to complement the prevailing limited feed resources (Lead *et al.*, 2005; Amata, 2014). However, many studies do not encourage rumen digesta to be fed alone to livestock but rather to be supplemented with other feed ingredients at a recommended rate during feed formulation (Togun *et al.*, 2010; Mondal *et al.*, 2013; Elfaki *et al.*, 2014; Osman *et al.*, 2015). The chemical composition of dried rumen digesta, blood meal and their mixture has drawn the interest of nutritionists to use them as cheaper feedstuff formulation (Togun *et al.*, 2010; Mondal *et al.*, 2013; Elfaki *et al.*, 2014; Osman *et al.*, 2015). On the other hand, rumen content and blood are environmentally unfavourable to life, causing air pollution, ground water pollution and eutrophication if not handled properly. Conversion of these IEBPs into livestock feed can enhance the flexibility of feed formulation and lessen environmental pollution (Orskov, 2007). It was pointed out that the use of dried rumen digesta as feed ingredients has no harmful effect on growth performance of the animals (Yitbarek *et al.,* 2016) A mixture of blood and rumen content is a good source of feed ingredients in poultry ration, catfish ration, quail ration, lamb ration and cattle ration, which are significant with no adverse effects on animals (Dairo and Aina, 2000; Adeniji and Balogun, 2001; 2002, Cherdthong *et al.*, 2014; Mishra *et al.,* 2015; Osman *et al.,* 2015). When a suitable processing method is adopted, it reduces the amount of microorganisms present in the dried rumen digesta and reduces environmental pollution to a minimum level (Makinde and Sonaiya, 2007; Agbabiaka *et al.,* 2012; Cherdthong *et al.*, 2014).

2.9 Nutritional Benefits of Feeding Rumen Content to Livestock

Rumen digesta are usually processed by applying light heat or sun-drying before utilisation in feed formulation. The mixing of dry rumen digesta (DRD) with dried blood can improve the protein content of the ration when used as feed ingredients. The availability of amino acid contents and other compounds retained after processing depends on the intensity of heat applied on the rumen digesta (Makinde and Sonaiya, 2007). Dry rumen digesta have been administered as feedstuff at varying levels, on different animal species (Table 2). Most of the studies conducted in the evaluation of DRD on the performance of livestock were carried out in Central Africa (Cameroon), North Africa (Egypt and Sudan) East Africa (Ethiopia), West Africa (Nigeria), Asia Middle East (Saudi Arabia), South East Asia (Thailand) and South Asia (India). Dried rumen digesta may vary in their proximate composition because of the different chemical composition of preferred pastures consumed by different animal species (Togun *et al.,* 2010). The dry matter (DM) of dried rumen digesta ranges from 13.36 to 98.4%, crude protein (CP) 11.38 to 19.6% and crude fibre (CF) 15.3

to 41.84% (Table 2). In view of this, DRD was mixed with other feedstuffs to give value addition, increase palatability and enhance better efficiency (Wilson, 1992).

Table 2: Chemical composition of cattle dried rumen contents from different countries.

Country	Animal Type	DM	CP	EE	CF	ASH	NFE	NDF	ADF	Ca	P	References
		%										
Cameroon	Broiler	92.44	15.21	7.81	41.84	9.25	-	-		-	-	Colette *et al.*, 2013
Egypt	Duck	91.3	18.53	7.81	28.28	9.25	35.97	-	-	0.7	0.69	Said *et al.*, 2015
India A	Quail	92.64	18.26	3.6	24.99	14.47	-	-	-	-	-	Mishra *et al.*, 2015
India B	Goat	90.25	12.8	-	-	-	-	78.7	54.5	-	-	Mondal *et al.*, 2013
Nigeria A	Rabbit	91.81	11.38	6.1	24	8.11	42.21	-	-	-	-	Togun *et al.*, 2010
Nigeria B	Broiler	81.8	18.52	8.79	15.3	7.6	38.39	-	-	-	-	Uchegbu *et al.*, 2006
Saudi Arabia	Lamb	13.36	14.2	1.7	-	11.6	-	59.2	36.7	-	-	Abouheif *et al.*, 1999

DM= dry matter, EE=ether extract, CF= crude fiber, CP= crude protein, NFE= nitrogen free extract energy, Ca= calcium, P= phosphorus, NDF= neutral detergent fiber, ADF= acid detergent fiber.

2.9.1 Broilers and Layers

Esonu *et al.* (2011) in their study reported that broiler birds fed a diet containing dried bovine blood and rumen digesta mixture at varying levels of 0, 5%, 10%, 15% and 20% generally had better feed intake, body weight gain, organ weight and nutrient utilization values compared to the control group. Similarly, Makinde and Sonaiya (2008) observed that broiler chickens fed sun-dried rumen and content blood meal at 5%, 10% and 15% levels had higher carcass yields and lower feed cost per unit weight gain than the control group. Uchegbu *et al.* (2006) highlighted that feed intake and weight gain of the broilers fed with dried rumen digesta increased, due to increase in high fibre and crude protein content of the diet which stimulated the birds to eat more to meet up with their energy requirement for swift growth and development. Therefore, Uchegbu *et al.* (2006) also concluded in their study that the use of DRD as supplements in the diets of broiler provides cheaper cost of feed per kilogramme of meat produced and this idea is practical as an alternate source of feed in economic terms. Colette *et al.* (2013) in their study found that the diet with 5% DRD inclusion and a mixture of castor oil seed cake with DRD at 25% inclusion level significantly influence the juiciness and consumer preference of broiler meat compared to the control group. As a result of this, the meat quality indicator of broilers fed with DRD is preferable to that of the broilers in the control diet, however, birds that were fed castor oil seed cake at 15% inclusion in the diet performed better. However, the colour, tenderness, juiciness, flavour and acceptability of the carcass quality of the boilers fed with DRD with or without enzyme inclusion were not different from each other (Elfaki *et al.*, 2014). Furthermore, when dry rumen digesta was supplemented with other feed ingredients in broiler diets, there were no side effect on the performance and biochemical quality of plasma in broiler chicks (Abouheif *et al.*, 1999).

In a similar study by Makinde and Sonaiya. (2007) where chemical composition of dried rumen content with blood meal and its effect on broiler performance were undertaken, the results showed that birds fed with dried rumen content with blood meal at 0, 5%, and 10% had higher feed intake than birds fed with 15% rumen content with blood meal. For this reason, the performance of the broilers revealed that the final body weight, feed conversion ratio, and daily weight gain were higher at 10% inclusion level. As a result of this, the feed cost per unit weight gain was cheaper for all rumen content with blood meal while mortality was not influenced.

Furthermore, Gebrehawariat *et al.* (2016) reported that layers that were fed with diets containing dried rumen digesta had better performance in terms of increase in egg weight, improved yolk colour and better chick quality performance, while the blood performance of the chicken layers was within the normal range. However, the body weight gain is not in agreement with Onu *et al.* (2011) who reported an overall increase in the growth rate as DRD inclusion increases.

2.9.2 Sheep

In recent years, Osman *et al.* (2015) reported a consistent increase in feed intake and feed conversion efficiency in sheep as the inclusion level of DRD in the diet increases. In this regard, sheep fed with 10% DRD had the highest weight gain, while weight gain was the lowest in the animals fed with no dried rumen content. The final body weights were 30.27, 31.25 and 31.75 in animals fed 0, 5% and 10% DRD, respectively, but there were no significant differences between the weights.

2.9.3 Cattle

Cherdthong *et al.* (2014) also found that the replacement of soya bean meal with 100% dried rumen digesta (DRD) as feed ingredients in cattle ration helped to enhance the intake of rice straw compared to other diets.

2.9.4 Lamb

Abouheif *et al.* (1999) in their study reported no significant difference in the growth performance, hot carcass weight and dressing percentage of lambs fed with a dietary mixture of rumen contents and barley mixture at ratio 4:1 compared to the control group.

2.9.5 Quail

Mishra *et al. (*2015) also reported that the inclusion of solar dried blood and the ruminal digesta at varying levels of 0, 5%, 10%, 15%, 20%, 25% and 30% to replace soybean meal in Japanese quail diets resulted in higher weight gains compared to the control group.

2.9.6 Rabbit

The replacement of maize with DRD at 0, 12.5%, 25% levels in rabbit diet resulted in no significant difference in the haematological parameters when compared to the control, indicating that the DRD diet was able to supply the required nutrition to maintain the normal blood parameters and health status of the experimental animals (Oluwafemi and Iliyasu, 2016) A similar study was conducted by Mohammed *et al.* (2011) where rabbits were fed a mixture of bovine blood and rumen content at different inclusion levels. It was reported that there was no significant difference in the daily weight gain of the rabbits, but an increase in daily feed intake was observed among the treatments.

2.9.7. Goat

In a study conducted by Abbator *et al.* (2016) where rumen digesta was supplemented with wheat offal at varying levels in goat diets, the results revealed that all the goats had higher dry matter intake due to the palatability of the diets. However, goats that were placed on the 25% of dried rumen digesta with 75% wheat offal had the highest daily weight gain due to better feed conversion ratio, low inclusion level of DRD and high metabolizable energy. This is in agreement with Khattab *et al* (1996) who reported earlier that the inclusion of DRD in the diets of ruminants had no negative effect on the palatability.

In addition, the safety of DRD in animal feed was assessed and the pathogenic potential of rumen contents was also determined. Mondal *et al.* (2013) revealed that rumen bacteria are non-pathogenic due to the lack of the enterotoxin gene and thus will not be harmful if fed to animals. In view of this, when *E. coli* were counted in post-dumped rumen content, there was an initial increase in the number of *E. coli* which decreased subsequently, but *Staphylococcus aureus* increased in number, although the microbial load was within the recommended level. For this reason, Mondal *et al.* (2013) concluded that rumen bacteria are non-pathogenic due to the lack of the enterotoxin gene, and thus will not be harmful if fed to animals.

2.10 Concerns Associated with the Use of Inedible By-Products

Production of animal feed through recycling of animal waste to ease cost of feed has been in operation for over forty years (Bhattacharya and Taylor 1975; Sapkota *et al.,* 2007). Initially, rendering of animal carcases was a routine practice in Europe and other countries before the outbreak of Bovine Spongiform Encephalopathy (BSE) in 1988 (Onodera and Kim, 2006). Bovine Spongiform Encephalopathy is an affiliate of the Transmissible Spongiform Encephalopathy (TSE), known as neurodegenerative disorders. The general point of BSE infection is through the ingestion of feed contaminated with animal protein infected by a prion agent. A prion is an infectious protein that modifies normal cellular proteins into a pathogenic form that impairs the central nervous system of animals (Dormont, 2002; Doyle, 2002). Prions are impervious to processes that disintegrate nucleic acid and are responsible for the acquired form of neurodegenerative disease (Zafar *et al.,* 2011). Typically, prions are often found in most vulnerable parts of the central nervous system (brain and spinal cord) and bone marrow (Glatzel and Aguzzi., 2000; Kaatz *et al.,* 2012). In cattle, the symptoms of BSE are: change in temperament, aggression, lack of coordination, reduced milk yield and loss of appetite. In this regard, many studies have reported that contaminated animal tissues serve as the prion carriers (Collinge, 2001; Hill and Collinge, 2003; Houston *et al.,* 2003; Collinge, 2005; Mathiason, 2015). For this reason, specified risk materials such as the brain, nerves attached to the brain and spinal cord are removed and separated from meat during processing in the abattoir in order to prevent the spread of BSE disease to animals and humans (Momcilovic. and Rasooly., 2000). Furthermore in 2005, the Food and Drug Administration (FDA) agency proposed that the use of brains and spinal cords from cattle older than 30 months of age or cattle of any age not inspected and passed for human consumption should be prohibited in the food or feed of all animals (United States Department of Health and Human Services, 2008) This strategy has been successful in controlling the spread of BSE, and allows utilization of other inedible by-products, especially rumen digesta in animal feed. In fact, it is yet to be well established that either processed or unprocessed rumen digesta contains prions that can aid the spread of BSE.

2.10.1 Heavy Metal Accumulation with the Use of Rumen Digesta

The concentration of toxic metals in dried rumen content depends on exposure of forage crops eaten by the animals, soil content, human and natural activities. Unlike lead (Pb), cadmium (Cd) is readily absorbed and circulated evenly in plant tissues (Arduini et al., 2004). Certain plants species have the ability to absorb heavy metals within their tissues and this may heighten the risk of contamination of the food chain (Mantovi *et al.,* 2003). Due to consumption of these contaminated pastures by ruminants, deposition of toxic metals in meat, tissues and organs may occur. Meats from animals raised on pastures close to mining areas have been reported to contain more heavy metals due to natural activity (Taggart *et al.,* 2011). After the digestion of the contaminated forage in the animal, toxic metals are also excreted in their faeces (Kim and Schrenk, 2012). The presence of heavy metals in the animal manure gives an idea that the forage or pasture consumed by the animal contains a certain level of these toxic metals (Nicholson *et al.,* 1999). For this reason, grazing and browsing animals are more exposed to toxic metals compared to other livestock and this may be residual in the rumen content (Kim and Schrenk, 2012). Typically, about 90% of toxic metals are transferred through food consumption as a major pathway for human vulnerability (Loutfy *et al.*, 2006; Demirezen and Uruç, 2006). For this reason, the potential for accumulation of heavy metals in the undigested rumen content should be investigated to determine its sustainability in food chain.

2.11 Conclusions and Future Perspectives

It is well known that EBPs and IEBPs have been fully explored in many industries for their benefits. Findings from this study have revealed that EBPs contain nutrients of high nutritional values and can be efficiently utilized as alternative protein sources to reduce the menace of malnutrition and food insecurity across the world. While the addition of IEBPs such as dried rumen content in livestock diet can be used as alternative feed ingredients to lessen prevailing cost and scarcity of feed materials which have high competition between animals and humans. If properly processed in livestock diets, dried rumen content can suitably fill the gap of non-conventional feed sources. Therefore, it could be better explained that most animal by-products are globally used adequately for humans, pets or animals except for rumen contents which has a great opportunity for better uses than the current practices. However, the limitation of DRD may be linked to the possibility of accumulation of heavy metals in the undigested rumen content that may be recycled into the animal feed. Consequently, residual toxic metals may be present in meats and especially offal, which are later consumed by humans. Toxic metal contamination in food has been held responsible for related problems in humans such as amnesia in adults, stunted growth in infants, reproductive problems, high blood pressure, nervous disorders, oligospermia in males, and abortion in females. Therefore, further investigation should be conducted on the presence of toxic metals in DRD and in meats from animals that have been fed with diets containing DRD.

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CHAPTER THREE

CONSUMERS' PERCEPTION ON OFFAL MEAT QUALITY AND ATTRIBUTES INFLUENCINT ITS' CONSUMPTION IN AMATHOLEDISTRICT

(This section has been published under Sustainability Journal)

Abstract

This study was conducted to determine the consumers' perceptions and factors influencing offal meat consumption in Amathole District in the Eastern Cape Province of South Africa. A total of 202 consumers from Amathole District were randomly sampled from three municipalities (Mbhashe, Raymond Mhlaba, and Ngqushwa Municipalities) through exponential non-discriminative snowball sampling. Data were gathered through a structured questionnaire which comprised of open ended and closed ended questions. Correlation analysis was carried out to establish the relationships between offal meat attributes and demography. The results showed that there was a significant association at p-value 0.026, p- value 0.012, p-value 0.020 and p- value 0.031 but, a positive correlation between gender and colour, packaging, tenderness and juiciness of the offal meat products. The association between the education of the respondents and their perception about smell of the offal was significant at p-value 0.025 but with weak negative correlation. On the other hand, the level of education was significant at p-value 0.018 with a positive correlation with visual display at the point of purchase. The results of the study also showed that, consumers were more influenced by the freshness, price and availability of the product and these factors determined the point of purchase. The most preferred purchase point for offal meat in this study was the butchery. Consequently, promotion of offal meat products in the municipality have the tendency to improve food security at grass root as a results of its nutritional value, availability and price.

Keywords: offal, consumers, perception, consumption, meat quality

3.1 Background of the study

A study done by Irshad and Shama, (2015) shows that demand for offal meat has progressively declined due to concerns about health and economic returns. For instance, consumption of offal has extensively reduced in Western Europe, in the past years due to the outbreak of ‘‘mad cow” disease, commonly referred to as bovine spongiform encephalopathy (BSE). Consequently, this led to purchasing of offal to decrease in regions that were affected with BSE because of the undesirable brand image of the by-product leading to offals being turned into pet foods product (Selmane *et al.,* 2008). Thus, offal meat’s reputation as a food constituent has been driven by changes in consumers’ attitudes and related alarms like BSE (Grunert, 2006).

Today offal meat remains an excellent source of protein for several people across the continent, though meat carcass largely preferred. Offal meat is suitable for consumption due to the essential nutrients that it contains. Offal meat consists of tripe (stomach), spleen, heart, tongue, lungs, kidney, liver, heart and intestine. Generally, offal meat yield has been reported to contain 12% live weight of large ruminants (Awana *et al.,* 2015). In many countries around the globe, various part of offal meat are now considered as delicacies used as basic traditional dishes. However, in other regions of the continents their consumption may be associated with low income earners. In fact, Awana *et al.* (2015) reported that consumption of offal meat is commonly identified by low income house holders.

Offal meat is usually sold at a cheaper price, despite the fact that, it is highly valued as a delicacy in many countries due to its high protein and mineral contents (Kurt and Zorba, 2007; Hoffman *et al.,* 2013; Van Heerden and Morey, 2014). In this view, offal meat is frequently used in a low cost way in pastries (for example steak pie, steak and kidney pie) to get high- quality protein and nutrition. Offal meat has been incorporated as constituents of traditional diets in many countries.

In South Africa for example, abattoir managers would prefer that an animal produce twice or more offals than what they get presently. This is due to the increase in demand for offal consumption and the inability to meet up with such demand. Presently, meat and offal meat is a vital piece in human diet as a result of the nutritional benefits obtained from these products (Fayemi and Muchenje, 2013). The nutritional benefits enjoyed by the society cannot be over emphasized. Reason being, recent studies highlight that meat and offal meat has proven to be an excellent source of protein, fats, vitamins, and minerals that resourcefully enhance outstanding performance in human body systems (Xazela *et al.,* 2017).

Perception is the process by which consumers select, organize, and interpret information for immediate decision making (Novak, 2011). It is well understood that consumers usually form their feelings about expected quality for meat while at the point of purchase (Acebrón and Dopico, 2000). This is directly related to quality cue which is defined as informational stimuli accessible by consumer prior to purchase (Steenkamp and van Trijp, 1996; Bernués *et al.,* 2003). Quality cues are a prerequisite required for consumers to evaluate displayed products and make final decision at the point of purchase (Hoffmann, 2000). Consumers therefore, end up making interpretations centred on cues they have confident on, such as colour of meat, packaging, freshness and visible fat content, even when they were aware of the fact that these physical appearance may not always be predictive of taste and tenderness (Grunert, 2005).

Consumers' expectations on the quality cues can be divided into extrinsic or intrinsic cues with clearly outlined features. Intrinsic cues are measured objectively as part of the physiological features (such as: freshness, colour, visible fat, shape, marbling and cut of the meat) of a product that cannot be altered without changing the products itself (Olson & Jacoby, 1972; Olson, 1977; Krystallis and Arvanitoyannis, 2006). This means that, consumers are able to evaluate meat attributes such as appearance, marbling, colour, shape, size and freshness during shopping period (de Carlos *et al.*, 2005). Whereas, other attributes such as taste, tenderness and juiciness are experienced following meat preparation and consumption of the product (Bredahl, 2004). Conversely, extrinsic cues are features that are associated with the products but are indirectly not associated with the physical part of the product (Olson, 1977; Acebrón and Dopico, 2000). The examples of the extrinsic cues are outlet type, price, presentation, promotion, brand name and packaging (Bredahl, 2004).

Several studies have been conducted on the perceptions of consumers on meat quality, factors associated with perceived beef quality, consumer perception and their role in meat industry, consumer perception of fresh meat quality and perception of consumers' on the quality of the meat (Becker *et al.,* 2000; Mannio *et al.,* 2000; Rani *et al*., 2013; Troy and Kerry, 2010; Xazela *et al.*, 2017). However, it should be noted that all the foregoing studies did not consider offal meat. One of the reasons may be attributed to the difficulty in getting precise data for offal production and consumption. It is important to note that the perception cues on beef cuts and offal meat may vary with regards to many factors. Factors such as, educational background, household size, income and age may technically influence offal meat consumption come into play. Undoubtedly, to attain and sustain a good status and to satisfy consumers' expectations, it is important that cues influencing offal meat demands are considered. Thus, it is imperative to take the account of offal meat in meat perception study. Therefore, this study was aimed to examine consumers' perceptions and factors influencing its demand in Amathole District in the Eastern Cape Province, South Africa.

3.2 Materials and methods

3.2.1 Study site

The Amathole District Municipality is a Category C municipality situated in the central part of the Eastern Cape. It spans along the Sunshine Coast from the Fish River Mouth and alongside the Eastern Seaboard along South of Hole in the Wall along the Wild Coast. It is bordered to the north by the Amathole Mountain Range. Amathole District Municipality comprises of six local municipalities: Mbhashe, Mnquma, Great Kei, Amahlathi, Ngqushwa and Raymond Mhlaba.

The study was conducted in three different municipalities in the Amathole District of Eastern Cape Province of South Africa using exponential non-discriminative snowball sampling. The chosen municipalities were Mbhashe Municipality (Butterworth with coordinate: latitude -32°19'50.99"S longitude 28° 08' 59.32" E and Kentani: latitude 32º30'23.58" S, longitude 28º19'1.1" E), Raymond Mhlaba Municipality (Alice with coordinate: latitude -32°47'14.96", longitude 26° 50' 3.84" E and Fort Beaufort: latitude -32°46'29.17"S, longitude 26° 38' 1.54" E) and Ngqushwa Municipality (Peddie with coordinate: latitude 33º11'41.6" S, longitude 27º06'52.95" E and Hamburg: latitude 33º11'41.6" S and longitude 27º06'52.95" E). Thus, these 3 municipalities are where the consumers and meat traders who were the participants of the study were selected and interviewed with the aid of structured questionnaire.

Figure 1: Map of Amathole District

https://municipalities.co.za/map/102/amathole-district-municipality

3.2.2 Ethical Consideration

Ethical principles were considered in this study to conform to the South African national standards governing research of this type. Before the field interview was conducted permission was obtained and was approved by the University of Fort Hare's Research Ethics Committee (UREC) with certificate reference number MUC341SBAB01 (Appendix 3.1).

3.2.3 Selection of the respondents

The municipalities were randomly sampled to eliminate any bias through non discriminative snowball sampling. A total of 202 consumers from Amathole Districts in Eastern Cape Province from three randomly selected municipalities (Mbhashe, Raymond Mhlaba, and Ngqushwa Municipalities) were sampled from a total of six towns in the municipalities. Consumers were randomly selected and interviewed in their shops, schools, butcheries, parks, garages and those that were close to the shopping areas. Consumers who were purchasing offal meat such as liver, tripe, tongues and heart from the retail shops and butcheries in the commercial areas were randomly interviewed. The key quality indicators such as colour of offal, packaging, fatness, freshness, visual display, consumption pattern (flavour, tenderness, juiciness) which point toward the acceptability and preferred offal meat were included in the interview.

3.2.4 Data collection

The data used in the present study was obtained from 202 respondents. Data were gathered by means of individual interviews using consistent structured questionnaires. Prior to data collection a group of trained interpreters that could effectively communicate to the respondents in vernacular (Xhosa) and English languages were recruited to administer the questionnaires. Consumers were chosen through exponential non-discriminative snowball sampling and cross-examined at different points such as: point of purchase, shops, schools, butcheries, parks, garages, and door to door visits were carried out along with those that were close to the shopping areas. During data collection, those consumers that did not have interest in being interviewed were left not forced to participate in the study. In addition, supervisor or managers were interviewed with the aid of structured questionnaire in their respective shops. The key quality indicators which point toward the acceptability of meat offal were included in the interview and these were colour of offal, packaging, fatness, freshness, visual display, smell, flavour, tenderness and juiciness. The amount of time taken to interview each respondent in native language was 10 minutes while those interviewed in English took approximately 5 minutes. Patterns similar from recent studies on individual contributing factor on offal meat preference based on their demographic characteristics (Russell and Cox, 2004; Verbeke & Vackier, 2004) were used. Information on demographic characteristics such as, gender, age and family size were included (Table 1) while educational status and monthly income of the respondents were presented in Figure 3 and 4 respectively. The consumers also answered questions pertaining to offal meat demanded in the last three months, preferred offal meat and preferred purchase point (butcher, supermarket, others) and this was conducted in line with a study by Verbeke *et al.* (2000). With respect to approach, consumers were asked to indicate which factors influenced their demand for offal meat, precisely for purpose of nutritional value, health reason, cheapness (price) and availability (Grunert *et al.,* 2004). The questionnaire further included eleven attributes on 5-point likert scale to measure consumer awareness of the offal meat quality attributes by visual assessment (colour of offal, packaging, fatness, freshness, visual display) and consumption pattern (flavour, tenderness, juiciness) but were all measured on descriptive scale.

3.2.5 Statistical analyses

Data generated was entered in Microsoft excel programme and were summarized as frequencies of respondent profiles on consumers perception. Descriptive statistics was used to determine associations between age, income, educational status as factors (flavour, packaging, visual display, colour, smell, price, freshness and juiciness) influencing offal consumption using SPSS version 20 for the analysis. Chi-square statistics were used to test the association between variables at 95% confidence interval. Thus, $P<0.05$ was considered as statistically significant.

3.3. Results and Discussion

3.3.1. Consumer demography and attributes.

The distribution of respondents showing their observed occurrence with respect to their municipalities is shown in Figure 2. It can be deduced from Figure 2 that, Raymond Mhlaba had the maximum number of respondents (49%) this was followed by Mnquuma with (34%) and the least was Nqusha (19%). The results of the study showed that out of a total number of 202 respondents who were interviewed, the majority of the respondents were females and comprised of 53.3% while males represented 46.5% of the research sample. The results of the study showed that most of the respondents preferred sheep offal (83%) as compared to cattle offal (33%) though, the percentage of those who preferred the sheep and cattle offal (86%) was the highest (Table 1). The emerging results were in agreement with Walsh (2013) who reported that, the distribution of sheep offal is in more demand than for cattle offal. Furthermore, it was observed that most of the respondents had formal education. However, the finding of the study showed that 4.5% of the respondents had the lowest form of education and had stopped at elementary grade. Meanwhile, 46% had gone through matriculation and 27.2% possessed at least undergraduate degree respectively (Figure 3). The majority of the respondents were either working within the governmental departments, private sector or owned their personal business earning between R500 to more than R10,000 on monthly basis. In Figure 4, the most prevailing earned income among the respondents was R501-R2,000 (56.4%) while the least income were R8,001-R10,000 (2%) and R6,001-R8,000 (2%)respectively.

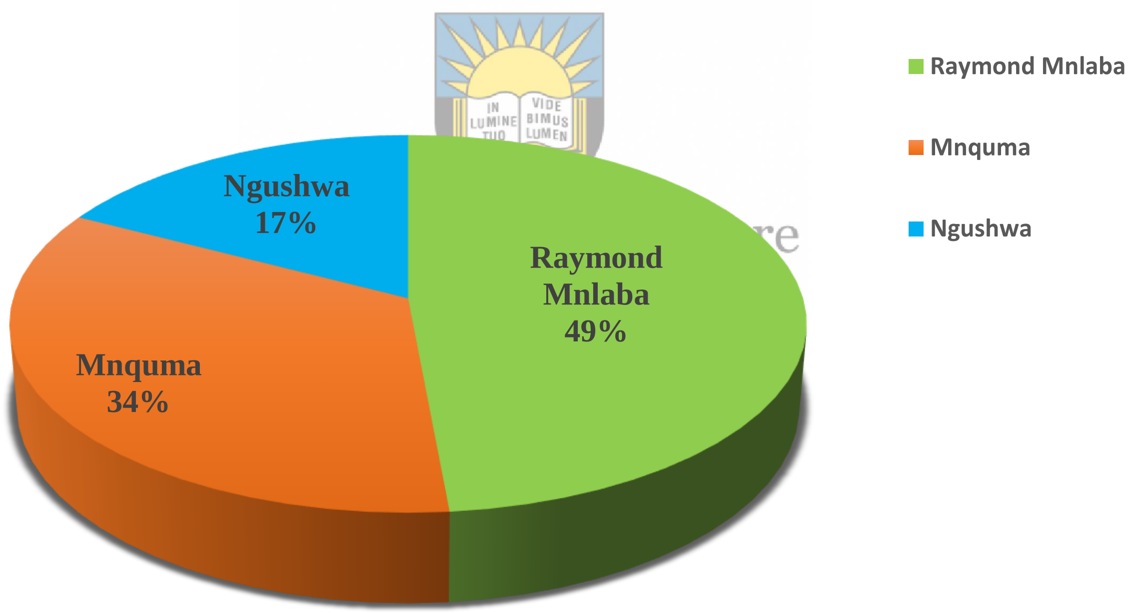

Figure 2: Percentage of respondents from different municipalities in Amathole Districts.

Table 1: Demographic characteristic of consumers interviewed on in Amathole District.

	Variable	Percentage	Frequency
Gender			
	Female	53.5	108
	Male	46.5	94
Household Size			
	0-5	75.8	153
	6-10	23.2	47
	>10	1	2
Age			
	15-24	11.6	23
	25-34	29.7	60
	35-44	27.4	55
	45-55	13.5	27
	55-64	11.9	24
	65-74	5.9	12
	75-84	0.01	1
Preferred Offal			
	Sheep offal	41.1	83
	Cattle offal	16.3	33
	Both	42.6	86

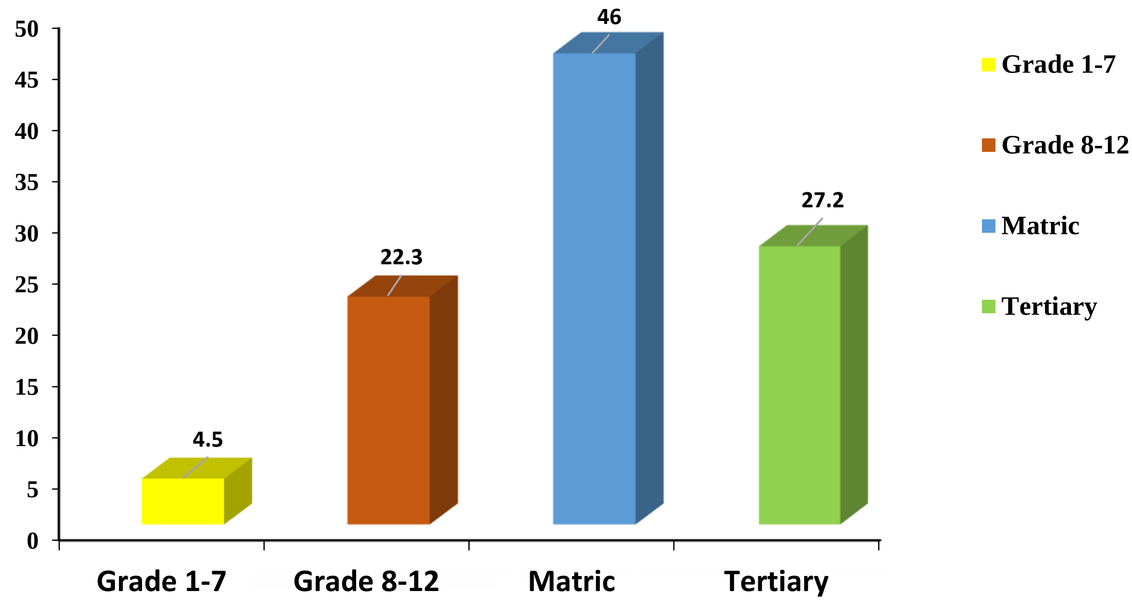

Figure 3: Educational status of respondents

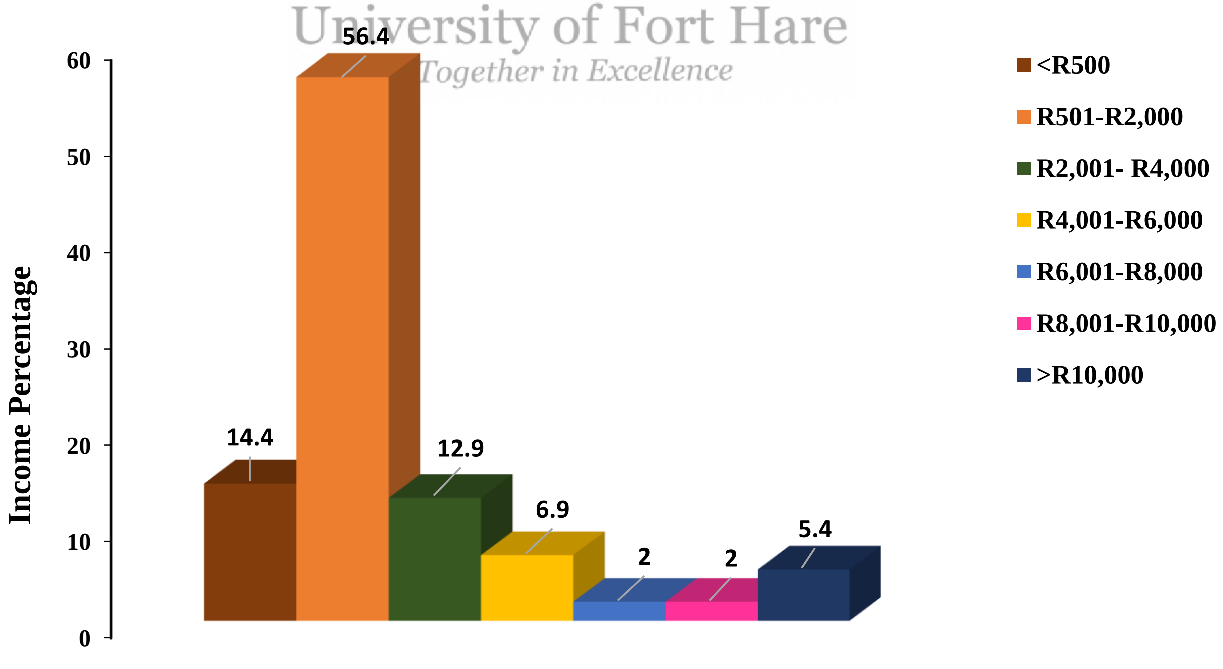

Figure 4: Monthly income of the respondents

With respect to purchasing decisions, the interview focused on the preferred place of purchase, preferred offal, and offal meat products consumed in the last three month. When consumers were asked what type of offal meat products do they preferred to eat and from which type of animal. It was observed that, liver (94.1%), tripe (78.2%) and intestine (68.8%) were the most demanded for and consumed in the last three month (Figure 5). This same trend for the demand of liver, tripe and intestine was seen among the respondents that preferred sheep offal (37.6%, 32% and 31.2%) and cattle offal (15.3%, 12.5% and 8.9%) in decreasing order respectively. However, the results from this study showed that, sheep offal was mostly preferred by the respondents (Table 1).

In general, it could be deduced that consumers explored all the retail outlets (butchery, supermarkets and other retail outlets.) for the purchase of offal meat. However, the study revealed that, the majority of respondents preferred to buy offal meat from butchery (Figure 6). A greater percentage of respondents who purchased liver (64.4%), heart (42.6%), tongue (40.1%), kidney (37.6%) tripe (59.4%), spleen (34.7%), intestine (59.4%), and lungs (37.6) did so in butcheries as compared to other outlets. Furthermore, the respondents were asked why they chose the butchery in preference to other selling or retail outlets. The respondents replied that the offal meat sold at butchery was fresher and cheaper. In addition, the respondents alluded to the fact that they preferred the butchery because the other types of offal meat were not readily accessible as compared to the butchery. Moreover, it emerged that purchase of offal meat at the butchery also gave the consumers the opportunity to buy a combination of different offals otherwise called combo as compared to the supermarkets where the chances of purchasing in bulk are limited. Offal combo therefore, appears as a variant due to the internal environment of the consumer and preference conditions. This variant can be called consumers' bias preference which may involve factors such as: consumers' evaluation of the product, products attributes and weight preference (Platz and Veres. 2014). Nevertheless, there were a few number of respondents who chose to buy fresh offal products occasionally from supermarkets and street traders.

The interview were similarly focused on visual and quality assessment of offal meat (colour, packaging, visual display, fat inclusion, freshness, and price). Assessment of visual appearance was derived from previous work from De Andrade (2017) and measured on descriptive scales using likeart scale on 1-2–3–4–5 (disagree to strongly agree). The variables which best described the quality of offal meat with respect to their importance in the consumers' decision to purchase offal are shown in Figure 6. The results showed that respondents who purchased fresh offal products from retail outlets cited freshness as the major factor which assisted them to distinguish the quality of the meat offered in any retail outlets. Consumers' perception on the freshness of offal is therefore, very important at any selling point. These results commensurate with Verbeke and Viaene, (2000) who reported that freshness is the most effective factor that influences consumers' decision to purchase fresh meat. Jabbar, (2009) also concluded in his study that freshness and price among other quality attributes play a vital role for consumers to make their decision at the point of purchase.

The price of offal was also observed and presented by consumers as one of the factors that attribute to favour offal meat when compared to other types of meat which are more expensive. Most of the respondents felt price was a strong factor which contributed whether or not to eat or purchase offals. Some respondents acknowledged that offal products sold at butcher shop were relatively cheaper and the quantity was high as compared to the supermarkets. The findings also indicated that the more the consumers ate any offal meat products the higher the demand for the products in the last three months. A possible reason could be as a result of the price of offal, which was found to be considerably cheaper at the butchery than supermarkets. This is in agreement with the law of demand which states that, the quantity of goods lead to a rise in demand rises as the price falls, and vice versa. Although, offal meat products still accounts for an insignificant part of meat markets and its demand still far behind the production potential of resources available (Liu *et al.*, 2007).

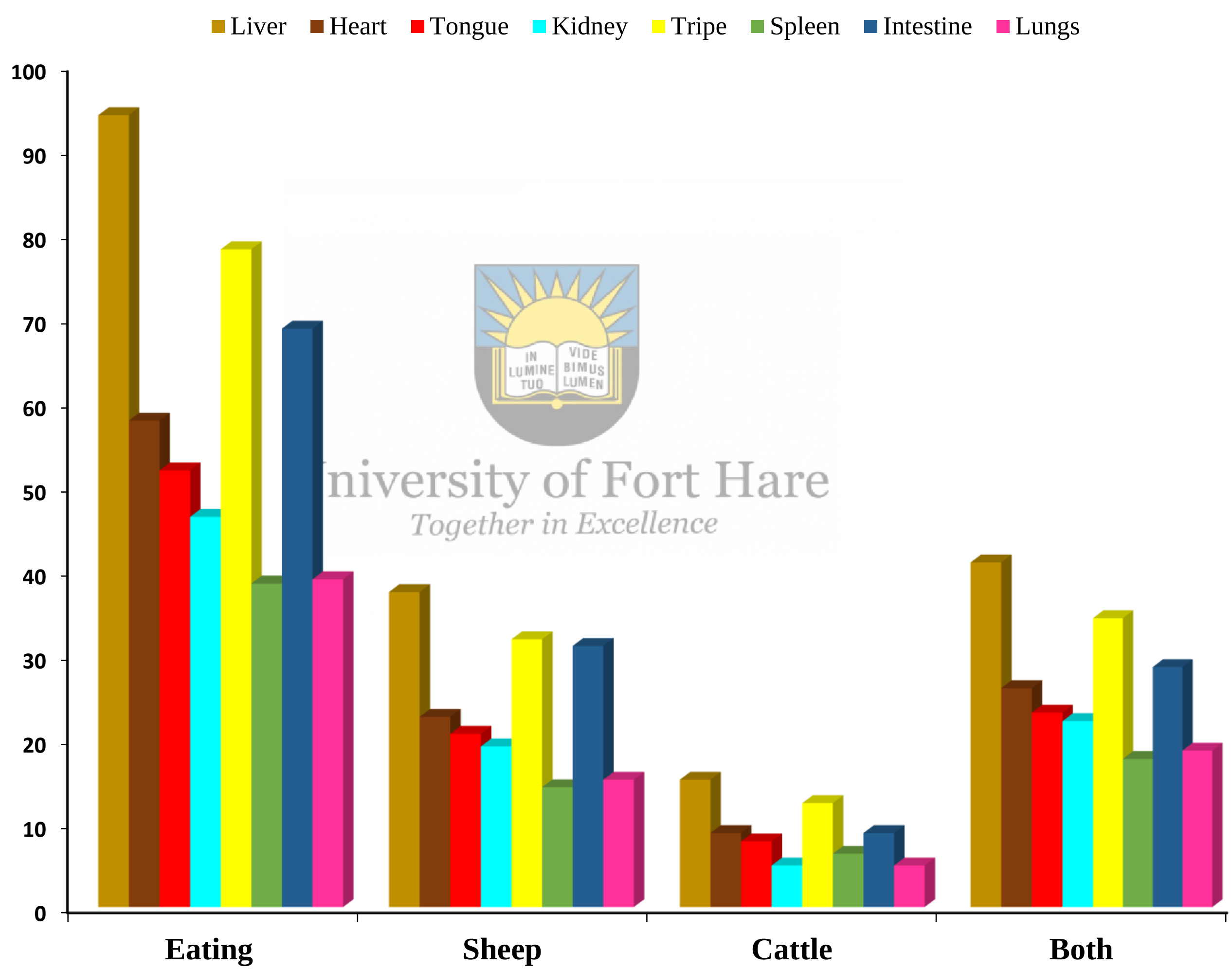

Figure 5: Distribution percentage of offal meat demanded and type of offal.

Table 2: The correlation coefficients between demographic and perception on eleven offal meat quality.

Demography	Colour	Leanness	Presence of Fat	Smell	Freshness	Flavour	Packaging	Price	Tenderness	Juiciness	Visual Display
Age	0.227	0.292	-0.660	0.310	-0.231	-0.899	-0.029*	0.702	-0.867	-0.952	0.889
Gender	0.026*	0.668	0.474	-0.392	-0.820	0.750	0.012*	0.248	0.020*	0.031*	-0.149
Education	0.876	-0.175	0.102	-0.03*	-0.982	-0.460	0.174	0.414	0.573	0.061	0.018*
Income	0.088	-0.145	0.523	-0.187	-0.904	-0.816	0.774	0.228	-0.107	0.145	0.084
H/ Size	-0.397	0.865	0.029*	0.234	-0.173	-0.933	-0.242	-0.87	-0.459	0.860	0.291

* Correlation coefficients is significant at the p-value <0.05

Correlation analysis was performed to establish the relationships between offal meat attributes and demography (Table 2). The result showed that there was a significant relationship at p-value 0.026, p-value 0.012, p-value 0.020 and p- value 0.031 but a positive correlation between gender and colour, packaging, tenderness and juiciness of the offal meat products. This means that the colour, packaging, tenderness and juiciness of the offal meat products tends vary from male to female at the point of purchase.

The estimated relationship between the education of the respondents and their perception about smell of the offal was significant at p-value 0.025 though weakly correlated. On the other hand, the level of education was significant at p-value 0.018 with a positive correlation due to visual display at the point of purchase. This shows that as the level of education increases consumers attach more credence to the visual display of the offal and this influences decision at purchase points. Thus, it should also be noted that demography was also used to a great extent for the anticipated outcome that is intended for interpreting consumers' purchasing behaviour. However, a study by Romano and Stefani (2006), revealed that there is a narrow line between demographic variables and purchase decision. This is in agreement with the results obtained from this study where variables like age, monthly income, family size, gender and educational status were observed to be weak factors that influenced consumers' purchase decision.

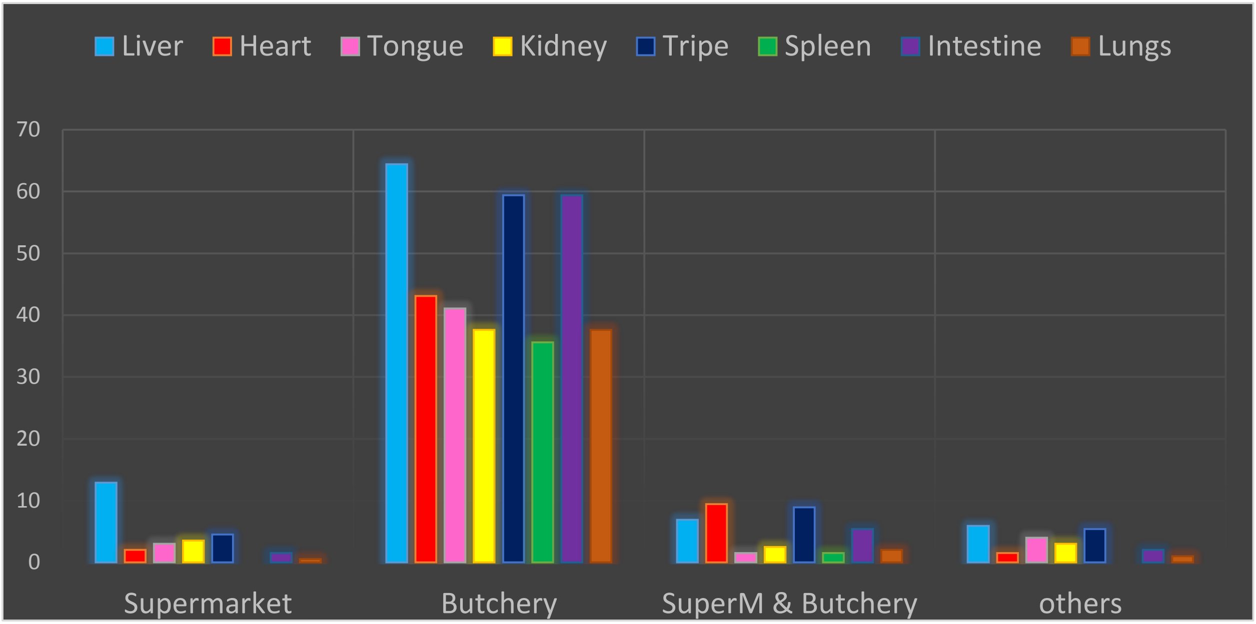

Figure 6: Distribution percentage of offal meat purchase points

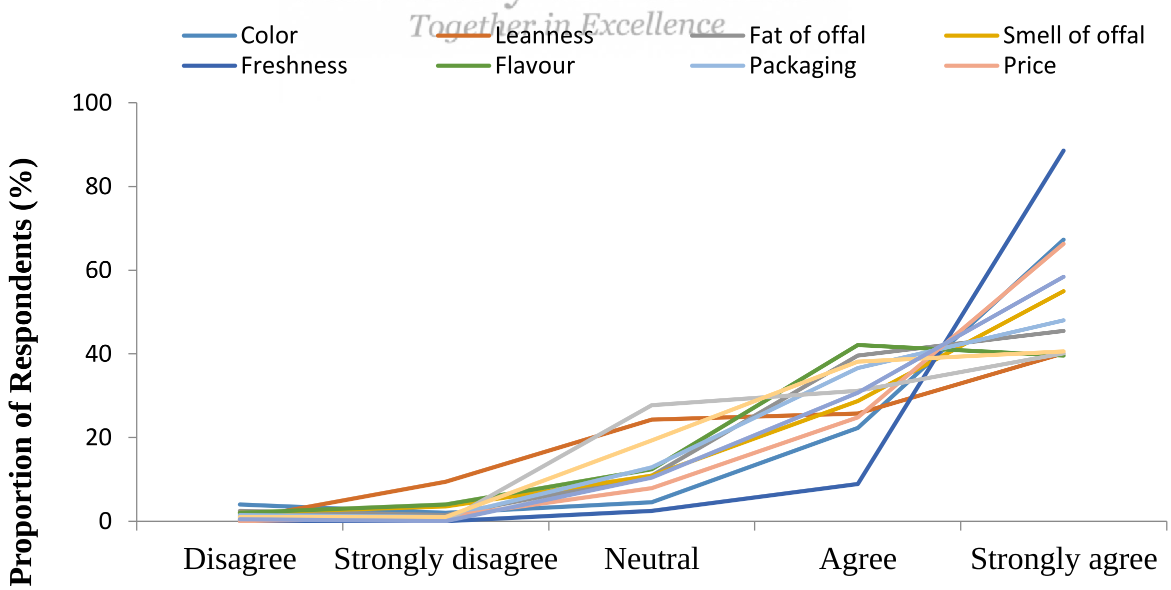

Figure 7; Ranking of offal meat attributes influencing consumers' purchase

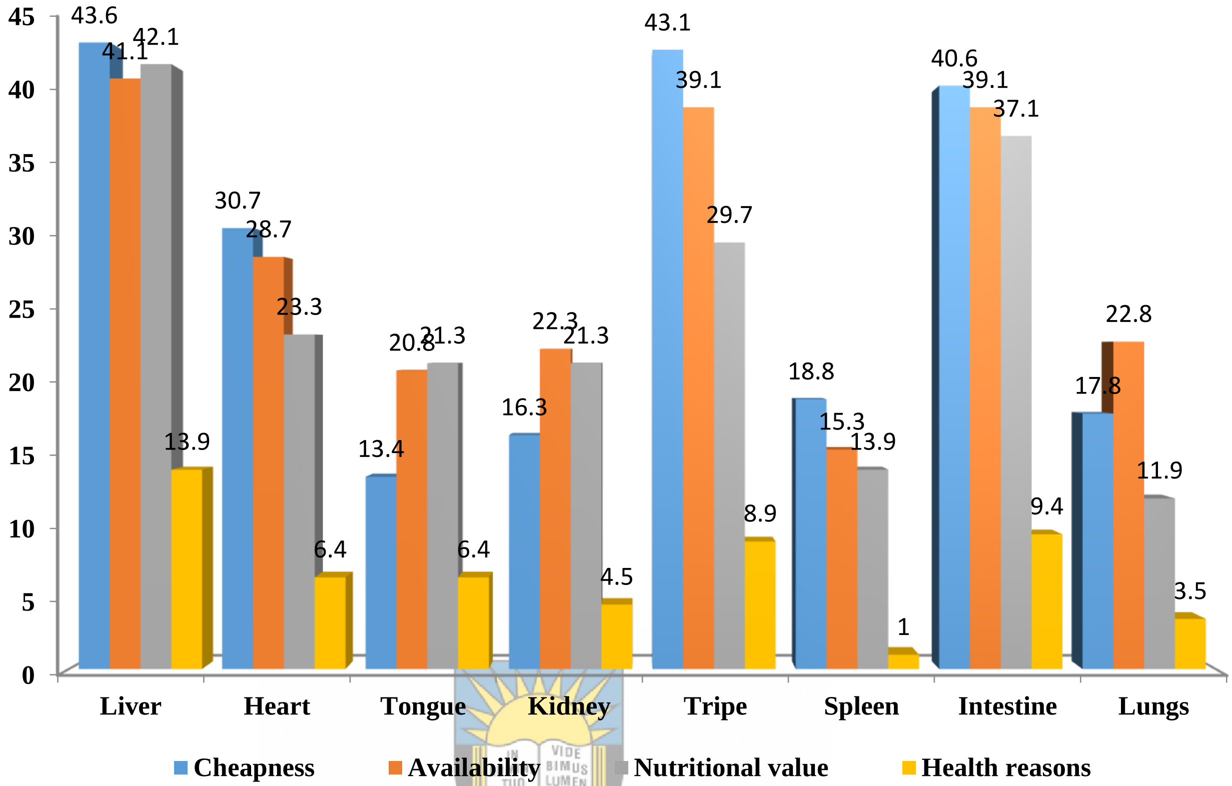

Figure 8: Factors influencing the demand for offal meat

It was further observed that, the highest point of preference when offal meat was to be purchased was the price of offals that is, whether they were cheap or not. This implies the price of the product, followed by availability, nutritional value are critical (Figure 7). These three factors form the major factors influencing offal demand. The price of liver (43.6%), heart (30.7%), tripe (43.1%), spleen (18.8%), intestine (40.6%) and availability of liver (41.1%), heart (28.7%), tongue (20.8%), kidney (22.3%). tripe (39.1%), spleen (15.3%), intestine (39.1%), lungs (22.85) emerged as being very important for demand of offals. The consumers also revealed that, they have nutritional knowledge of the offal meat products before making their purchase. Meanwhile, health reasons emerged as the least factor that the consumers considered at the point of purchase (Figure 8). This however, contradicts the observation of Jabbar (2009) that price was the least important factor relative to income of consumer. In as much as the Jabbar (2009) observation may be true for purchases of beef but does not apply to offal meat.

3.4 Conclusion

In Amathole District, consumers had higher preference for offal meat products from the butchery because it was cheaper, readily available and fresher. Most of the consumers strongly agreed that, the meat quality attributes influenced their decision during purchase of offal meat. However variables such as the colour, price, freshness, visual display and packaging of the offal were ranked as the most influential in making choice to purchase in comparison to other factors such such tenderness and fat content. The point of purchase however, remains a prominent factor among other factors that could influence decision making for any consumer. When it comes to offal meat, the results showed that a majority of the consumers purchased more liver, intestine and tripe, this is due to the fact that they are often sold in combo at the butchery. Although, some consumers may expect distinct or special quality attributes based on their individual experience. It is also known that consumers' mental attitude and insight about acceptable quality attributes could be attached to socio-economic status and personal preference of the consumer.

In addition, the findings of the study inferred that, nearly all the types of offal meat are consumed in Amathole district especially liver, kidney, tripe, intestines, heart and tongue, though kidney and spleen were mentioned by some respondents to be mostly consumed by men. The foremost factors influencing offal consumption comprised of availability of offal meat, price, freshness, nutritional value and health reasons. These offal meat products are nutritionally appropriate for different age groups especially children and women. Since the perception of consumers on offal meat consumption is similar to the indicators and factors that are considered when consumer is about to purchase red meat. This suggest that, the results have important effects for developing effective growth strategies to promote the offal meat market in the municipality. In addition, this means that municipality need to re-orientate and enlighten her people more about nutritional benefits, food safety and healthy implication of offal.

3.5 Reference

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CHAPTER FOUR

SENSORY EVALUATION AND CONSUMER ACCEPTABILITY OF EDIBLE MEAT WASTE IN SAUSAGE AS FAT REPLACER

(This section is currently under review in Sustainability Journal)

Abstract

This study investigated the textural and sensory characteristics of sausage, where edible meat waste was partially replaced with fat in the formulated sausage (10% fat and 90% meat, 70% edible meat waste and 30% beef, 50% edible meat waste and 50% beef replacement). Three treatments including the control (10% fat and 90% beef) were used in this study. Chi-square statistics were used to determine the significant difference between the population of the respondents that dislike, like, neither like nor dislike the sausage. The association between the attributes were further determined, using correlation coefficients to determine the strength of that association. The correlation coefficients of most attributes were significant ($P< 0.01$) in describing the different mix of sausage cooked under different methods. The colour of the microwaved sausage had a moderate positive correlation with the appearance of the sausage ($P<0.01$), taste ($P<0.05$) and overall attributes ($P<0.05$) with weak positive correlation. Descriptive analysis revealed that the pooled likeness was 84.7% for WFM while 65.5% was WSM, on the other hand WFO (56.1%) and WSO (56.9%). With regards to all the attributes, sensorial evaluation showed that microwaved sausage formulated with 50% beef and 50% edible meat waste (WFM) was most acceptable.

Keywords: Sausage, edible meat waste, attributes, acceptability, fat replacer, sensory

Background of the study

The food processing industry has inherent capacity to reduce pollution and waste production with the aim of generating more profit and reducing overall cost of production (Klemeš and Perry, 2007; Roupas *et al.,* 2007). This is achievable because abattoir by-products are generally produced in large quantity and their disposal can be a threat (Russ and Meyer, 2004). Nevertheless, edible by-product possess inherent capability to be used on a large scale in the meat processing industry for additional value without any threat to consumers acceptability (Alao *et al.,* 2017). An example, is the recovery of edible meat waste for sausage production and this can improve the profitability of the industry. Processing of animal carcass at the abattoir involves the production of substantial amount of wastes. Once the carcasses are cut and sorted according to the market demand, abattoirs usually discard the meat wastes (Roupas *et al.,* 2007). The discarded meat wastes are often inedible whereas the edible products may be recycled back into the food chain in the form of sausage. The processing of sausage involves the addition of different food components that could enhance human well-being. Processed meat products is a natural portion of sausages that is associated with other components of the meal, which adds to its dietary attributes and enhance digestibility (Louis-Sylvestre *et al.,* 2010). For instance, the addition of these components also provide functional properties that improve the structure, nutritional and health qualities of the finished products (Fernández- Ginés *et al.,* 2005).

In the processing of edible animal products any edible parts can be used and blended with lean meat to make good sausages. The blending of lean meat with offals (liver, kidney, heart) and other meat products (edible meat waste) can also provide a cheaper animal protein with a better flavour. Many studies has been successfully conducted on sausages by replacing the beef with other meats including mutton, pork, chicken, fish and rabbit meat. The findings of these studies shows that, this enhances the juiciness, texture, fat reduction with associated positive health implication (Aleson-Carbonell *et al.*,2005; Asmaa *et al.*, 2015; Santana *et al.*, 2015; Malekian *et al.*, 2016; Xue *et al.*, 2017). In fact, other studies revealed that some edible by products such as liver could be used either partly or wholly during sausage making while blood sausage is commonly produced in the western countries (Schut., 1978; Nollet and Toldrá., 2011; Melngaile *et al.*, 2014; Irshad and Sharma, 2015). For instance, in Finland liver sausage is considered appealing and approved by the general public whereas liver paˆte´s are customarily prepared in France and Spain (Estévez *et al.*, 2005). In this regard, the act of using edible meat by products in meat processing has been very effective in producing sustainable meat production system (Jayathilakan *et al.*, 2012; Lobato *et al.*, 2014). However, the amount of the edible meat by-products that has been utilized is to a greater degree smaller as compared to the amount produced at the abattoir.

Presently, consumers' attention has been drawn not only to the quantity but also the quality of the meat and meat products (Węglarz, 2010). The unified effort among the nutritionists on the benefits of wholesome processed meats have led to a higher demand for healthier processed products from the consumers (Arildsen Jakobsen *et al.*, 2014). As a result, meat industries were motivated to produce meat products that are safe and easy to prepare with all the characteristic meat qualities (Herrero *et al.*, 2008).

It is well-known that sausage is a product of meat processing categorized as an essential product for which demand is constant. This is because it may be consumed at least four times a month (Moon *et al.*, 2016). Moreover, sausages can be served as the main food or taken as a snack with other foods and this provides a positive effect on its popularity (Korkeala and Björkroth, 1997). Despite this, a remarkable care is been put in place towards reducing dietary fat intake to the barest minimum in the meat products. To achieve this, an appropriate balanced quantity of all the fatty acid in the daily nutrition for good well-being is encouraged (Siciliano *et al.*, 2013).

In South Africa, raw boerewors sausages are produced naturally from the meats of cattle, sheep, pig or combination of two meats of any species. The meat content in raw boerewors is expected to contain 90% of meat and about 30 - 50% fat. (Colmenero, 2000; Magoro *et al.*, 2012). On the other hand, fat is recognized as the activator of chronic diseases hence, World Health Organization (WHO) restricted the dietary daily intake of dietary fat to less than 30% (Mora-Gallego *et al.*, 2013). In order to comply with the proposed WHO daily fat intake, several investigations have been carried out to reduce or replace the fat content of meat and meat products. For example, Inulin has been successfully substituted for fat in a low fat fermented sausage and the results showed an all ground improvement on the sensory properties of the sausage (Mendoza *et al.*, 2001). Luruena-Martınez *et al* (2004), in their findings substituted olive oil for pork fat and concluded that, fat reduction does not have impact on sensory properties and overall acceptability. This means that reducing the dietary content of sausages or substituting the fat with a product that can reduce the health risk will not alter the sensory properties of the sausage. However, the present day consumers use foods as a rudimentary means for managing their health (Jo *et al.*, 2001). Although microbial biodegradation and lipid oxidation

are not acceptable but these are principal processes through which sensory quality of beef sausage can declines (Gray *et al.*, 1996).

Culinary methods are marked by different progressive stages during the preparation of meat with cognitive impact on organoleptic properties. In this regard, any of the culinary methods can be employed for cooking sausages. Examples of the cooking methods include grilling, microwave cooking, oven grilling and frying, (Singh *et al.*, 2015; Adam and Abugroun. 2015). The culinary method used for preparation contributes to the adhesion properties of the sausage batter while the composition of the sausage equally has a significant effect on the adhesion(Mukprasirt *et al.*, 2000). In addition, the effect of culinary methods have been reported to have significant effect on the sensory characteristics amongst different cooking methods while tenderization depends on cooking conditions (Pawar *et al.*, 2000; Obuz *et al.*, 2003). The colour of meat products such as sausages is marked by the sausage composition, cooking temperature and time of cooking (Singh *et al.*, 2015). However, the structure and nutritive properties of the emulsified sausage batter is influenced by dietary fat and cooking methods (Mohammad *et al.*, 2010). The presence of dietary fat in emulsified batter enhances the texture, juiciness and flavour of the sausage while, culinary method determine its compositional and sensory features (Mohammad *et al.*, 2010). Although the consumer's decision are influenced by the tenderness of meat, other factors such as flavour, juiciness, appearance, price, colour and food safety also plays significant role in overall judgement (Wood *et al.*, 1995; Troy and Kerry. 2010). The structural changes in the muscle as a result of stimulated heat has been reported to improve the tenderness of meat and meat products, therefore tenderness was acknowledged as one of the important meat quality attributes (Obuz *et al.*, 2003). However, replacement of edible meat wastes as a fat replacer in sausage have not been widely investigated. Therefore, the present study aimed to determine the acceptability of edible meat wastes as replacements for fat in sausages using two cooking methods namely microwave and oven-grilling methods and subjecting the final products to sensory evaluation.

4.2 Materials and methods

4.2.1 Description of the study site

The present study was submitted to and approved by the Ethics Committee of the University of Fort Hare. The study was conducted in Meat Science laboratory at the University of Fort Hare. Parts of the sausage batter produced in the latter chapter comprising of different mixtures of beef and edible meat waste were used (Table 1). The sausages were cooked under two different methods and sensory evaluation was conducted.

Table 1: Formulation of sausage made with edible meat waste

	Treatment 90:10		**Treatment 50:50**		**Treatment 30:70**	
[a] **Raw materials**	**Amount Kg**	**Composition %**	**Amount Kg**	**Composition %**	**Amount Kg**	**Composition %**
Lean meat	6.75	90	3.75	50	2.25	30
Fat	0.75	10	-		-	
Edible meat waste	-	-	3.75	50	5.25	70
[b] Ingredient						
Ice	0.33	0.33	0.33	0.33	0.33	0.33
Complete Spice	0.33	0.33	0.33	0.33	0.33	0.33
Salt	0.19	0.19	0.19	0.19	0.19	0.19

[a]**:** The sausage made with edible meat waste was prepared with raw material as 100% of the formulation.

[b]**:** The ingredients were added in relation to the total weight of raw materials.

4.2.2 Ethical Consideration

Ethical values were considered to conform to the South African policy governing research of this type. Request was made to conduct a survey through questionnaire and was approved by the Research Ethics Committee of the University of Fort Hare, South Africa with ethical clearance certificate reference number MUC341SBAB0.

4.3 Cooking Methods

4.3.1 Microwave

The prepared sausage samples were carefully arranged on the microwave plate and cooked in a domestic microwave grill oven (Litton Generation 2, Model SA 2075.002, Minneapolis USA) at 80°C for 4min. The experiment was executed at 700W for 4min while the internal temperature was measured using digital probe thermometer Thermo-pro TP- food thermometer). The samples were considered done when the digital thermometer gave an alarm and flashed a green light. The samples were cooled at room temperature, vacuumed packed and stored at -80°C until the laboratory analysis was carried out.

4.3.2 Oven-grilling

The oven was pre-heated at 180°C before the sausage samples were placed in the oven. The sausage samples were arranged in a tray according to their mixing ratios and the oven set to grilling. Samples were oven-grilled in a conventional oven (name of oven) until the internal temperature of the sausage fingers reached an average of 90°C. Thermometer (Thermo-pro TP- food thermometer) was pre-set to beef-medium to measure the internal temperature of the sausage. The thermometer was designed with LCD visual presentation and pre-set temperatures for meat at different cooking levels. By inserting the probe into the sausage the thermometer indicated when the sausage was fully done by sounding alarm with a flash. The time taken for the sausage to be cooled was 20minutes.

4.4 Warner-Bratzler shear force and cooking losses determination

For determination of cooking loss and Warner-Bratzler shear force (WBSF) values, samples were taken out of the fridge a day before and were left to thaw at 25ºC, room temperature. Samples were weighed, labelled and cooked under two cooking methods (microwave and oven-grilling). Cooking loss was evaluated as differences in the weight of raw and cooked meat samples.The samples were allowed to cool and were cut cylindrically and placed under instron machine. Warner–Bratzler shear force (WBSF) values were determined on meat samples as indicators of tenderness Coring was obtained using hand-held coring device to make round cores of about 10mmfrom the cooked samples. About 3 core was obtained at the center of each sample of the sausage. Shearing was done using Warner-Bratzler shear machine, with the speed of 400mm/min. The thickness of the vee-shaped cutting blade was about 1.02mm. The cored sausage was placed on the machine and cutting blade was used to cut through the sample. The maximum force (N) required to shear for each specimen was measured and the mean was recorded for tenderness.

4.5 Sensory Analysis

4.5.1 Consumer panel testing

A total of 60 untrained panellists which largely involved students and staff at the University of Fort Hare were recruited for the consumer evaluation of sausages under ambient conditions. The panelists were seated in an individual booth without any contact. The room was big and free of noise and odour and suitably lightened with natural light. The entire procedure in the sensory test was described in detail to the panelists taking part in the analyses especially, for those who cherished consumption of sausage.

The panelists were asked to rate their attributes on a 9-point hedonic scale, with 1 being “disliked extremely” and 9 being “liked extremely” in the middle “neither like nor dislike”. The six most widely used sausage sensory characteristics were selected and panelists were asked to score each sample for overall likeness as well as the acceptability of appearance, flavour, taste, texture, and juiciness using a 9 hedonic scale. The sausages with three mixing ratios cooked under two cooking methods were evaluated. The sausages were cooked in the microwave and oven grilled separately. The sausages were cut into slices of approximately 4 mm thickness and served at room temperature on white paper plates. The sausage samples were named according to their mixing ratio and cooking methods (TCO 10% fat, 30% edible meat waste WSO, 50% edible meat waste WFO, 10% fat TCM, 30% edible meat waste WSM and 50% edible meat waste WFM) were evaluated by the consumers using hedonic scale. Furthermore, clean water was provided for rinsing the palate before each sample was tested. For each sample, the panellists were expected score the overall acceptability as well as the acceptability of appearance, flavour, taste, hardness and juiciness using a 9-box scale labelled on the bottom with “dislike very much”, in the middle “neither like nor dislike” and on the top “like very much”

4.6 Statistical analysis

Data generated were entered in Microsoft excel programme and were summarized as frequencies of respondent profiles on consumers acceptability. Descriptive statistics were used to determine the relationship between sausage attributes and the response of the respondents using SPSS version 20 for the analysis. Chi-square statistics were used to determine the significant difference between the population of respondents that dislike, like, neither like nor dislike the sausage. The association between the attributes were further determined, using correlation Pearson's coefficients (r) to determine the strength of that association. Effects were considered significant at $p < 0.01$ and $p < 0.05$.

4.7 Results and Discussion

The Pearson correlation analysis between the sausages attributes influencing consumers acceptability of sausage made from edible meat waste is shown in Tables 2 and 3 respectively. The correlation coefficients of most attributes were significant (P< 0.01) in describing the different mixing ratio of sausage cooked under different methods. The colour of the sausage in treatment TCM (90:10) (Microwaved) had a moderate positive correlation with the appearance of the sausage (P<0.01), taste (P<0.05) and overall attributes (P<0.05) represented a weak positive correlation. The table also shows that, the colour had a very weak negative correlation with the texture (P> 0.05). However, overall attributes of the sausage had a strong positive correlation with appearance, flavour and taste (P<0.01) while, texture and colour appear to be weakly correlated (P<0.05). Normally, a correlation coefficient compares the relationship between two variables and when there is a strong correlation the value will be ±0.79. Therefore, significant differences were observed between the sausage treatment and the cooking methods (microwave and oven-grilling). The values of the sausages were consistent and more positively correlated at P<0.01 (Tables 2 and 3).

Table 2: Pearson correlation matrix between sensory attributes of the control and microwaved sausage containing edible meat waste

Treatments	Attributes	Appearance	Colour	Texture	Taste	Flavour	Overall
TCM 90/10	Appearance	1					
	Colour	0.507**	1				
	Texture	0.01	-0.176	1			
	Taste	0.465**	0.314*	0.385**	1		
	Flavour	0.385**	0.117	0.214	0.664**	1	
	Overall	0.514**	0.284*	0.306*	0.644**	0.757**	1
WSM 30/70	Appearance	1					
	Colour	0.794**	1				
	Texture	0.647**	0.795**	1			
	Taste	0.742**	0.604**	0.697**	1		
	Flavour	0.606**	0.757**	0.720**	0.573**	1	
	Overall	0.710**	0.702**	0.697**	0.614**	0.877**	1
WFM 50/50	Appearance	1					
	Colour	0.795**	1				
	Texture	0.327*	0.492**	1			
	Taste	0.561**	0.505**	0.231	1		
	Flavour	0.539**	0.517**	0.613**	0.647**	1	
	Overall	0.557**	0.682**	0.786**	0.551**	0.779**	1

* Correlation is significant at the 0.05 level (2tailed).
** Correlation is significant at the 0.01 level (2-tailed).
r- value is the correlation coefficient

TCO 10% fat, 30% edible meat waste WSO, 50% edible meat waste WFO (Oven dried samples)
TCM 10% fat, 30% edible meat waste WSM and 50% edible meat waste WFM (Microwaved samples)

Table 3 Pearson correlation matrix between sensory attributes of the control and oven-grilled sausage containing edible meat waste.

Treatments	Attributes	Appearance	Colour	Texture	Taste	Flavour	Overall
TCO 90/10	Appearance	1					
	Colour	0.310*	1				
	Texture	0.098	0.625**	1			
	Taste	0.442**	0.515**	0.23	1		
	Flavour	0.249	0.626**	0.606**	0.646**	1	
	Overall	0.671**	0.498**	0.244	0.690**	0.594**	1
WSO 30/70	Appearance	1					
	Colour	0.700**	1				
	Texture	0.684**	0.731**	1			
	Taste	0.687**	0.650**	0.649**	1		
	Flavour	0.738**	0.530**	0.645**	0.800**	1	
	Overall	0.767**	0.530**	0.661**	0.802**	0.845**	1
WFO 50/50	Appearance	1					
	Colour	0.642**	1				
	Texture	0.193	0.095	1			
	Taste	0.672**	0.359**	0.409**	1		
	Flavour	0.656**	0.305*	0.370**	0.712**	1	
	Overall	0.576**	0.547**	0.222	0.675**	0.637**	1

*   Correlation is significant at the 0.05 level (2tailed).
** Correlation is significant at the 0.01 level (2-tailed).
r- value is the correlation coefficient
TCO 10% fat, 30% edible meat waste WSO, 50% edible meat waste WFO (Oven dried samples)
TCM 10% fat, 30% edible meat waste WSM and 50% edible meat waste WFM (Microwaved samples)

With regards to all the attributes, the sensorial evaluation showed that the cooked sausage formulated with 50% (WFM and WFO) of edible meat waste proved to be the most acceptable product to the panelists. Furthermore, the results showed that, there was a close line of acceptance between the 10% edible meat waste in oven-grilled sausage (control) with the sausage formulated with 50% (WFO) of edible meat waste (Table.4). The result of the sensory evaluation also showed that oven-grilled TCO sausage scored the highest (50%) under overall attributes while WFO and WSO scored 13.3% and 20% under overall attributes respectively. The oven-grilled WSO sausage samples had a high score in all the attributes as compared to 50% sausage. Similarly, the WFM samples that were microwaved were more acceptable in comparison to WSM (Table 4). However, the tenderness of sausage treatments are significantly different from one another at $P<0.01$ and there was an interaction between the tenderness of the sausage samples and cooking methods at $P<0.01$ (Table. 6). The texture and overall acceptability of sausages formulated with edible meat waste were all tender and acceptable by panelists,

Table 4. Sensory evaluation of oven-grilled sausage with edible meat waste as fat replacer

Treatment	Attributes	Dislike extremely	Dislike very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely
10%	Appearance	0	0	3.3	6.7	18.3	11.7	36.7	20	33
	Colour	0	0	3.3	8.3	15	28.3	33.3	11.7	0
	Texture	0	3.3	3.3	3.3	6.7	43.3	20	20	0
	Taste	0	0	0	13.3	10	16.7	43.3	16.7	0
	Flavour	0	0	0	20	16.7	10	33.3	20	0
	Overall	0	0	3.3	6.7	16.7	16.7	50	6.7	0
70% WSO	Appearance	0	0	6.7	15	26.7	15	16.7	16.7	3.3
	Colour	0	3.3	3.3	13.3	20	20	21.7	5	3.3
	Texture	0	6.7	6.7	3.3	26.7	13.3	8.3	18.3	6.7
	Taste	3.3	6.7	3.3	10	16.7	13.3	13.3	20	13.3
	Flavour	0	0	6.7	20	13.3	20	20	6.7	13.3
	Overall	0	3.3	0	13.3	30	13.3	13.3	23.3	3.3
50% WFO	Appearance	0	0	6.7	13.3	13.3	18.3	23.3	16.7	8.3
	Colour	0	3.3	0	10	20	28.3	21.7	13.3	3.3
	Texture	0	3.3	3.3	13.3	20	20	21.7	15	3.3
	Taste	0	0	0	16.7	26.7	16.7	23.3	16.7	0
	Flavour	3.3	3.3	6.7	13.3	16.7	16.7	26.7	13.3	0
	Overall	0	0	6.7	16.7	10	30	20	16.7	0

Table 5: Sensory evaluation of microwaved sausage with edible meat waste as fat replacer

Treatment	Attributes	Dislike extremely	Dislike very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely
10%	Appearance	0	0	8.3	11.7	5	21.7	21.7	16.7	15
	Colour	3.3	6.7	0	6.7	6.7	26.7	33.3	11.7	5
	Texture	0	0	3.3	3.3	16.7	0	21.7	38.3	10
	Taste	0	0	3.3	0	6.7	20	28.3	25	16.7
	Flavour	0	0	3.3	6.7	3.3	16.7	30	23.3	16.7
	Overall	0	0	0	6.7	10	16.7	23.3	36.7	6.7
70% WSM	Appearance	0	0	3.3	6.7	13.3	23.3	13.3	21.7	15
	Colour	0	3.3	3.3	16.7	16.7	16.7	21.7	11.7	6
	Texture	0	3.3	3.3	13.3	26.7	13.3	13.3	18.3	8.3
	Taste	3.3	6.7	6.7	3.3	10	23.3	16.7	13.3	16.7
	Flavour	0	6.7	6.7	6.7	16.7	20	23.3	3.3	16.7
	Overall	0	6.7	0	0	20	16.7	30	10	16.7
50% WFM	Appearance	0	0	0	6.7	8.3	6.7	21.7	45	11.7
	Colour	0	0	3.3	3.3	13.3	8.3	35	15	21.7
	Texture	0	0	6.7	3.3	13.3	10	31.7	21.7	13.3
	Taste	0	0	3.3	0	6.7	6.7	23.3	30	30
	Flavour	0	3.3	0	3.3	3.3	26.7	20	23.3	20
	Overall	0	3.3	0	0	10	16.7	20	30	20

Table 6: Tenderness of the cooked sausage

Cooking method (C)	Treatments (T)	Mean	SEM	T	C	C X T
	TCM 90/10	8.23				
Microwave	WFM 50/50	5.94	0.64			
	WSM 30/70	11.071		0.0004	0.0001	0.0052
	TCO 90/10	6.016				
Oven-grilling	WFO 50/50	5.745	0.64			
	WSO 30/70	6.38				

It was further observed that irrespective of the edible meat waste proportion in the sausage and the cooking methods, the sausages were all acceptable to the consumers (Figures 1-6). For instance, the like and the dislike responses from the sensory evaluation test were pooled together and compared between the two cooking methods within the same treatment. Emerging from the results was that, the distribution of those who liked WFM (84.7%) were more, compared to WSM (65.5%) and this is shown in Figure 2 and 3, respectively. The results infer that, the low acceptability of WSM may be as a result of excess fat which may affect the sensory attributes and thus, reduce the acceptability of the sausage. The distribution of panelists who liked WFM was higher comparable to control TCM (Figure 1 and 2) and the percentage calculated as shown below:

Those who liked (%)

$$= \frac{\text{Total number of all liked}}{\text{Total number of measured attitude } \times \text{Total number of panellist}} \times 100$$

$$\text{Those who liked TCM} = \frac{299}{360} \times 100 = 83.1\%$$

$$\text{Those who liked WFM} = \frac{305}{360} \times 100 = 84.7\%$$

$$\text{Those who liked WSM} = \frac{236}{360} \times 100 = 65.5\%$$

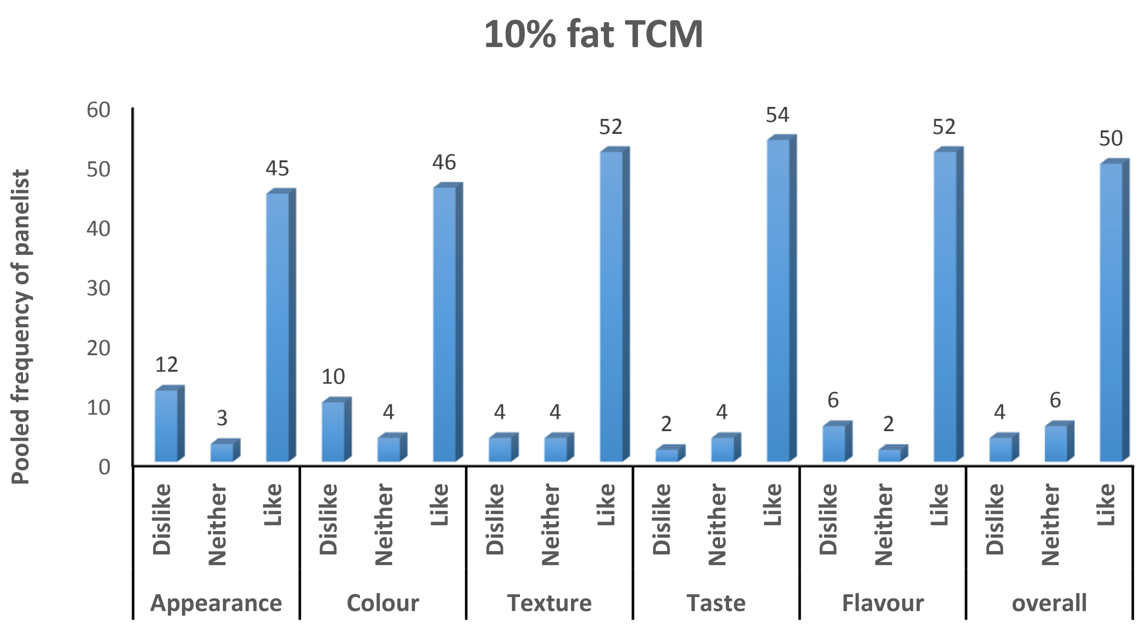

Figure. 1 Distribution of panelist who liked 10% fat TCM microwaved sausage

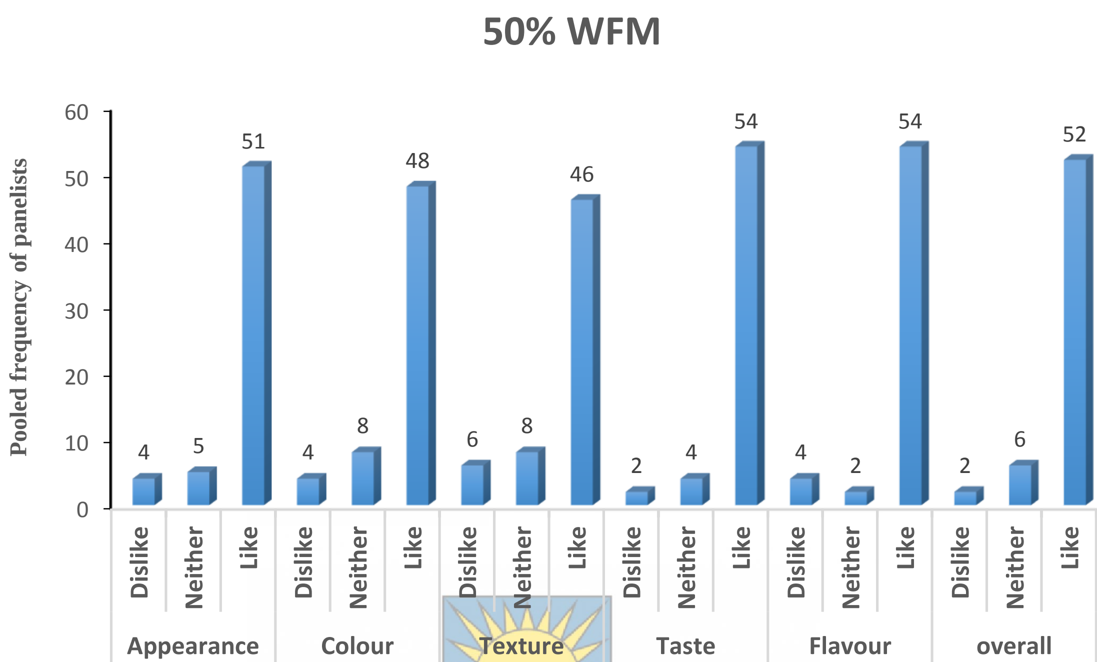

Figure. 2 Distribution of panelist who liked 50% WFM microwaved sausage

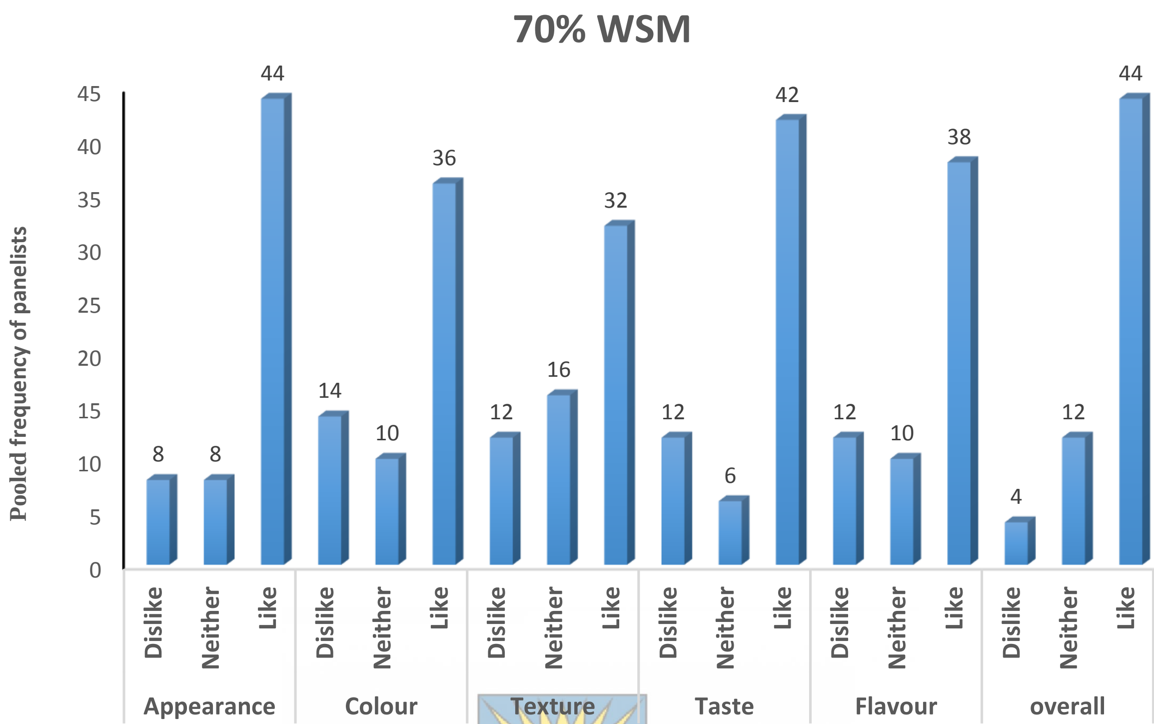

Figure 3: Distribution of panelist who liked 70% WSM microwaved sausage

Similarly, the distribution of those who liked WFO (56.1%) with regards to the scored attributes were calculated and was found to be the same with that of WSO (56.9) as shown in Figure 5 and 6 respectively. The distribution of panelists who liked 50% WFO was likewise compared to control 10% TCO. The results showed that a total of 73.6%, 56.1% and 56.9% of panelist liked 10%TCO, 50%WFO and 70% WSO respectively. This suggests that addition of edible meat waste as fat replacer in the sausages affected the sensory characteristics of the sausages. As a result, WFO and WSO differed significantly from the control sausages samples (TCO). The assessment of consumer liking showed that liking was higher for WFM than for WFO and WSO. The results suggest that the cooking method in the present study, affected the acceptability of these sausages. Therefore, the results of the study revealed that the consumers preferred the microwaved sausage more that the oven-grilled.

$$\text{Those who liked (\%)} = \frac{\text{Total number of all liked}}{\text{Total number of measured attitude} \times \text{Total number of panellist}} \times 100$$

$$\text{Those who liked TCO} = \frac{265}{360} \times 100 = 73.6\%$$

$$\text{Those who liked WFO} = \frac{202}{360} \times 100 = 56.1\%$$

$$\text{Those who liked WSO} = \frac{205}{360} \times 100 = 56.9\%$$

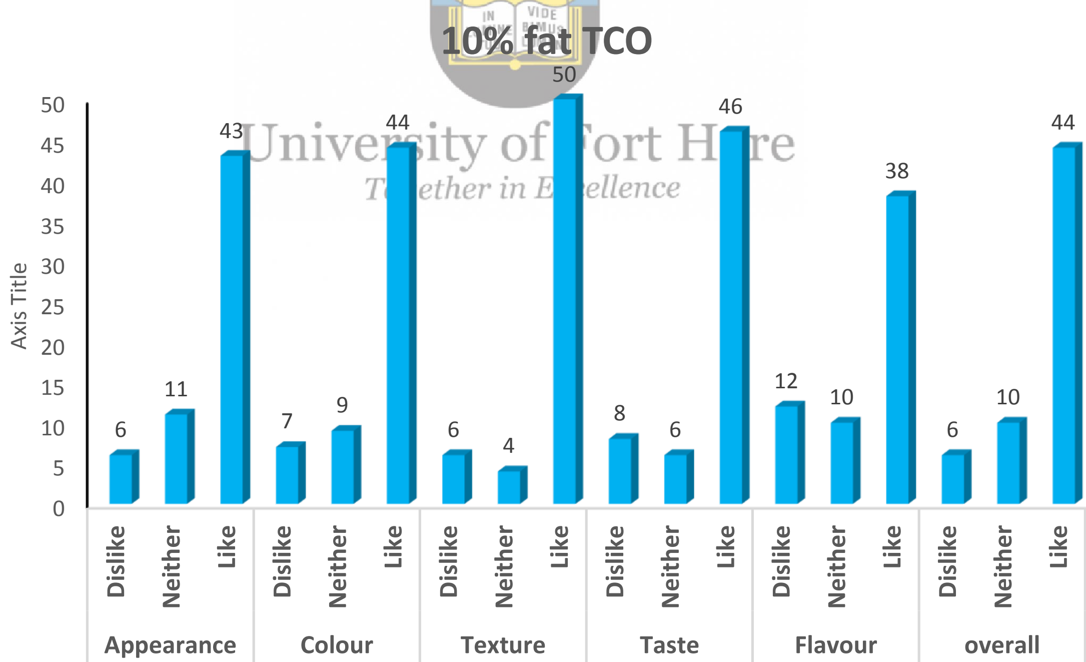

Figure. 4 Distribution of panelist who liked TCO (90:10) oven-grilled sausage

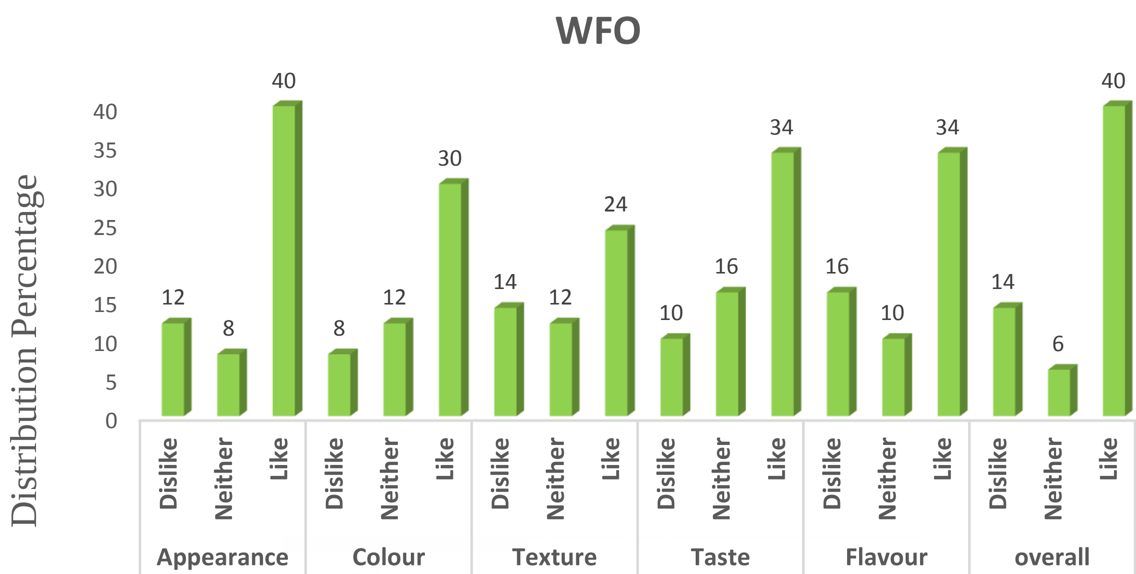

Figure. 5 Distribution of panelist who liked WFO (50:50) oven-grilled sausage

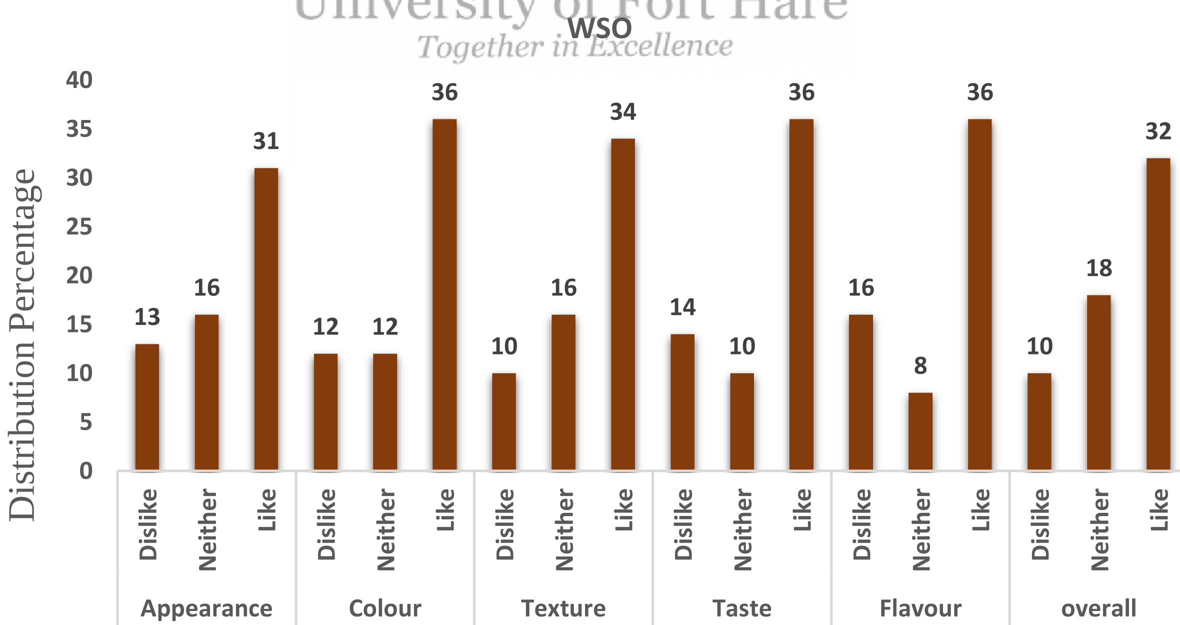

Figure. 6 Distribution of panelist who liked WSO (30:70) oven-grilled sausage

The results of the study also illuminated that, since the cooked sausages were acceptable to the consumers, this revealed that edible waste may successfully replace fat in sausage production. This is possible because edible meat waste consists of carbohydrates, proteins and fat based constituents that are needed for fat substitutes (Weiss 2010). For instance, a study by Maurice (2007) showed that, fat replacers becomes effective substitutes for fat, when they stimulates chemical characteristics of fat and oil on weight basis. Although, Giese, (1996) reported that excessive fat reduction can affect the acceptability of meat products. However, in this study, the replacement of fat in the sausage, compensated for the needed fat required, hence all cooked sausages were acceptable to the consumers. However, the results in this study differ with the Pappa *et al*, (2000) who reported that when pork back fat was substituted with olive oil, overall acceptability of frankfurter decreased.

4.8 Conclusion:

In conclusion, the replacements of fat with edible meat waste in sausage production showed overall acceptance in most of the attributes scored (colour, appearance, taste, texture and flavour) and these were above the desirable average. Although, overall acceptability revealed that, the scores of sausages made with edible meat wastes were accepted however, these were slightly different in cooking methods. The 50% replacement of edible meat waste showed the highest acceptability scores as compared to the 70% edible meat waste replacement. In this regards, replacement of fat with edible meat waste in sausage production is well acceptable to the consumers. In addition, the cooking method that was more acceptable to consumers in this study was microwave cooking. Thus, the utilization of the edible meat waste in production of sausages has the potential to increase profitability in meat industry and minimise meat waste in the industry. Therefore, based on the results of the study consumer acceptance test, the edible meat waste in sausage should be replaced at a rate of 50%.

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CHAPTER FIVE

EFFECT OF DIFFERENT COOKING METHODS ON PROXIMATE AND MINERAL COMPOSITION OF SAUSAGE MADE WITH EDIBLE MEAT WASTE AS FAT RELACER

Abstract

The effects of different cooking methods (microwave and oven-grilling) on proximate and mineral composition of sausage were investigated. Edible meat waste was used as fat replacer in the formulated sausage. The formulated sausage were made in ratios consisting of 90/10 (90% lean beef and 10% fat), 30/70 (30 % lean beef and 70% edible meat waste) and 50/50 (50 % lean beef and 50% edible meat waste). The mean content of moisture of the uncooked sausage was found to be (70.34, 65.37, 63.54%), protein (11.02, 13.9, 19.34%), fat (13.91, 11.29, 7.49%) and ash (3.64, 4.41, 4.38) for 90/10, 30/70 and 50/50 respectively. The moisture content of the uncooked sausage was 70.34% and this showed an apparent decrease of 56.3% for the cooked sausages. The cooking of the sausage led to significant changes ($P<0.01$) in ash content, protein contents and lipid content between the treatments. There was a significant interaction ($P<0.01$) between the sausage type and the cooking type. However, the cooking process appeared to have a significant effect on most of the minerals in the sausage. The results showed that, the mean values for calcium, potassium, magnesium, zinc, copper, manganese, sodium and iron in the uncooked and cooked sausage varied greatly among the treatments. In this study, the microwave method of cooking was found to be the best for healthy eating while sausage 50/50 which had a lowest amount of lipid and higher protein content can be produced commercially.

Keywords: sausage, cooking, minerals, edible, microwave, oven-grill

5.1 Background of the study

It is well known that South Africa has a large livestock production with sophisticated meat processing industries distributed across all the provinces (Meissner et al., 2013). Throughout the continent, one or more processed meat products such as sausage are extensively consumed in daily diets, though they may be costly at times (Elbakheet *et al.,* 2017). To make sure that such processed meat are available to everyone, the nutritionist are working hard to reduce the cost of meat production (Bender, 1992; Subak, 1999; Hall, 2015). Meat is well known as an important source of dietary nutrients in food and how it assists to provide appropriate growth and normal functioning of the body. Meat can defined as any edible part of animals slaughtered for food at the abattoir. The growing cost of meat and meat products is one of the motivating factors for researchers to evaluate the partial replacement of fat in sausage. This is carried out in comminuted meat products to lower formulation cost without compromising the quality (Lin and Zayas, 1987). However, reduction of fat content in sausage has the tendency to change the sensory attribute of the products and increase the cost of production depending on what is used as the fat replacer (Colmenero, 2000).

Production of sausage is usually done principally with meat and certain portion of animal fat which is mixed with spices and ice to form an even mass and is typically packed in a casing for ease of cooking (Quasem *et al.,* 2009; Mercadante *et al.,* 2010; Piotrowicz and Mellado, 2015). Sausages are important contributors of dietary fat, which may be above World Health Organization recommended levels and this can affect the consumer's heath (Shrivastava *et al.,* 2016). In this regard, this again led nutritionist to replace fat with non-meat constituents in sausage (Bolger *et al.,* 2017). Therefore, decreasing the fat contents in emulsified meat products may have a substantial optimistic effect on communal health especially where there is high consumption of these products (Keeton, 1994; Bolger *et al.*, 2017).

The transition of what needs to be eaten to sustain human body such as food containing the required protein, vitamins and energy is symbolised by consumption of more meat and meat products (Popkin, 2009; Lang and Barling, 2012). Presently, many people consume these processed meat products because these meals save time because they are faster to cook. Earlier studies indicates that consumption of high content of saturated and unsaturated fat, may increase the likelihoods of getting tumours of the colon, breast, prostate and endometrium (Claus, 1992; Chin *et al.,* 2004). Therefore, low level of fat in the diet can minimize the risk of these diseases. There are growing fears about the impending health threats related to high fat in our daily diet. This has led the food industries to improve the composition of processed meat products to attain fat reduction (Mendoza *et al.,* 2001; Lorenzo *et al.,* 2011). On the other hand, fat reduction beyond normal limits can lead to tough and undesirable appearance of the products (Keeton, 1994; Muguerza *et al.,* 2002; Lorenzo *et al.,* 2011).

Meat products such as fresh sausage vary from one region to another and are commonly stored chilled or frozen (Feiner, 2006). Meat contains abundant natural protein with vital micronutrients that are required for good health, while the dietary composition may vary to some extent depending on the breed, season and type of meat (William, 2007; Quasem *et al.,* 2009; McAfee *et al.,* 2010). The mineral content of meat is relatively constant under normal conditions but may depend on factors like animal genetic, physiological, environmental factor, meat cuts, meat processing and preparation (Lombardi- Boccia *et al.,* 2005; Jiménez-Colmenero *et al.,* 2006; Jiménez-Colmenero *et al.,* 2010). In this view, the amount and degree of macronutrients and micronutrients may change considerably, depending on the variety and quality of meat product consumed. The cooked meat may contain higher amount of protein as compared to raw meat because there is reduction in water content of the cooked meat whereas the nutrients become more condensed (Oz and Celik, 2015). For instance, red meat is known to have abundant supply of minerals, iron and zinc. The iron in the meat is in form of haem-iron that can be readily absorbed while absorption of zinc from red meat is beneficial to human. Apart from minerals, meat also contains fat otherwise called marbling, which is reasonably low and poor in mineral content (González-Tenorio *et al.*, 2012). In this regards, meat industry has shown great interest in sustaining high standard in the production of meat products, with great attention given to minerals composition which could satisfy consumers demand (Ramos *et al.*, 2013). The major minerals in meat are made of phosphorous and potassium with small amounts of sodium, magnesium, calcium and zinc. Minerals has been reported as structural components in cells and tissues for effective growth and biochemical metabolism (Lilly et al., 2017). The lack of an adequate quantity of essential minerals in the body may result in undesirable health aftermath and low productivity (Beighle, 2000; Murphy and Allen, 2003; Lilly et al., 2017). As a result of this, sodium, potassium, magnesium, calcium, phosphorus and other microminerals like iron, manganese, copper and zinc are needed to monitor the normal functioning of human body, such as formation of good bone and regulation of enzymes (Ersoy and Özeren, 2009; Karimian-Khosroshahi *et al*.,2016).

Meanwhile, observations have been made that consumers are more interested in what could make their health status better. Nutrition may not be the only factor responsible for good health, but it is definitely most imperative, and consequently there is growing mandate for harmless and improved foods. Lined with the foregoing, this shows that the underlying information on sausage quality is required to help consumers make to knowledgeable decision in purchasing such products. Thus, the objective of this study was to compare and examine the proximate and minerals composition of raw and cooked sausages made with edible meat waste as a fat replacer on different cooking methods.

5.2 Materials and methods

5.2.1 Description of the study site

The present study was submitted to and approved by the Ethics Committee of the University of Fort Hare. The study was conducted in Meat Science laboratory at the University of Fort Hare. Parts of the sausage batter produced from the previous chapter comprising of different mixtures of beef and edible meat waste were utilised in this study (Table 1). The sausages were cooked under two different cooking methods and sensory evaluation was conducted. However, the proximate and mineral analysis was carried out at the laboratory of Döhne Agricultural Development Institute, Stutterheim. Thus, two grams from each sausage treatments were used for proximate analysis (Moisture content, crude protein, Fat and Ash). These parameters were determined according to AOAC (2000).

5.2.2 Ethical Consideration

Ethical values were considered in this study to conform to the South African policy governing research of this type. Request was made to conduct a survey through questionnaire and it was approved by the Research Ethics Committee of the University of Fort Hare, South Africa. Ethical clearance certificate with reference number MUC341SBAB01 was issued to this effect.

5.2.3 Preparation of Sausages

All the sausages were prepared in the Meat Processing Laboratory of the Department of Livestock and Pasture Science, University of Fort Hare. The deboned lean meat and edible meat waste (TCO 90/10, WSO 30/70, WFO 50/50, TCM 90/10, WSM 30/70 and WFM 50/50) were prepared according to the required ratios and cooking methods respectively. Lean beef and edible meat waste samples were combined in ratios of 90:10, 50:50 and 30:70 and these were separated into three treatments with six (6) batches for each treatments. In general, the description of EMW in this study refers to meat waste generated during the meat cut and trimming at the abattoir and this usually consist of tendons, connective tissues and trimmed meat. Treatment 1 (T1) contains 30% lean beef and 70% for edible meat waste both cooking methods, Treatment 2 (T2) contains 50% lean beef and 50% for edible meat waste both cooking methods and Treatment 3 (T3) contains 90% lean beef and 10% fat for both cooking methods. All ingredients were properly weighted according to the instructions of the recipe prior to mixing.

The lean sirloin (90%) was purchased from East London Abattoir because the percentage of fat is theoretical close to the percentage of fat in beef meat. A complete seasoning pack was sprinkled and mixed thoroughly with the chopped meat before grinding. Each treatment (T1, T2 and T3) with six (batches) was mixed and grinded separately. The meat samples and edible meat waste were minced through a 5mm plate using a mincer (TC22 EL ELEG.PLUS, Italy) and processed within 24 hours following their storage at 4°C The emulsified meat were grinded again through the 5mm coarse plate at an approximate temperature of 18°C. The casing at the opening end of the tube was held cautiously with the forefinger and thumb. The batter was then pumped and stuffed lightly into 25mm diameter sheep sausage casing (Freddy Hirsch Company, Capetown. South Africa) with Tre-spade sausage filler tool. Subsequently, the stuffing were stopped about 50mm from end of the casing to tie the other end. Starting from one end of knotted batter filled casing, the sausage batter were twisted in the same direction at every 150mm to form a link. The raw sausages were cooked separately with two cooking method. The samples were vacuumed packed after cooling and stored under -4°C until they were ready for analysis.

5.2.4 Cooking Methods

5.2.4.1 Microwave

The prepared sausage samples were carefully arranged on the microwave plate and cooked in a domestic microwave grill oven (Litton Generation 2, Model SA 2075.002, Minneapolis USA) at 80°C for 4minutes. The experiment was executed at 700W for 4min while the internal temperature was measured using digital probe thermometer Thermo-pro TP- food thermometer). The samples are considered done when the digital thermometer gives an alarm and flashes green light. The samples were cooled at room temperature, vacuumed packed and stored at 80°C until the laboratory analysis was carried out.

5.2.4.2 Oven-grilling

The oven (Stove Defy Compact, Made in RSA) was pre-heated at 180 °C before the sausage samples were placed in the oven. The sausage samples were arranged in a tray according to their mixing ratios and the oven set to grilling. Samples were oven- grilled in a conventional oven (name of oven) until the internal temperature of the sausage fingers reached an average of 90°C. Thermometer (Thermo-pro TP- food thermometer) was pre-set to beef-medium to measure the internal temperature of the sausage. The thermometer was designed with LCD visual presentation and pre-set temperatures for meat at different cooking levels. By inserting the probe into the sausage the thermometer would indicate when the sausage was fully done by sounding an alarm with a flash. The time taken for the sausage to be cooed was 20minutes.

5.3 Mineral and Proximate Analysis

The cooked and raw samples of the sausage were freeze dried, vacuum packed and sent for mineral analysis at the laboratory of Döhne Agricultural Development Institute, Stutterheim. The laboratory used conventional method of the Association of Analytical Chemist (AOAC 2000;

AOAC 2005). The samples were analysed in triplicates. The determination of moisture content (official method of analysis 934.01), ash (official method of analysis 942.05), ethanol extraction (official method of analysis 954.02), nitrogen (official method of analysis 968.06) while 6.25 factor was used to calculate the crude protein. Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES) was used to determine the minerals in the sausage.

5.3.1 Sample Preparation

The samples for analysis were taken out of the freezer and allowed to thaw at room temperature at approximately 23°C and these were analyzed using standard American Official of Analytical Chemists (AOAC 2000, 2005).

5.3.2 Determination of crude protein

The Kjeldahl method was used to determine nitrogen (ALASA 2007**)**. The crude protein was later determined by multiplying the amount of total nitrogen content by 6.25. Two grams of the sample was digested in a kjeldahl flask (Gerhardt Kjeldatherm KB, Bonn, Germany) by boiling it with 25 ml concentrated sulfuric acid (H_2SO_4) using mercury tablets as catalysts and heated for 3hrs until the mixture was clear. The digested samples were cooled and transferred to volumetric flasks. Organic nitrogen was distilled from the flask in 40% of NaOH solution and received in 4% boric acid. The mixture was titrated against 0.1M of HCl solutions. The formula used for calculation of crude protein was as follows:

The % nitrogen content was calculated as:

Crude protein %= T x 0.1 x 14 x 100 x 6.25 Weight of sample x 1000 T= Titration volume

5.3.3 Determination of moisture content

Moisture content was based on weight loss of five gram of sample. An empty weighing crucible was oven dried at 105°C for 2hours and cooled in a desiccator and then weighed (W0). The samples of the sausage weighing 2g were put in a crucible (W1) and oven dried at 105°C for 24 hrs. The samples were then cooled in a desiccator after which their weights was determined (W2). The percentage moisture content was calculated as:

Moisture %= sample weight – dried sample weight/ sample weight X 100

$$= \frac{W1-W2}{W1-W0} \times 100$$

W0= weight of dry empty crucible

W1= weight of dry empty crucible + sample before drying

W2= weight of dry crucible+ dried sample at constant weight

5.3.4 Measurement of ash content

A porcelain crucible was dried in the oven at 105°C for 2 hours then allowed to cool in the desiccator and later weighed (W0). Two grams of the sample were placed into a dried crucible of known weight (W1). The crucible and the sample were later placed inside a muffle furnace at 150°C and ashed. The temperature was increased steadily till it reached 550°C for 3 hours. And the crucible was then taken out, cooled inside the desiccators and re-weighed (W2). The ash content was determined using a Phoenix microwave furnace (CEM corp., Matthews, NC) figure 1.

Figure 1: Phoenix microwave furnace (CEM corp)

Crucible plus sample weight (after ashing) - Pan weight = Sample ash weight

%Ash = (Ash weight/Dry weight) x 100

This means that the ash percentage was calculated by the following formula:

$$\% \text{ Ash content} = \frac{W1 - W0}{\text{Weight of sample}} \times 100$$

W1= Weight of crucible before ashing

Where W0= weight of empty crucible

W1= weight of crucible + Ash

5.3.5 Determination of crude fat

Fat was determined by the ether extract. Using soxhlet apparatus 2g from the sample were taken and were subjected to uninterrupted extraction with ether for 5 hrs. The sample was then moved out from the extractor and allowed to dry for 2 hours at 105^{o}C in the oven till no traces of ether remained. The sample was then cooled and weighed for ether extraction determination as following:

%fat= W1W0/weight of sample x 100

Where W0= weight of empty extraction flask

W1= weight of flask +oil extract

Lipids were extracted using a chloroform/methanol solution with butylated hydroxytoluene (BHT) as an antioxidant, and determined gravimetrically. Aliquots were taken from lipid extracts for determination of fatty acids. Whereas, protein content was determined using thermal conductivity on a Series II Nitrogen Analyzer 2410 (PerkinElmer Instruments, Norwalk, CT).

5.4 Mineral Analysis

5.4.1 Microwave digestion

Microwave digestion procedure was applied for chicken samples. One gram of each sample was digested with 6 mL of HNO_3 (65%) and 2 mL of H_2O_2 (30%) in microwave digestion system and diluted to 10 mL with deionized water. A blank digest was carried out in the same way. All sample solutions were clear. Digestion conditions for microwave system were applied as 2 minutes for 250 W, 2 minutes for 0 W, 6 minutes for 250 W, 5 minutes for 400 W, 8 minutes for 550 W and ventilation for 8 minutes, respectively.

5.4.2 Mineral Analysis using ICP-OES

Sausage samples (1g) were digested with 4ml of HNO3 (65%) and 2ml of H2O2 (30%) in microwave digestion oven. Microwave digestion method was used as a medium in order to complete digestion process in a short time. High pressure microwave oven (Multiwave 3000, Anton Paar, Germany) was used to carry out the digestion of the samples. After cooling, the resultant homogenized solutions were diluted up to 10 mL in volumetric flasks with 1 M HNO_3. Three replicates (acid digests) were performed for each sample. Calibration standards were used for the determination of iron, copper, zinc, manganese, potassium, sodium, calcium and magnesium. Concentrations of zinc, manganese, potassium, sodium, calcium and magnesium in the samples were determined using ICP-OES. The inductively coupled plasma-optical emission spectrometry (ICP-OES) was calibrated for Cu (224.7), Mn (257.6), Zn (214), Fe (237.1), Ca (393.4) and Mg (279.5nm) with nitric acid/water standard solutions of 2, 5 and 10 ppm of each element, and for Na (589.6) and K (766.5) with nitric acid/water standard solutions.

5.5 Statistical analysis

The Statistical Analysis System (SAS version 9.1.3 of 2007) was used for all the analyses. PROC GLM procedure of SAS was used to consider the effects of the types of cooking used (microwave and oven-grill) and meat type (90/10, 30/70, and 50/50) on the fatty acid beef sausage. Significant differences between the least square means for cooking oil types were performed using the Fishers' least significance difference (LSD) method of SAS, with a significance level of $p < 0.05$.

5.6 Results and Discussion

A relational difference between the states of moisture, protein, fat, and ash contents of sausages made with edible meat waste after cooking process are shown in Table 1. The moisture content of the uncooked sausage treatments decreased after cooking and the samples varied from 63.54 to 70.34%. In Table 2, the cooked sausages treatments had the lowest moisture contents which ranged from 53.36 to 56.3% per sample. The results indicated that, uncooked sausage treatments contained higher level of moisture as compared to the cooked treatments. The decline in moisture content can be as a result of evaporation during the cooking process as the temperature rises (del Pulgar *et* *al.*, 2012). However, Oz *et al.* 2017 reported that, as the temperature increases during the cooking process, the myofibrillar proteins becomes smaller and tauter. Similarly, Tornberg (2005) reported in his study that cooking may cause structural changes to occur rapidly while decreasing the amount water holding capacity in the meat. On the other hand, there is a reduction in the inter-fibrillar property of the sausage that causes the loss of moisture in myofibril. The results from this study showed that, cooking methods had a significant effect (P<0.01) on moisture content of the sausages. The moisture contents of the cooked sausages are different within the limits of 53.36% to 56.3% while the moisture content for the cooking methods were 51.37% and 57.55%. The oven-grilled samples had the highest moisture contents as compared to microwaved samples and they were statistically significant at P<0.01 (Table 2). It was also observed that the interaction of sausage treatment with cooking methods was significant at P<0.01 with the water content of the treatments.

Consequently, the moisture content in cooked sausage treatments was found to be indirectly related to the total lipid. The lipid content of uncooked treatment was 30/70 (11.29%) and 50/50 (7.49%) increased in the cooked samples 30/70 (14.46%) and 50/50 (11.24%) respectively (Table 1 and 2). The increase of lipid content in the microwaved sausage can be attributed to the oil penetration on the sausage after water is evaporated and partially lost (Saguy and Dana, 2003; Morris *et al.*, 2004; Sainsbury *et al.*, 2011; Kouba *et al.*, 2012). In this view, the results of the study align with Alfaia *et al.* (2010) who reported that, there were significant differences (p < 0.01) of total lipid content in microwaved sausage treatments only. However, there is significant increase in the ash and protein contents of the microwaved and oven-grilled sausages as compared to uncooked sausages. The protein content in the uncooked treatment was found to be lower 90/10 (11.02%), 30/70 (13.9%) and 50/50 (19.34%) as compared to the cooked treatments which was 90/10 (21.04%), 30/70 (26.13%) and 50/50 (26.17%) respectively. The cooking methods had a significant effect at P <0.01 on the nutrients availability. It was observed that the nutritional values of the sausage was better preserved after the cooking process due to higher mean values obtained after cooking.

Table: 1Proximate composition of raw sausage made with edible meat waste as fat replacer

Parameters	Sausage Type				
	90/10	30/70	50/50	SEM	P-Value
Lipid %	13.91[a]	11.29[b]	7.49[c]	0.21	0.0001
Ash %	3.64[c]	4.41[a]	4.38[b]	0.11	0.0001
Moisture %	70.34[a]	65.37[b]	63.54[c]	0.11	0.0001
Crude Protein %	11.02[c]	13.9[b]	19.34[a]	0.36	0.0001

Table 2: Proximate composition of raw sausage made with edible meat waste as fat replacer using different cooking methods

Parameters	Sausage Type (S)			Cooking Type (C)			P- Value		
	90/10	30/70	50/50	Microwave	Oven-G	SEM	S	C	S x C
Lipid %	10.29^{b}	11.87^{a}	10.29^{b}	13.05	8.58	0.1	0.0001	0.0001	0.0001
Ash %	8.71^{a}	5.47^{c}	5.79^{b}	5.06	8.25	0.45	0.0001	0.0001	0.0001
Moisture %	56.3^{a}	53.73^{b}	53.36^{c}	51.37	57.55	0.18	0.0001	0.0001	0.0001
Crude Protein %	21.04^{c}	26.13^{b}	26.17^{a}	27.49	21.41	0.68	0.0001	0.0001	0.0001

This emerging results were similar to the findings of Ersoy and Özeren. (2009); Marimuthu *et al.* (2012); Hosseini *et al.*, (2014) and Karimian-Khosroshahi *et al.*, (2016), who reported that cooking reduces moisture content and subsequently increase the concentration of lipid and protein. The protein content in the uncooked treatment (Table 1) was found to be lower in 90/10 (11.02%), 30/70 (13.9%) and 50/50 (19.34%) as compared to the cooked treatments (Table 2) which was 90/10 (21.04%), 30/70 (26.13%) and 50/50 (26.17%). The cooking methods had a significant effect at $P < 0.01$ on the nutrients availability. It was observed that the nutritional values of the sausage was better preserved after the cooking process due to higher mean values obtained. These results are similar to the findings of Ersoy and Özeren. (2009); Marimuthu *et al.* (2012); Hosseini *et al.*, (2014) and Karimian-Khosroshahi *et al.*, (2016), who reported that cooking reduces moisture content and subsequently increase the concentration of lipid and protein. This implies that, the dry cooking method retains the protein level much better than the boiling method (Bognar, 1998; Farfán and Sammán., 2003).

The findings of the study also indicated that, as the lipid content of the uncooked sausage samples decreased 13.91% (90/10), 11.29% (30/70) and 7.49% (50/50), the protein content increased 11.02% (90/10), 13.9% (30/70) and 19.34% (50/50). A recent study conducted by Cunningham *et al.* (2015) reported that, the values of ash were comparable in the treatments irrespective of lipid content, the result in the present study are in agreement with this report. Furthermore, the lipid content in the cooked sausage treatment 30/70 (11.87%) had the higher mean value as compared to 50/50 (10.29%) which is the same value with the control. In a similar way the protein content in the cooked sausage treatment was 30/70 (26.13%) and 50/50 (26.17%) close mean values as compared to the lower value in control (21.04%). Statistically, the results were significantly different at $P < 0.01$. As a result of this the decrease in lipid content in ratio 50/50 and higher protein contents may be adopted for commercial purposes. This is due to the fact that the lower lipid content and higher protein content have better health implication for consumer. This is parallel with the previous studies where it was reported that, a decrease in lipid content in meat product had a positive health implication on humans (Keeton, 1994; Bolger *et al.*, 2017).

The values of ash for raw and cooked sausages with edible meat waste as fat a replacer (30/70 and 50/50) and control (90/10) are shown in Table 1 and 2. Ash value is known as a pointer of total mineral content in a sample. The value obtained for raw sausage treatment was 3.64% (90/10), 4.41% (30/70) and 4.38% (50/50), while the ash contents increased in the cooked sausage treatments 8.71% (90/10), 5.47% (30/70) and 5.79% (50/50) respectively. The findings highlighted that cooking of the sausage treatments led to significant changes in ash content among treatments ($P < 0.01$). For instance, Table 2 showed that, cooking with a microwave (5.06 g/100 g) and oven-grilling (8.25 g/100 g) increased the ash content of the cooked sausage. These results are in agreement with Lopes *et al.* (2015) who reported that microwave and grilling are dry cooking methods and may be responsible for greater retention of ash compared to other cooking methods that involved cooking in water.

Table 3: Mineral composition of uncooked sausage made with edible meat waste

Parameters	Sausage Type				
g/100g	90/10	30/70	50/50	SEM	P-Value
Ca	286.18^a	132.18^b	114.79^c	0.005	0.0001
Mg	189.89^a	33.97^b	48.11^c	0.57	0.0001
K	206.64^b	113.83^c	207.81^a	0.001	0.0001
Na	566.47^a	530.79^b	527.35^c	2.71	0.0001
Cu	2.92^b	2.73^c	3.89^a	0.0008	0.0001
Fe	77.56^a	58.68^b	45.42^c	0.0007	0.0001
Mn	1.42^a	0.11^c	0.35^b	0.14	0.0001
Zn	61.05^a	28.09^b	26.44^c	0.03	0.0001

Table 4: Mineral composition of raw and cooked sausage made with edible meat waste

Parameters (g/100g)	Sausage Type			Cooking Type			P- Value		
	90/10	30/70	50/50	Microwave	Oven-G	SEM	S	C	S x C
Ca	173.1[c]	221.76[b]	231.29[a]	191.63	225.8	0.006	0.0001	0.0001	0.0001
Mg	83.43[c]	257.97[a]	127.27[b]	94.13	218.32	0.78	0.0001	0.0001	0.0001
K	444.57[a]	158.58[b]	156.67[c]	369.51	137.04	0.07	0.0001	0.0001	0.0001
Na	589.42[b]	604.45[a]	529.79[c]	599.74	549.36	0.04	0.0001	0.0001	0.0001
Cu	8.8[a]	7.07[b]	4.44[c]	6.9	6.64	0.002	0.0001	0.0001	0.0001
Fe	63.3[c]	85.38[a]	74.81[b]	73.16	75.84	0.003	0.0001	0.0001	0.0001
Mn	8.74[a]	0.65[b]	0.08[c]	5.97	0.34	0.01	0.0001	0.0001	0.0001
Zn	52.94[a]	35.27[c]	37.13[b]	47.43	36.12	0.82	0.0001	0.0001	0.0001

The cooking processes appeared to have an effect with regards to the mineral deposits in this study. Table 3 and 4 shows the minerals contents for uncooked and cooked sausage. It was observed that the mean value for sodium levels was lower for the un-cooked formulated sausages at 90/10, 30/70 and 50/50 was 566.47, 530.79 and 527.35 respectively (Table 3). Meanwhile, the mean values of cooked formulated sausages was 90/10, 30/70 and 50/50 was 589.42, 604.45 and 529.79 respectively (Table 4). These results could be attributed to salt addition and presence of sodium from the spices in form of sodium phosphates. The sodium in the cooked sausage was found to be relatively higher in treatment with the higher proportion of edible meat waste (30/70). The increase in the sodium content could be as a result of additional salt added to enhance the palatability of the sausage. In addition, this could also be as a result of the cooking methods which reduces the moisture content and therefore increase nutrient concentration in the sausage (Sales *et al.*, 1996; Badiani *et al.*, 2002). Table 4, revealed that the level of sodium in the cooked and uncooked sample had significant of effect ($p < 0.01$) on the level of edible meat offal in the sausages.

The zinc levels were considerably higher in the cooked sausages with edible meat waste of 30/70 (28.09) and 50/50 (26.44), which perhaps revealed the use of leaner meat that contains more zinc than (FSANZ. 2015). In addition, the cooked sausage treatments had Zn value that was significantly higher ($p < 0.01$) than the, mean values parallel to the raw samples. A similar trend was observed in the Fe contents in the cooked formulated sausage which increased in 30/70 (85.38) and 50/50 (74.81) in comparison to the control of 90/10 (63.3). However, the indissoluble mineral resources like iron and zinc are associated with meat proteins. Therefore, this study showed that Fe and Zn concentration in cooked samples was increased. The findings of this study are similar to an earlier study conducted by Severi *et al.* (1997) who reported that cooking is accountable for bioavailability of iron.

The mean values for calcium were (173.1, 221.76, 231.29), potassium (444.57, 158.58, 156.67), magnesium (84.43, 257.97, 127.27), zinc (52.94, 35.27, 27.13), copper (8.8, 7.07, 4.44), manganese (8.74, 0.65, 0.08), sodium (589.42, 604.45, 529.79) and iron (63.3, 85.38, 74.81) in cooked. And the mean values for calcium (286.18, 132.18, 114.79), potassium (206.64, 113.83, 207.81), magnesium (189.89, 33.97, 48.11), zinc (61.05, 28.09, 26.44), copper (2.92, 2.73, 3.89), manganese (1.42, 0.11, 0.35), sodium (566.47, 530.79, 527.35) and iron (77.56, 58.68, 45.42) in uncooked sausage varied greatly among the treatments as reported by Oz *et al.* (2017). Reasons being that, the edible meat waste collected at the abattoir is a mixture from different breed, management system, muscle type and nutrition type. This degree of unevenness and lack of uniformity in mineral composition may be credited to several features, such as muscle type (Hermida *et al.*, 2006), breed (Farfán & Sammán, 2003), nutrition (Driskell *et al.*, 2011) and production area (Hoffman *et al.*, 2007).

Table 4 showed the result of minerals in cooked meat. Thus, it could be deduced that, the cooked sausages showed higher mineral contents as compared to the raw samples owing to the evaporation and moisture loss during cooking process. Furthermore, cooking processes affected the various minerals in different ways. For instance, there was a slight change in the content of iron and it was significant at P < 0.01. on the other hand, the mean values of zinc (35.27 g/100g, 7.07 g/100g) and copper (37.13g/100g, 4.44 g/100g) in cooked treatments 30/70 and 50/50 increased and were significantly different at P <0.01. There is a significant increase in the contents of magnesium in between the cooking methods. Magnesium contents in oven-grilling (218.32g/100g) was higher than using the microwave at (94.13g/100g) and this was also significant at P <0.01. However, the potassium content declined after cooking. This may be due to a very high temperature which prompts evaporation and water loss thereby condensing the minerals.

5.7 Conclusion

Sausage is one of the important meat products that are in high demand throughout the world and this is likely to increase in the coming years. Unfortunately, the cost of the meat products such as sausage are sometimes on the high side. This study showed that edible meat waste could be utilized in comminuted meat products with reduced fat content in the final product. Protein content, fat content, ash content and crude fiber content were increased, with the inclusion level of 50% edible meat waste. The results of the study also showed that, edible meat waste acted as a fat replacer in beef sausage production and could be a beneficial substitute in the meat industry. This study showed that edible meat waste have the potential to provide value addition and equally minimise waste production at the abattoir. Thus, it may be concluded that edible meat waste could be added at 50% for consumers who would like to reduce their fat intake. When raw and cooked sausages were compared, the results showed that cooking had a significant effect on the proximate composition of sausages made with edible meat waste. The results that were obtained for proximate and mineral composition, indicated that the use of microwave was found to be the best cooking technique for healthy eating.

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CHAPTER SIX

EFFECT OF COOKING OIL ON FATTY ACID PROFILE OF BEEF SAUSAGE FORTIFIED WITH EDIBLE DEBONED MEAT WASTE

Abstract

The effect of frying with two different oils (sunflower oil and olive oil) on the fatty acid composition of sausage made with edible meat waste as fat replacer was evaluated. The sausage were formulated in ratios of 30% lean meat and 70% edible meat waste T1 (30/70), 50% lean meat and 50% edible meat waste T2 (50/50) and 90% lean meat and 10% fat T3 (90/10) respectively. The proximate analysis results revealed significant differences ($p < 0.05$) in fat, fat free dry matter (FFDM) and moisture contents across the treatment. The beef sausage containing 70% edible meat wastes (T1) had a higher fat content (25.7±0.83%) than other treatments. On the other hand, beef sausage fortified with 10% fat (T3) had lowest fat content but, consisted of highest FFDM (55.85±0.57%) and moisture content (69.15±0.62) than other treatments. In addition, among individual saturated fatty acids, beef sausage fortified with 50% meat wastes (T1) revealed significantly higher palmitic (31.06±0.13), Stearic acid (22.52±0.29), Myristic (3.84±0.05), Lauric (0.04±0.05) and lowest Margaric (0.98±0.02) contents as compared to treatment T2 and T3. The polyunsaturated fatty acid content were significantly higher in beef sausage containing 10% fat (T3) as compared to treatments T1 and T2. In general, it was observed that the values of total monounsaturated fatty acid, polyunsaturated fatty acid, *n-6*, *n-3,* PUFA: SFA, PUFA/MUFA, n-6/n-3 and desaturase indexes (DI) were higher in beef sausage fortified with 10% fat than other treatments. The interactions of MUFA, PUFA, omega-6 and PUFA/SFA ratio of the fried sausages significantly increased in comparison to raw samples while, the amounts of SFA decreased.

Keywords: sunflower oil, olive oil, sausage, fatty acid, edible meat waste

6.1 Background of the study

Meat and meat products are important sources of protein, fat, essential amino acids, minerals, vitamins and other bioactive compounds in human diet (Decker and Park, 2010). The extant literature shows that, much attention has been directed to the production, development and culinary process of meat and meat products to improve palatability, tenderness and nutritional content, promote health conditions and to prevent the risk of diseases (Brugiapaglia and Destefanis, 2012; El-Nashi *et al.*, 2015). The culinary process is often carried out either by frying, grilling, roasting or microwave. However, frying of meat has been a common practice and accepted for a relatively long time due to better sensational qualities of the end products. Frying is a cooking method that help to render potential organism inactive and increases nutrient availability of a product (Bognar, 1998). The temperature used for frying is normally between 170°- 200°C (Wai, 2007). During the course of frying, water and volatile elements are evaporated from meat products while a small part or a portion that remains is retained in the fried meat products (Wai, 2007; Ghidurus *et al.*, 2010). Nevertheless, superficial oil on the meat products does not enters the microstructure of the product until the cooling stage (Pedreschi, 2012).

According to Estévez *et al.*, (2004); Ramírez *et al.*, (2005) frying with vegetable oil brings out some changes and variations in meat products, this changes may include alteration in fatty acid profile, and cooking loss. The chemical changes that occurs during recurrent frying and within the oil is due to the formation of non-volatile compound which often make the product unsuitable for consumption as a result of nutritional disintegration (Ghidurus *et al.*, 2010). The heat effect causes the cell structures of the meat to be disrupted and provide a series of polyunsaturated fatty acids leading to lipid oxidation, hydrolysis, polymerization and decomposition (Romero *et al.*, 2000; Pedreschi. 2012). The lipid polymers generated from oxidized products as a result of recurrent frying contains a significant quantity of cholesterol and saturated fatty acids (Ghidurus *et al.,* 2010; Calder, 2015). Other factors influencing transmission of heat when meat products are being fried consist of the shape of the product, oil temperature, pressure and chemical properties of the oil and the product (Pedreschi, 2012). Furthermore, during heating (frying), the polyunsaturated fatty acid (PUFA) for example eicosapentaenoic and docosahexaenoic are to a large extent more affected by oxidative deterioration of lipid that may cause discolouration and unpalatable flavour (Chowdhury *et al.,* 2007; Weber *et al.,* 2008; Jones- Hamlow *et al.,* 2016).

Research studies indicated that, vegetable oil represents a well-known dietary source of energy. The utilization of vegetable oil in meat products is effective in lowering the amount of saturated fatty acid contents thereby giving a positive effect on human health (Zheljazkov *et al.,* 2009; Rodríguez-Carpena *et al.,* 2012). Studies established that olive oil has beneficial effects in relation to nutritional value, a high level of oleic acid and monounsaturated fatty acid (MUFA) while sunflower increases the oxidative stability due to higher level of polyunsaturated fatty acid (Nuernberg *et al*., 2005; Rodríguez-Carpena *et al*., 2012). Any quantity of oil used in frying meat can either increase or reduces fatty acid profile and this depends on the type of oil used. A minimal amount of the fatty acid profile found in meat after frying implies that the oil may have good health implication (Romero *et al.,* 2000; Ghidurus *et al.,* 2010). Therefore, an examination of the quantity of dietary fat and the ratio of saturated, monounsaturated and polyunsaturated fatty acid in a fried product is important (Sheard *et al.,* 1998) in meat industry.

Presently, the interest of many researchers is to produce meat products, such as meat sausage, that can promote human health conditions. Meat sausages are usually made from ground meat (pork, beef, mutton, poultry or veal) along with salt, spices and other flavouring ingredients. In addition, products such as pork backfat, camel hump fat, beef fat, edible animal by-products and vegetable oils have been incorporated into meat sausages with specific amount to enrich their textural and sensory quality, nutritional content and reduce their production cost (Kargozari *et al.*, 2014; Leite *et al.*, 2015; Singh *et al.*, 2015; Monteiro *et al.*, 2017). Therefore, the aim of the present study was to evaluate the effect of cooking oils on fatty acid profile of beef sausages fortified with edible meat waste.

6.2 Materials and methods

6.2.1 Description of the study site

The study was conducted in a commercial abattoir in East London situated under Buffalo City Metropolitan Municipality and Meat Science laboratory at the University of Fort Hare. The East London abattoir is located 120 km away from Alice where the University of Fort Hare is established at latitudes and longitudes of 32.97 º S and 27.87 º E. The East London abattoir is a high throughput equipped with sophisticated machines and equipment fit for a standard abattoir. The lean beef meat and edible meat waste were collected separately from cattle slaughtered using the halal method at the high throughput abattoir. Samples were packed in low density poly ethylene plastic bags and kept in a cooler. Ice packs were placed on the samples inside the cooler to keep the temperature at 4º C and it was transported to the laboratory within 180minutes

6.2.2 Production of Meat Sausage:

6.2.2.1 Sausage preparation.

The deboned lean meat (Figure.1) and edible meat waste (EMW) were procured from high throughput commercial abattoir, in East London, South Africa and processed to produce beef sausage. Lean beef and edible meat waste samples were combined in ratio 90:10, 50:50 and 30:70 respectively into three treatments. EMW in this study refers to meat waste generated during the cutting and trimming of the meat at the abattoir and this usually consist of tendons, connective tissues and trimmed meat fat (Figure.2a and 2b). For instance, Treatment 1 (T1) contains 30% lean beef and 70% EMW, Treatment 2 (T2) contains 50% lean beef and 50% EMW and Treatment 3 (T3) contains 90% lean beef and 10% EMW. All ingredients were properly weighted in accordance with the recipe instructions prior to mixing.

Figure. 1 Deboned lean beef

Figure. 2a Edible meat waste

Figure. 2b Edible meat waste

6.2.2.2 Grinding

The beef meat and edible meat waste were first chopped into 0.00129 meters square and dispersed widely in a bowl, they were then pulverized to particle size in an electrical grinder. To ensure a consistent distribution of the seasoning and improve the binding quality, ice was mixed with the chopped meat (Figure.3). A complete seasoning pack was sprinkled and mixed thoroughly with the chopped meat before grinding (Figure.4). Each treatment was mixed and grinded separately. The meat samples and edible meat waste were minced through a 5mm plate (Figure.5) using a mincer (TC22 EL ELEG.PLUS, Italy) and processed within 24 hours following their storage at 4^{o}C. The emulsified meat was grinded again through the 5mm coarse plate at a temperature of 18^{o}C. At this stage the homogenized batter emulsion had absorbed all the water.

Figure. 3 Ice mixed with chopped meat

Figure. 4 Mixing of the spice with the beef cuts

Figure. 5   Grinding of the beef cuts and the edible meat waste

6.2.2.3 Casing preparation

A small piece of sheep casing was cut off at about 1.2m long. The preservation salt on the sheep casing were rinsed off under cold tap water. The rinsed casings were then placed in a bowl to soak it for about 45 minutes. One open end of the casing was opened under the tap to allow the free flow of water to run through the casing. The casings were left inside a bowl of water, rinsed and drained before use.

6.2.2.4 Filling

The air in the homogenized sausage emulsion were excluded through the vacuum filling tool. This was to minimize oxidation of fat and improve the visual impression of the sausage. Sheep casing was kept in warm water during the filling process. The attached tube on the filler was lightly grease with water to prevent the casing from tearing. The casing was moved smoothly over the sausage funnel tube until it filled the funnel (Figure. 6). About 50mm of the casing was pulled off from the several folds on the tube and tied to prevent air coming out from the casing. The casing at the opening end of the tube was held cautiously with the forefinger and thumb. The batter was then pumped and stuffed lightly into 25mm diameter sheep sausage casing (Freddy Hirsch Company, Capetown. South Africa) with Tre-spade sausage filler tool. Thereafter, the stuffing were stopped about 50mm from end of the casing to tie the other end. Starting from one end of knotted batter filled casing, the sausage batter were twisted in the same direction at every 150mm to form a link (Figure.7).

Figure. 6 Casing attached to the filler

Figure. 7 Knotted sausages

6.2.3 Cooking procedure

Frying: The sausage samples were carefully placed in a non-sticky frying pan containing oil. The shallow frying method was used for all the samples at160-180^{o}C using Olive and Sunflower oil. All the treatments consisted of eight sausage fingers with an average weight of 125g each. From the treatments, three fingers of sausages weighing a total of 375g were fried for 5-10 minutes using two types of cooking oils (Olive and Sunflower) separately. During the period of frying, a probe thermometer (Thermo-pro TP- food thermometer) was inserted in geometrical centre of the sausage without touching the bottom of the frying pan to measure the internal temperature of the sausages and to receive notification when they are cooked. The samples were considered done when the digital thermometer gave an alarm and flashed green light. The samples were drained, cooled at room temperature, vacuumed packed and stored at 80^{o}C until laboratory fatty acid analysis was carried out.

6.2.4 Determination of fatty acid composition

A lipid aliquot (±30 mg) of sausage batter lipid were converted to methyl esters by base-catalyzed transesterification, in order to avoid CLA isomerization, with sodium methoxide (0.5 M solution in anhydrous methanol) during 2 h at 30 °C, as proposed by Park *et al.,* 2001; Kramer *et al*., 2002; Alfaia *et al*., 2007. Fatty acid methyl esters (FAMEs) from sausage batter lipid were quantified using a Varian 430 flame ionization GC, with a fused silica capillary column, Chrompack CPSIL 88 (100 m length, 0.25 mm ID, 0.2 μm film thicknesses). Analysis was performed using an initial isothermic period (40°C for 2 minutes). Thereafter, temperature was increased at a rate of 4°C/minute to 230°C. Finally an isothermic period of 230°C for 10 minutes followed. FAMEs n-hexane (1μm) were injected into the column using a Varian CP 8400 Auto sampler. The injection port and detector were both maintained at 250°C. Hydrogen, at 45 psi, functioned as the carrier gas, while nitrogen was employed as the makeup gas. Galaxy Chromatography Data System Software recorded the chromatograms.

Fatty acid methyl ester samples were identified by comparing the retention times of FAME peaks from samples with those of standards obtained from Supelco (Supelco 37 Component Fame Mix

47885-U, Sigma-Aldrich Aston Manor, Pretoria, South Africa). Conjugated linoleic acid (CLA) standards were obtained from Matreya Inc. (Pleasant Gap, Unites States). These standards included: cis-9, trans-11 and trans-10, cis-12-18:2 isomers. Heneicosenoic acid (C21:0 was used as the internal standard to improve quantitative FAME estimation.

Fatty acids were expressed as the proportion of each individual fatty acid to the total of all the fatty acids present in the sample. Fatty acid data were used to calculate the following ratios of FAs: total SFAs total MUFAs; total PUFAs; PUFA/SFA; Δ^9 desaturase index (C18:1*c*9/C18:0); total omega-6; total omega-3; the ratio of omega-6 to omega-3 (*n*-6)/(*n*-3) FAs. Atherogenicity index (AI) was calculated as: AI = (C12:0 + 4 x C14:0 + C16:0)/(MUFA + PUFA) (Chilliard *et al.*, 2003).

6.3 Statistical analysis

The Statistical Analysis System (SAS version 9.1.3 of 2007) was used for data analysis. PROC GLM procedure of SAS was used to consider the effect of the types of cooking oil (Olive oil and sunflower oil) and meat type (T1, T2, and T3) on the fatty acid beef sausage. Significant differences between the least square means for types of cooking oil were performed using the Fishers' least significance difference (LSD) method of SAS, with significance level of $p < 0.05$

6.4 Results and Discussion

Result of the proximate analysis of selected nutrients in raw beef sausages fortified with edible meat wastes is shown in Table 1. The result revealed significant differences ($p < 0.05$) in intramuscular fat, fat free dry matter (FFDM) and moisture contents across the treatments. As expected, beef sausage containing 70% edible meat wastes (T1) had higher fat content (25.7±0.83%) than other treatments. Beef sausage fortified with 10% fat (T3) had the lowest fat content but highest FFDM (55.85±0.57%) and moisture content (69.15±0.62) than other treatments. A similar trend was also observed in the fried beef sausage, with treatment containing 70% edible meat wastes (T1) having the highest fat content and lowest moisture content while treatment T3 had the lowest fat content and highest moisture content. The results of the study revealed that, the fat content of the beef sausages in this study fell within the standard fat content of sausages (Malekian *et al*., 2014; Lee *et al.,* 2015). Furthermore, Lee et al. (2015) state that the fat content of sausages can be as high as 30%. Meanwhile, it could be concluded from the emerging results that cooking beef sausage with sunflower oil revealed higher significant value ($p<0.05$) in fat content (18.36%) and lower FFDM (25.93%) and moisture (55.91%) contents compare those cooked with olive oil. This could be attributed to the inherent fat and fatty acid content of each of the oil.

Table 1: Proximate composition of the raw beef sausage fortified with edible animal wastes

Parameters	**Sausage Type**			***P-value***
	T1	**T2**	**T3**	
Fat (%)	25.7 ±0.83^{a}	24.34±0.70^{a}	8.43±0.76^{b}	0.01
Fat free dry matter (%)	19.50±0.22^{a}	19.92±0.19^{a}	22.42±0.20^{b}	0.01
Moisture (%)	54.83±0.67^{a}	55.85±0.57^{a}	69.15±0.62^{b}	0.01

T1: beef sausage containing 30% lean beef and 70% EMW, T2: beef sausage containing 50% lean beef and 50% EMW, T3: beef sausage containing 90% lean beef and 10% fat. Significance: ($P\leq0.05$), Not significant: ($P>0.05$)

Table 2: Effect of cooking oil on the proximate composition of the beef sausage fortified with edible meat wastes

Parameters	**Sausage type (S)**			**Cooking oil Type (O)**			***P-value***		
	T1	**T2**	**T3**	**Olive**	**Sunflower**	**SEM**	**O**	**S**	**O x S**
Fat (%)	23.5[a]	19.76[b]	9.31[c]	16.68	18.36	0.31	0.01	0.01	0.11
Fat free dry matter (%)	24.06[c]	25.67[b]	28.67[a]	26.32	25.93	0.23	0.23	0.01	0.09
Moisture (%)	52.44[c]	54.57[b]	62.05[a]	56.99	55.91	0.28	0.01	0.01	0.44

T1: beef sausage containing 30% lean beef and 70% EMW, T2: beef sausage containing 50% lean beef and 50% EMW, T3: beef sausage containing 90% lean beef and 10% EDMW. Significance: ($P \leq 0.05$), Not significant: ($P > 0.05$)

Table 3 showed the fatty acid composition of the beef sausages fortified with edible meat waste. There were significant difference ($p<0.05$) in individual fatty acid composition of raw beef sausage across the treatments. Among individual saturated fatty acids, beef sausage fortified with 50% meat wastes (T1) revealed significantly higher palmitic (31.06±0.13), Stearic acid (22.52±0.29), Myristic (3.84±0.05), lauric (0.04±0.05) and lowest Margaric (0.98±0.02) contents compared to treatment T2 and T3. On the other hand, the individual monounsaturated fatty acid showed that beef sausage fortified with 10% fat (T3) had higher oleic (39.25±0.34), vaccenic (0.52±0.02), heptadecenoic (0.67±0.02) content and lowest myristoleic (0.45±0.01) and palmitoleic (2.50±0.05) content as compared to Treatment T1 and T2. The individual polyunsaturated fatty acid content were significantly higher in beef sausage containing 10% meat wastes (T3) as compared to treatments T1 and T2. In general, it was observed that the values of total monounsaturated fatty acid, polyunsaturated fatty acid, *n-6*, *n-3*, PUFA: SFA, PUFA/MUFA, n-6/n-3 and desaturase indexes (DI) were higher in beef sausage fortifies with 10% fat than other treatments. Omega-3 (n-3) and omega-6 (n-6) are two groups of PUFA which is based on the position of the last double bond relative to the terminal methyl end of the molecule (Wall et al., 2010; Patterson et al., 2012) Meanwhile, the beef sausage fortified with 50% edible meat wastes (T2) had higher saturated fatty content and atherogenicity (AI) compared to treatment T1 and T3. Thus, the findings in this study was in agreement with Food and Agriculture Organization of the United Nations and World Health Organization, where the values of n-3: n-6 ratio and PUFA : SFA for raw beef sausages fell within the recommended ratio of ≥ 1 and > 0.04, respectively, as required in human diet (Simopoulos, 2002, 2008; FAO 1994; Gladyshev *et al.,* 2006; Gómez-Candela *et al.,* 2012). However, there is a dearth of literature to support the findings from this study because there continues to be scanty research work that has focused on evaluating the fatty acid composition of beef sausages fortified with edible meat waste.

Table 3: Fatty acid composition of the raw beef sausage fortified with edible animal waste

Parameter (%)	**Sausage Type**			***P-value***
	T1	**T2**	**T3**	
Saturated fatty acid (SFA)				
Lauric	0.03±0.01[a]	0.03±0.01[a]	0.02±0.01[b]	0.02
Myristic	3.74±0.05[a]	3.84±0.05[a]	2.68±0.05[b]	0.01
Pentadecylic	0.41±0.01[a]	0.39±0.01[a]	0.39±0.01[a]	0.30
Palmitic	30.5±0.15[b]	31.06±0.13[a]	27.02±0.14[c]	0.01
Margaric	1.07±0.02[b]	0.98±0.02[c]	1.26±0.02[a]	0.01
Stearic acid	22.0±0.34[a]	22.52±0.29[a]	20.24±0.31[b]	0.01
Arachidic	0.15±0.03[a]	0.14±0.004[a]	0.12±0.004[b]	0.01
Total SFA	58.09±0.46[a]	59.10±0.39[a]	51.90±0.42[b]	0.02
Monounsaturated fatty acids (MUFA)				
Myristoleic	0.66±0.02[a]	0.65±0.01[a]	0.45±0.01[b]	0.01
Palmitoleic	3.02±0.05[a]	3.09±0.04[a]	2.50±0.05[b]	0.01
Heptadecenoic	0.64±0.02[b]	0.56±0.02[c]	0.67±0.02[a]	0.001
Vaccenic	0.22±0.02[a]	0.20±0.02[a]	0.52±0.02[b]	0.01
Oleic	35.26±0.37[b]	34.07±0.32[c]	39.25±0.34[a]	0.01
Erucic	0.02±0.01[a]	0.23±0.01[a]	0.12±0.01[b]	0.01
Total MUFA	39.99±0.42[b]	38.78±0.36[c]	43.98±0.39[a]	0.01
Polyunsaturated fatty acids (PUFA)				
Conjugated linoleic acid (CLA)	0.24±0.01[a]	0.24±0.01[a]	0.32±0.01[b]	0.01
Linoleic	1.27±0.07[b]	1.47±0.06[c]	2.97±0.06[a]	0.01
Linolelaidic	0.04±0.01[a]	0.05±0.01[a]	0.00±0.01[b]	0.02
α-Linolenic	0.32±0.01[b]	0.29±0.01[c]	0.38±0.01[a]	0.01
Eicosenoic	0.32±0.00[a]	0.29±0.00[a]	0.38±0.00[a]	0.84
Elaidic	0.12±0.01[a]	0.13±0.01[a]	0.42±0.01[b]	0.01

Phytanic	0.06±0.00[a]	0.06±0.00[a]	0.04±0.00[b]	0.01
Arachidonic	0.06±0.25[a]	0.09±0.02[a]	0.41±0.02[b]	0.01
Nonoadecanoic	0.07±0.01[a]	0.08±0.01[a]	0.15±0.01[b]	0.01
Docosapentaenoic	0.00±0.01[a]	0.00±0.01[a]	0.07±0.01[b]	0.01
Total PUFA	1.93±0.09[a]	2.12±0.08[a]	4.12±0.09[b]	0.01
n-6	1.61±0.09[c]	1.83±0.07[b]	3.69±0.08[a]	0.30
n-3	0.32±0.01[a]	0.31±0.01[a]	0.43±0.01[b]	0.01
PUFA:SFA	0.04±0.00[a]	0.04±0.00[a]	0.08±0.00[b]	0.01
PUFA/MUFA	0.05±0.00[c]	0.05±0.00[b]	0.10±0.00[a]	0.01
n-6/n-3	5.06±0.21[c]	6.22±0.18[b]	8.43±0.12[a]	0.01
Atherog. Index	0.82±0.01[b]	0.86±0.01[a]	0.62±0.01[c]	0.01
Desaturas. Index	1.60±0.04[a]	1.52±0.04[a]	1.96±0.04[b]	0.01

T1: beef sausage containing 30% lean beef and 70% EMW, T2: beef sausage containing 50% lean beef and 50% EMW, T3: beef sausage containing 90% lean beef and 10% EDMW. Significance: ($P \leq 0.05$), Not significant: ($P>0.05$)

As shown in Table 4, there were variations in fatty acid composition between samples ($P < 0.05$). As expected, beef sausage containing 10% fat (T3) had lowest total SFA, and highest MUFA and PUFA compared to treatment T1 and T2. In comparison to the raw beef sausage, cooking of the meat samples by frying significantly decreased the percentage of individual SFA values while, increasing the individual MUFA and PUFA values as well as n-*6, n-3, PUFA*: SFA, PUFA/MUFA, n-6/n-3, atherogenicity (AI) and desaturase indexes values across the treatments. These results are similar to the findings of Cunningham et al. (2015) who reported that beef sausage cooked by pan-frying had lower SFA content and higher MUFA and PUFA, compared to raw sausages. Furthermore, the cooking of beef sausages with olive oil greatly increased the content of individual saturated and monounsaturated fatty acidy compared to cooking with sunflower oil ($P<0.05$). While on the other hand, cooking of beef sausage with sunflower oil revealed higher PUFA, *n-6, n-3, PUFA*: SFA, PUFA/MUFA, n-6/n-3, atherogenicity (AI) and desaturase indexes values than cooking with olive oil. These differences could be attributed to the individual fatty acid content of the cooking oil. Sunflower oil used in this study is known to contain 9.40% SFA, 28.30% MUFA, 62.40% PUFA, 0.2% n-3 PUFAs and 62.4% n-6 PUFAs (Orsavova et al., 2015). While Olive oil contains 19.4% SFA, 68.2% MUFA, 18.0% PUFA, 1.6% n-3 PUFAs and 16.4% n-6 PUFAs (Orsavova et al., 2015). The study also reported that meat samples that were fried with canola cooking oil had higher n-6, MUFA and PUFA content as compared to meat that was cooked through boiling and baking (Neff *et al.,* 2014). Similarly, Asmaa and Tajul. (2017) found that, chicken sausage fried with palm oil had higher fatty acids content than other treatments. All the authors attributed the increase in fatty acid content to the amount of oil retention on meat samples after cooking. Likewise, a recent study has also shown that people eating diet cooked with

Soyabean oil significantly had higher serum α-linolenic acid concentrations compared to those fed diet cooked sunflower oil (Villamor *et al.*, 2015).

Table 4: Effect of cooking oil type on fatty acid composition of the beef sausages fortified with edible meat waste.

Parameters (%)	Sausage Type (S)			Cooking oil Type (O)			*P-value*		
	T1	**T2**	**T3**	**Olive**	**Sunflower**	**SEM**	**O**	**S**	**O x S**
Saturated fatty acid (SFA)									
Lauric	0.01^{a}	0.03^{b}	0.00^{c}	0.02	0.01	0.003	0.37	<0.01	0.599
Myristic	3.59^{b}	3.74^{a}	2.60^{c}	3.37	3.27	0.031	0.01	<0.01	0.176
Pentadecylic	0.38^{a}	0.38^{a}	0.37^{a}	0.38	0.38	0.006	0.52	0.65	0.537
Palmitic	30.03^{b}	31.12^{a}	26.48^{c}	29.45	28.96	0.158	0.04	<0.01	0.993
Margaric	1.01^{b}	0.94^{c}	1.19^{a}	1.05	1.05	0.011	0.80	<0.01	0.738
Stearic acid	20.42^{b}	20.94^{a}	18.90^{c}	20.07	20.11	0.159	0.87	<0.01	0.562
Arachidic	0.12b	0.13^{a}	0.11^{c}	0.11	0.12	0.002	0.02	<0.01	0.542
Total SFA	55.67^{b}	57.69^{a}	49.16^{c}	54.58	54.02	0.280	0.167	<0.01	0.931
Monounsaturated fatty acids (MUFA)									
Myristoleic	0.71^{b}	0.66^{b}	0.02^{a}	0.63	0.59	0.015	0.08	<0.01	0.810
Palmitoleic	3.26^{a}	3.25^{a}	2.58^{b}	3.09	2.96	0.044	0.04	<0.01	0.441
Heptadecenoic	0.67^{b}	0.57^{c}	0.68^{a}	0.65	0.63	0.007	0.16	<0.01	0.144
Vaccenic	0.26^{b}	0.20^{c}	0.48^{a}	0.32	0.31	0.010	0.88	<0.01	0.600
Oleic	36.99^{b}	34.34^{c}	39.35^{a}	37.18	36.61	0.258	0.12	<0.01	0.514
Erucic	0.02^{b}	0.05^{a}	0.18^{c}	0.08	0.09	0.005	0.22	<0.01	0.763
Total MUFA	42.08^{b}	39.31^{c}	44.16^{a}	42.21	41.49	0.295	0.093	<0.01	0.445
Polyunsaturated fatty acids (PUFA)									
Conjugated linoleic acid (CLA)	0.23^{a}	0.20^{a}	0.30^{b}	0.25	0.24	0.010	0.39	<0.01	0.596
Linoleic	1.58^{b}	2.65^{c}	4.58^{a}	2.29	3.57	0.255	<0.01	<0.01	0.241
Linolelaidic	0.01^{a}	0.01^{a}	0.01^{a}	0.01	0.01	0.006	0.60	0.88	0.591
α-Linolenic	0.33^{b}	0.31^{a}	0.39^{c}	0.34	0.34	0.005	0.93	<0.01	0.747
Eicosenoic	0.06^{a}	0.06^{ab}	0.04^{b}	0.05	0.05	0.005	0.74	0.05	0.596
Elaidic	0.13^{a}	0.19^{a}	0.39^{b}	0.22	0.25	0.022	0.43	<0.01	0.441
Phytanic	0.06^{a}	0.05^{b}	0.04^{c}	0.05	0.05	0.001	0.55	<0.01	0.542
Arachidonic	0.09^{a}	0.13^{a}	0.62^{b}	0.28	0.28	0.019	0.80	<0.01	0.595

Nonoadecanoic	0.06^{a}	0.06^{a}	0.13^{b}	0.08	0.09	0.003	0.14	<0.01	0.514
Docosapentaenoic	0.00^{a}	0.00^{a}	0.11^{b}	0.03	0.04	0.005	0.54	<0.01	0.691
Total PUFA	2.23^{c}	3.29^{b}	6.02^{a}	3.21	4.49	0.251	0.0012	<0.01	0.248
n-6	1.90^{c}	2.99^{b}	5.52^{a}	2.83	4.10	0.252	0.0012	<0.0001	0.245
n-3	0.33^{a}	0.31^{a}	0.51^{c}	0.38	0.38	0.009	0.717	<0.0001	0.859
PUFA:SFA	0.04^{a}	0.06^{a}	0.12^{b}	0.06	0.09	0.005	0.0019	<0.0001	0.260
PUFA/MUFA	0.05^{c}	0.09^{b}	0.14^{a}	0.08	0.11	0.007	0.0014	<0.0001	0.180
n-6/n-3	5.74^{ab}	9.94^{a}	10.98^{a}	7.16	10.62	0.714	0.002	<0.0001	0.156
Atherog. Index	0.76^{b}	0.82^{a}	0.58^{c}	0.73	0.71	0.008	0.066	<0.0001	0.100
Desaturase Index	1.81^{b}	1.64^{c}	2.08^{a}	1.86	1.83	0.02	0.381	<0.0001	0.712

6.5 Conclusion

Despite the increase in omega-3: omega-6 fatty acid ratio in the sausage treatments after frying with the oils, the mean value of omega-3: omega-6 fatty acid ratio were greater than 1:5 and this was within the FAO/WHO recommended range. The omega-3: omega-6 association is well-known for its importance in the diet because it is a key factor for balanced eicosanoid production in the living organism. Therefore, it is highly recommended to consume oil that contain a moderate level of omega-3 and omega-6. On the other hand, their consumption must be balanced to take advantage of the health benefits they provide. A quantity much larger than needed may affect the breakdown of the other fatty acid, consequently, this brings a weaker condition in the tissues and changing their biological effects. Furthermore, the significant reduction in saturated fatty acids after cooking may also have a positive influence on the human health. Therefore, it may be concluded that using sausage made with edible meat waste as fat replacer may not have any negative effects on human if consumed.

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CHAPTER SEVEN

GENERAL DISCUSSION AND CONCLUSION

7.1 General Discussion

For many people protein from animal source is the most available and well consumed globally ((Bah *et al.,* 2013; Awana *et al.,* 2015). Although, muscle from the carcass may be the most consumed part of the animal, edible meat products such as entrails or internal organs are also extensively consumed (Toldrá *et al.*, 2012). The meat industry in the developed countries takes into account that everything produced from animals are by products except the muscle (Liu *et al.*, 2002). Today, animal by products are catergorised into edible and inedible by products (Irshad and Sharma, 2015). The decision to consume edible by product (liver, heart, kidney, spleen, heart, intestine, tongue and tripe) frequently or not is affected by, price, freshness, religion, economics, tradition of the region and availability of the product (Seong et al., 2015). In order to determine the freshness of the offal meat at the point of purchase, overall appearance, colour and package of the meat were all utilised. Therefore, the appearance of the product is important to determine the freshness of the meat, especially when meat has been packaged in retail outlets (Chamhur *et al.*, 2009). In spite of this, the stable economic growth of South Africa and increase in per capital income of the citizen among other factors will continue to encourage the demand for offal consumption. This study showed that, factors influencing offal consumption in Amathole District is similar to meat consumption except that, offals are mostly purchased at butcher shop.

Furthermore, meat processing industries generate large quantity of wastes materials which are sometimes underutilized. Proper processing of waste by- product such as edible meat waste obtained from meat trimming may come in handy during sausage production. Sausages are well-recognized processed meat product that is regarded with great fondness among the general public for its high palatability. Therefore, taking advantage of such waste can reduce the cost of sausage production, minimize waste and ultimately become a sustainable food. However, the regulation on the management and disposal of abattoir waste allows no deviation from the standard set to govern waste treatment at the abattoirs. Typically, the cost of managing meat waste is more expensive, it is therefore no longer practical to get rid of wastes that could have an economic impact on the livelihood of consumers (Toldra and Reig, 2011). Today, the disposal of by products are now channelled to desirable products that are economically profitable to consumers such as food, pharmaceutical, energy, cosmetics and fabrics (Ockerman *et al.*, 2004; Toldra *et al.*, 2012; Alao *et al.*, 2017). Therefore the ultimate goal of saleable meat waste products is to reuse, recycle and reprocess them into better products. This eventually decrease the monetary value of waste management and improve environmental effect (Ockerman *et al.*, 2000).

The present study may be influential in the improvement and development of effective healthy substitutes for potential meat products. Addition of edible meat waste therefore, have applied use in meat product processing. In this regard, the nutritional skill has been developed to allow efficient utilization of meat by products. This is imperative, because an increase in revenues and cheaper costs of production are essential for sustainability of the meat industry. The utilization of edible meat waste, by conversion into useful products of higher value can satisfy the needs for fat replacement in sausage production (Jayathilakan *et al.*, 2012).

Fat replacers must therefore, have the suitable structures similar to the fat globules and still maintain related sensorial properties of the improved product. This is important because fat is necessary in meat products to improve palatability by increasing its taste, tenderness and juiciness (Colmenero, 2000; Tokusoglu *et al.*, 2003). Besides, fat content has basic influence on a number of physicochemical and sensory characteristics such as flavour, mouth-feel, overall appearance, texture, handling, and reaction to cooking methods (Tokusoglu *et al.*, 2003). This study provides knowledge on how the addition of edible meat waste in sausages affects sensory properties and consumer liking. This exclusive combination of quantitatively evaluated sensory properties and subjective consumer liking shows that the edible meat waste represents a promising future. This equally represent an approach towards improving the health benefits of sausages, reduction in price while maintaining consumer liking. The results revealed the opportunity of adding edible meat waste to sausages, thereby obtaining a healthy product that is accepted by the consumers. Reason being, excessive fat in sausages do not normally contribute to a healthy diet, since they contain higher energy density (Arildsen *et al.*, 2014).

7.2 CONCLUSION

This results of the study provide factors which influence consumers in their choice of retail store when purchasing offal meat. Results from the main survey established and demonstrated that most South Africans in Amathole Districts prefer to purchase their offal meat from butcher shop as compared to other points of purchase. The utilization of edible meat waste as a replacement for fat in sausages are often ignored, however, these products can contribute a significant value to the meat industry. Sausages made with edible meat waste is safe nutritionally in terms of lower lipid content, reduced SFA and omega-3: omega-6 fatty acid ratio. The omega-3: omega-6 association is well-known for its importance in the diet and it was found to be within the FAO/WHO recommended range. The sensory evaluation revealed that, the sausage made with edible meat waste is acceptable to the consumers. Therefore, the potential value in edible meat waste may help to recover losses that are experienced in meat condemnations during processing at abattoir. Utilization of edible meat waste presents a great industrial development and better returns to meat industry.

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RESEARCH OUTPUT

(Presentations and Publications)

Conferences Presentations

1. **Alao Babatunde Oluwasegun and Voster Muchenje.** Body condition and management system of commercial layers. Poster presented at the 49th South African Society for Animal Science (SASAS) in Stellenbosch, Western Cape Province, **3-7 July 2016.**

   Authors: Alao, B. O., Salako A.E., and Voster Muchenje

2. **Alao Babatunde Oluwasegun and Voster Muchenje.** Consumers Perception on offal Meat Consumption in Amathole District. Poster presented at the 50th South African Society for Animal Science (SASAS) in Port Elizabeth, Eastern Cape Province, **18-22 September 2017.**

   Authors: Alao B.O and Voster Muchenje

Publications

1. **Babatunde O. Alao, Andrew B. Falowo, Amanda Chulayo and Voster Muchenje.** The Potential of Animal By-Products in Food Systems: Production, Prospects and Challenges. Published in *Sustainability Journal* **2017**, *9*(7), 1089; https://doi.org/10.3390/su9071089

2. **Babatunde O. Alao, Andrew B. Falowo, Amanda Chulayo and Voster Muchenje.** Consumers' Preference and Factors Influencing offal Consumption in Amathole District, Eastern Cape, South Africa. Published in *Sustainability Journal* **2018,** *10*(9), 3323; https://doi.org/10.3390/su10093323

EDITOR'S DECLARATION LETTER

I, **BELLITA BANDA-CHITSAMATANGA** hereby confirm that I have proof read and edited the following **PhD Thesis in Livestock and Pasture Science** for

ALAO BABATUNDE OLUWASEGUN

TITLED

Nutritional Quality Of Sausage Made With Edible Meat Waste And The Perception Of Consumers On Offal Products In Eastern Cape Province, South Africa.

The Windows 'Tracking' System was used to reflect my comments and suggested corrections for the author to action in all the chapters in the exception of Chapter Two which was done by a different editor.

During the process of the proof reading and editing, the following changes were recommended: punctuation, grammatical and sentence construction. In addition consistency in use of abbreviation, referencing style and capitalization, and also to improve on recommendations given by the editor. Although the greatest care was taken in the editing of this document, the final responsibility for the product rests with the author.

	25/06/2018
Editor's signature	**Date**

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APPENDICES

Appendix 3.1

Ethical clearance and permission to conduct the study

University of Fort Hare
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ETHICAL CLEARANCE CERTIFICATE
REC-270710-028-RA Level 01

Certificate Reference Number:	MUC341SBAB01
Project title:	**Characterization, Nutritional Quality, Fibre orientation, Technological Properties of Animal By-products and water Utilization Efficiency in South Africa Abottoirs.**
Nature of Project:	PhD
Principal Researcher:	Alao Babatunde
Supervisor:	Prof V Muchenje
Co-supervisor:	N/A

On behalf of the University of Fort Hare's Research Ethics Committee (UREC) I hereby give ethical approval in respect of the undertakings contained in the above-mentioned project and research instrument(s). Should any other instruments be used, these require separate authorization. The Researcher may therefore commence with the research as from the date of this certificate, using the reference number indicated above.

Please note that the UREC must be informed immediately of

- Any material change in the conditions or undertakings mentioned in the document
- Any material breaches of ethical undertakings or events that impact upon the ethical conduct of the research

The Principal Researcher must report to the UREC in the prescribed format, where applicable, annually, and at the end of the project, in respect of ethical compliance.

Special conditions: Research that includes children as per the official regulations of the act must take the following into account:

Note: The UREC is aware of the provisions of s71 of the National Health Act 61 of 2003 and that matters pertaining to obtaining the Minister's consent are under discussion and remain unresolved. Nonetheless, as was decided at a meeting between the National Health Research Ethics Committee and stakeholders on 6 June 2013, university ethics committees may continue to grant ethical clearance for research involving children without the Minister's consent, provided that the prescripts of the previous rules have been met. This certificate is granted in terms of this agreement.

The UREC retains the right to

- Withdraw or amend this Ethical Clearance Certificate if
  - Any unethical principal or practices are revealed or suspected
  - Relevant information has been withheld or misrepresented
  - Regulatory changes of whatsoever nature so require
  - The conditions contained in the Certificate have not been adhered to
- Request access to any information or data at any time during the course or after completion of the project.
- In addition to the need to comply with the highest level of ethical conduct principle investigators must report back annually as an evaluation and monitoring mechanism on the progress being made by the research. Such a report must be sent to the Dean of Research's office

The Ethics Committee wished you well in your research.

Yours sincerely

Professor Gideon de Wet
Dean of Research

25 July 2016

Appendix 3.2:

Consumer's perceptions on offal meat consumption in Amathole districts

University of Fort Hare
Together in Excellence

Important information

This survey is designed to gather information about consumer's perception on offal meat consumption in the Amathole District. It is intended to gather data for academic purpose only. Your response and cooperation will be immensely appreciated.

HOUSEHOLD INFORMATION

Municipality:
Residential Location
Date:
Occupation:

Part 1: Demographic information of the respondents

1.1 Please can you indicate your age...?

1.2 Educational status of the respondent:

No formal education□ Grade1-7□ Grade8-12 □ Tertiary□

1.3 Race: Black □ White □ Coloured □ Indians □ Other

1.4 What is your monthly total household income?

Less than R 500

R 501– R 2,000.

R 2,001.00 – R 4,000.

R 4,001.00 – R6,000.

R 6,001.00 – R8,000.00

R 8,001.00 – R 10,000

R 10,000and above

1.5 What is the size of your household……………………………………………….?

Part 2: Consumers

2.0 Which offal do you prefer most? Sheep offal ☐ Cattle offal ☐ Both ☐

2.1 Has your household demanded/spent in the last three months on any of the following offal.

Offal	Demanded	Demand source	Frequencies of demand	Factors influencing demand
Liver	Yes☐ No ☐	☐ Shop ☐Butcher ☐Both ☐Others	☐ Daily ☐Weekly ☐Fortnightly ☐Monthly ☐Rarely	☐ Cheapness ☐Availability ☐Nutritional Value ☐Health Reason ☐Other Reason
Heart	Yes☐ No ☐	☐ Shop ☐Butcher ☐Both ☐Others	☐ Daily ☐Weekly ☐Fortnightly ☐Monthly ☐Rarely	☐ Cheapness ☐Availability ☐Nutritional Value ☐Health Reason ☐Other Reason
Tongue	Yes☐ No ☐	☐ Shop ☐Butcher ☐Both ☐Others	☐ Daily ☐Weekly ☐Fortnightly ☐Monthly ☐Rarely	☐ Cheapness ☐Availability ☐Nutritional Value ☐Health Reason ☐Other Reason
Kidney	Yes☐ No ☐	☐ Shop ☐Butcher ☐Both ☐Others	☐ Daily ☐Weekly ☐Fortnightly ☐Monthly ☐Rarely	☐ Cheapness ☐Availability ☐Nutritional Value ☐Health Reason ☐Other Reason
Tripe	Yes☐ No ☐	☐ Shop ☐Butcher ☐Both ☐Others	☐ Daily ☐Weekly ☐Fortnightly ☐Monthly ☐Rarely	☐ Cheapness ☐Availability ☐Nutritional Value ☐Health Reason ☐Other Reason
Spleen	Yes☐ No ☐	☐ Shop ☐Butcher ☐Both ☐Others	☐ Daily ☐Weekly ☐Fortnightly ☐Monthly	☐ Cheapness ☐Availability ☐Nutritional Value ☐Health Reason

			☐Rarely	☐Other Reason
Intestines	Yes☐ No ☐	☐ Shop ☐Butcher ☐Both ☐Others	☐ Daily ☐Weekly ☐Fortnightly ☐Monthly ☐Rarely	☐ Cheapness ☐Availability ☐Nutritional Value ☐Health Reason ☐Other Reason
Lungs	Yes☐ No ☐	☐ Shop ☐Butcher ☐Both ☐Others	☐ Daily ☐Weekly ☐Fortnightly ☐Monthly ☐Rarely	☐ Cheapness ☐Availability ☐Nutritional Value ☐Health Reason ☐Other Reason

2.2 Is there a difference in offal purchased from a butcher and shop? Yes ☐ No ☐

If yes to question 2.1, what is the difference?

2.3 Are there any problems in accessing offal products in the shop or butcher? Yes ☐ No ☐

2.4. Do you agree there should be more offal in the market for human consumption?

Yes ☐ No ☐

If (yes/no) why?..

....

2.5 Which part of offal do you think is much healthier for consumption? (Tick all that applied)

Liver☐ Heart ☐Tongue ☐ Kidney ☐ Tripe ☐ Spleen ☐ Intestines ☐ Lungs ☐

2.6 Do you think that it's important to know the background information of where the offal comes from or you only consider what you are purchasing and consuming?

Yes ☐ No ☐

3. Consumers' perception on quality attributes of offal

How important are the following attributes in purchasing and consuming offal? Each attributes should be ranked on a scale of 1-5:

1= Disagree, 2= Strongly Disagree; 3= Neutral, 4= Agree; 5= Strongly Agree

Attributes of Offal	1	2	3	4	5
Colour of the offal					
Leanness of theoffal					
Presence of fat/ marbling					
Smell of the raw offal					
Freshness of the offal					
Texture of the offal					
Flavour					
packaging					
price					
Tenderness					
Juiciness of the offal					
Visual look at display					

Enkosi Ngexesha Lakho (Thank you for your time)

Appendix 4.1

Sensory Evaluation and Acceptability test

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Sensory Evaluation and Acceptability test

Instructions: You are presented with 6 coded samples of sausages. Please taste the samples and then place a number in the box according to the 9-point hedonic scale that best describes your feeling.

Rinse you mouth with the water provided before tasting any sample. Look carefully at the sample to note the colour and appearance. Place and hold each sample in your mouth and hold it for 15 seconds and note the appearance, flavour, colour, texture, taste, and overall likeness.

Panelist demographic information
Juror Number: __________
Age: ___________
Gender: Male ________ Female__________
Section A
(9) Like extremely
(8) Like very much
(7) Like moderately
(6) like slightly
(5) Neither like nor dislike
(4) Dislike slightly
(3) Dislike moderately
(2) Dislike very much
(1) Dislike extremely

From the 9 scales above, how do you evaluate the samples in regard to the following attributes?

	TCM126	TCO261	WFM356	WFO635	WSM209	WSM920
Appearance						
Colour						
Texture						
Taste						
Flavour						
Overall likeness						