DEVELOPMENT OF READY TO EAT BOVINE TRIPE ROLLS FOR BY-PRODUCT LOSS REDUCTION IN SELECTED SLAUGHTERHOUSES IN KENYA

BY

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other university.

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DEDICATION

This thesis is dedicated to my family for their love, support, care and encouragement throughout the entire school period.

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ABBREVIATIONS AND ACRONYMS

AOAC	Association of Official Analytical Chemists
ANOVA	Analysis of Variance
BGA	Brilliant Green Agar
MOLD	Ministry of Livestock Development, Kenya
FAO	Food and Agricultural Organization of the United Nations
STTP	Sodium Tri polyphosphate
MSG	Mono Sodium Glutamate
SPSS	Statistical Package for the Social Sciences
KEBS	Kenya Bureau of Standards
TVC	Total Viable Counts
CFU	Colony forming units
XLD	Xylose lysine desoxycholate
VRBG	Violet red bile glucose agar
mCCD	Modified charcoal-cefoperazone-deoxycholate agar
PV	Peroxide value
meq/kg	Milliequivalent per kilogram

GENERAL ABSTRACT

Slaughterhouse by-products losses pose a notable challenge in Kenyan abattoirs at present. Slaughterhouse owners, meat traders, renderers and operators of meat facilities often lack preservation technologies and appropriate knowledge for incorporating by-products into regular commercial products. Adding value to meat by-products is one of the approaches that can be employed to reduce losses because the developed products can significantly raise the uptake of the by-products. Consequently, the income for operators could increase, food and nutrition security enhanced, the environment is conserved and the market gets a variety of products. Bovine tripe and other internal organs (offals) contribute to significant losses among other by-products in abattoirs. The information on how they are utilized by various communities and their commercial potential is very limited in spite of the advances in modern processing technologies in Kenya.

Bovine tripe was identified as one of the major by-products obtained after slaughter operations in Kenya. This study was hence designed to establish how bovine tripe is utilized by pastoral communities and peri-urban consumers in Kenya with the aim of potential commercialization. The study was carried out in the pastoral Counties of Marsabit, Turkana, Kajiado and Garissa and the Kiambu County bordering Nairobi County to represent the peri-urban area. Data were collected using focus group discussions, key informant interviews, semi-structured questionnaires and direct visual observations in selected slaughterhouses.

The results showed that the yield of bovine tripe based on live weight of cattle was 0.76-2.0% and it was mainly utilized as human food and pet food by most communities in the study regions. Some communities also discarded significant quantities of tripe due to traditions, culture and religious beliefs. Generally, tripe used for human consumption was prepared in different ways such as stewing (36.36%), frying (81.81%), braising (54.54%) and broiling (72.72%). The study showed that tripe was not effectively utilized across all the counties resulting into huge post slaughter losses which differed significantly ($P<0.05$) among the study counties. Therefore, it was utilized in the development of commercial value added product in this study. Ready to eat bovine tripe rolls were formulated from a combination of rumen, reticulum, omasum and abomasum parts of tripe. Mechanical tenderization was used to improve the tenderness of the products which were then stored at 4±1°C for 28 days in different packaging conditions. They were evaluated for physico-chemical and sensory characteristics at intervals of 7 days for 28 days. Significant changes ($p<0.05$) in sensory and physico- chemical characteristics were observed in minced, blade tenderized and control (non-tenderized) products during storage. The cooking losses (9.07%-12.09%) and shear force values (2.31N-4.43N) among the minced, blade tenderized and control products differed significantly ($p<0.05$) during storage. The average pH ranged from 6.4 to 6.0, Extract release volume (ERV) (22.2-17.9ml), Peroxide value (1.81-16.04 meq/kg), TBA (0.55-0.91mg malonaldehyde/kg) and tyrosine value (0.43-0.78 mg tyrosine /100g) among the products.

Sensory evaluation was conducted on days 0, 7 14, 21, 28 days of storage by lining up a panel of 32 untrained members who are familiar with meat products. The scores for all the samples under vacuum packaging were well within the acceptable limits up to 28 days of storage at 4±1 °C. However, all the samples stored aerobically were acceptable until 21 days of storage after which extremely high off odors due to increased lipid oxidation were observed which reduced their scores significantly ($P<0.05$).

The evaluation of the product for microbial quality was done using standard analytical methods at intervals of 7 days for 28 days under refrigeration conditions. The microbial counts results

showed that *Listeria monocytogens, Campylobacter, Escherichia coli and Salmonella spp* were all absent in both aerobic and vacuum packed. The detected bacterial counts were in the ranges specified for Ready to eat (RTE) meat products by Kenya bureau of Standards (KEBS) for the 28 days storage period of vacuum packaged products. However, the microbial counts in aerobically packaged products were significantly ($p<0.05$) higher than in vacuum packed products and slight off odours and slime appeared in some products on 28^{th} day of storage. The highest days means counts for total viable counts, *Clostridium perfringens, Staphylococcus aureus,* yeast and molds, *Psychrophilic counts* and *Lactobacillus* spp were 5.4 log_{10} cfu/g, 1.7 log_{10} cfu/g, 1.9 log_{10} cfu/g, 4.1 log_{10} cfu/g, 5.2 log_{10} cfu/g, 2.1 log_{10} cfu/g respectively in both packages. The study revealed that acceptable tripe rolls can be developed from raw tripe. The study also concluded that vacuum packaging is extra effectual than aerobic packaging in inhibiting oxidation of lipids, microbial growth, protecting the organoleptic quality of the product as well as extending the shelf-life of the ready to eat bovine tripe rolls. There is also need to pursue other potential uses of bovine tripe to ensure no losses occur after slaughter.

CHAPTER ONE: GENERAL INTRODUCTION

1.1 Background information.

The population of livestock in Kenya is about 14.1 million for indigenous cattle and 3.4 million for exotic cattle while over 70% of the whole population is raised by the pastoralists (Farmer and Mbwika, 2012). The sector accounts for approximately half of the country's agricultural labour force and it serves as the main source of income for close to 6 million Kenyans living in arid and semi-arid lands (Behnke and Muthami, 2011). However, the livelihood of pastoral communities is characterized by low incomes and food insecurity despite the fact that two- thirds of total consumed meat in Kenya comes from the arid and semi-arid lands (ASALS) inhabited by pastoralists (Mathi, 2016). Almost 67% of the meat produced nationally goes via formal slaughter process while the remaining percent uses informal means.

Slaughter of animals for meat results in by-products, some of which are utilized for food and others are discarded. The by-products utilized for food are liver, kidney, heart, brains, tongue, stomach, intestines, fat, lungs, sweet breads and trimmings and the by-products discarded include manure, intestinal contents, condemned parts and glands. The utilization and value of by-products from meat entirely relies on the traditions, cultures and communities in question (Toldra *et al*., 2012). Some of the by-products and wastes have a great economic potential as raw materials in the development of new value added meat products. Meat by-products initially taken as wastes can be processed into products that can be consumed through value addition which requires innovative technologies (Ockerman & Basu, 2004a). They can also be processed into products with economic benefits such as plastics or pharmaceutical products.

Post-slaughter losses in slaughter establishments can be as high as 50% and this may result into food insecurity and low profit margins from sales (MOLD, 2010, Lewa 2010). Most of the post-harvest losses of meat and the by-products are caused by inappropriate post-harvest handling techniques and lack of processing and preservation technologies. Meat by-products that are not utilized can pollute the environment hence the need to enhance their use to raise the profits of the stakeholders in the entire meat industry. These losses can be minimised by increasing use efficiency along the chain and formulation of value added products (Aymerich *et al*., 2008).

Bovine tripe is one of the main by-products of meat slaughter that are not fully utilized and hence wasted by some communities. However, it can be utilized by incorporating into commercial products like sausage, RTE meat rolls and spreads (Li *et al*., 2012). Bovine tripe is highly available but perishable and extremely tough which makes its effective and efficient use a hard task among sections of communities in Kenya. Attempts to exploit the tripe in commercial application have failed due to its innate toughness caused by huge contents of the collagen coupled with short shelf life when kept at ambient environmental conditions (Parry, 2006). Therefore, it is essential to come up with suitable technology to add value to the tough, less acceptable and highly perishable bovine tripes into more beneficial and acceptable ready to eat products (Li *et al*., 2012).

Simple mechanical treatments of beef and other meat products by blade tenderization (BT) or mincing are widely accepted approaches of tenderizing tough meat in the meat industry. These techniques are mainly used to interfere with the structure of the muscles and ultimately set free myofibrillar protein resulting into more solubility of the proteins embedded in the muscles and hence enhance product tenderness and cooking yields (Pietrasik and Shand, 2004). BT entails piercing of the steak with blades which are very thin but close to each other. They cut the fibers in the muscles into extremely short segments and results in enhanced tenderness (Benito-Delgado *et al*, 1994). Several researchers reported increased tenderness of meat products that are tenderized using blades compared to the control products (Duran and Ardic, 2014). Mincing has also become a common practice during the processing of the meat and development of the meat products. It involves passing fresh meat through a mincer which breaks down the connective tissues hence softening them on cooking (Pietrasik and Shand, 2004). After subjecting the tripe to mechanical treatments, cooking and vacuum packaging can be employed to prolong the shelf-life. Vacuum packaging which modifies the atmosphere within the product by removing the air is mainly used to prolong the shelf-life of meat products (Anna *et al*., 2012).

Making better use of meat by-products potentially leads to minimised effect on the environment as a result of enhanced production of the meat and at the same time provides raw materials for the production and development of new and non-existing products (Van der and Driessen, 2013). The meat industry will get more profits if all the by-products are utilized efficiently. According to the United States Department of Agriculture (2011), beef by-products contribute about 11.4% of the country's gross income. The effective utilization of animal by-products in treatment and production plants has upgraded the public health in Kenyan societies in the recent past (Mathi, 2016). This research project was designed to find out the bovine tripe loss loopholes in the slaughterhouses and along the meat value chain and ultimately mend them by developing acceptable products.

1.2 Problem Statement

Post slaughter losses account for huge losses of meat and by-products in the ASALs and other slaughter establishments in peri-urban areas (Mathi, 2016). According to FAO (2011), 29.7 % of meat and by-products goes to waste during the post-slaughter period. The major cause of huge losses experienced along the meat value chain is the perishable nature of meat and by-products which contributes to quality and physical losses if the products are not properly handled. Lack of appropriate by-products processing technologies, storage and packaging facilities exacerbates the losses (Lewa, 2010; MOLD, 2010).

Small and medium size abattoirs and slaughterhouses lack technical skills and facilities needed to process, package and store the by-products (Abegaz, 2009). These problems are compounded by the fact that a lot of the by-products obtained from the beef industry are unsuitable for normal consumption since their chemical and physical features are very undesirable. Consequently, disposal costs increases and the revenue that would have been collected from the sale of these by-products is also lost (Liu, 2002). Bovine tripe is naturally tough because of huge contents of collagen; it has a very short life and emits undesirable odours hence limiting its use in the development of the products with significant added value (Parry, 2006). However, upon successful elimination of these limiting factors, tripe can provide a good capacity/opportunity to process new products (Anna *et al*., 2012).

Utilization and consumption of bovine tripe has further been limited by hygienic issues caused by improper washing after disembowelment. When they are not properly washed and decontaminated, the growth of microorganisms is encouraged and this can be risky to consumers (Ndeddy *et al*., 2011). Spoilage microorganisms lower the shelf-life of any given product eroding its value in the market eventually leading to huge economic losses to producers and suppliers when the demand is low (Bensink *et al*., 2002). The stakeholders along the meat value chain also lack the capacity for development of new products, diversification and information on post slaughter losses along the meat value chain (Pavanello, 2010). The stakeholders who suffer the losses in Kenyan slaughterhouses will find a reprieve in new ways of utilizing their tripe after slaughter when appropriate technologies are transmitted to them with the aim of value addition to prolong shelf life and improve acceptability (Bensink *et al*., 2002).

1.3 Justification

According to FAO (2011), post slaughter losses contribute approximately 29.7% in meat losses from harvest to retail centres. Technologies that improve the uptake of by-products can raise the earnings of stakeholders and reduce meat post-slaughter losses along the value chain. When post slaughter losses are reduced, the volume of food available increases effectively and sustainably without experiencing unfavorable effects on the regional economic and ecological situations (Hensel, 2009).

Bovine tripe is high in protein, minerals such as calcium, phosphorus, magnesium and B-complex vitamins (Parry, 2006). It is also rich in linoleic fatty acids and contains little fat. It is impractical to discard and waste a valuable by-product such as tripe because it possesses huge potential economically such as developing of value added products (Toldra *et al*., 2012).

Innovations in by-products processing and preservation techniques are crucial in fostering economic growth as they create platform for adding value to products that would otherwise have been wasted (Mathi, 2016). This together with the conventional techniques of processing meat and meat by-products will improve the products for small and large–scale commercialization. Unfortunately, the current techniques such as use of special packages have not been embraced successfully. The low adoption rate of processing and preservation technologies and the below average quality of conventionally processed products are the main hindrances to value addition of meat and meat by-products. Value addition can be enhanced through revamping and investing in meat and meat by-products distribution systems (Abegaz, 2009).

1.4 Study objectives

1.4.1 Main Objectives

To develop ready to eat (RTE) bovine tripe rolls from tripe, an under-utilized by-product with a view to reducing slaughterhouse losses and promoting uptake in Kenya.

1.4.2 Specific Objectives

1. To determine the status of utilization of tripe by the communities and the possible postharvest losses in selected slaughterhouses in pastoral regions and peri-urban areas in Kenya.
2. To formulate a ready to eat product from tripe by-products from slaughterhouses.
3. To determine the physico-chemical and microbiological characteristics of the product.
4. To evaluate the sensory attributes of the ready to eat bovine tripe rolls.
5. To determine the shelf-life of the ready to eat bovine tripe rolls under aerobic and vacuum packed conditions.

1.5 Hypotheses

1. Slaughter house losses as tripe are substantial
2. An acceptable, shelf-stable product can be developed from bovine tripe and the lumen contents.
3. Physico-chemical and microbial properties of the developed product are of expected standards.
4. An acceptable RTE product can be developed from bovine tripe.
5. The developed product from bovine tripe is shelf stable under aerobic and vacuum packed conditions.

CHAPTER TWO: LITERATURE REVIEW

2.1 Meat value chain in Kenya

There are several interdependent stakeholders along the meat value chain in Kenya. Beef is the most consumed meat in several households (Mathi, 2016). Meat from sheep and goat is rarely eaten at homes apart from some proportion of huge income earners in the society due to the fact that it is considered luxurious (Gamba, 2005). According to Muthee (2006), the national per capita meat consumption is approximately 10.8 kilograms per person. Nairobi and Mombasa topped the list with18.25 kilograms and 15 kilograms per person respectively.

Meat value chain comprises of several stakeholders who are interdependent. Producers who are livestock keepers top the list. Traders who act as the middlemen between the farmers and the processors at the slaughter houses in various counties are also prominent in the value chain (Muthee, 2006). Classification of slaughterhouse is done on the basis of the number of the animals slaughtered and the available facilities. Low class and middle class butcheries sell low grade meat and by-products while high end butcheries sell high grade meat and in some cases value added products (Muthee, 2006).

High quality meat from well finished animals is usually found in high end markets which comprises of high end butcheries and supermarkets (Gamba, 2005). The animals slaughtered in these cases are mostly from ranches that have been well-maintained and where the meat is cut into prime cuts. Consumers who live above the poverty line are the major buyers of meat from these premises with high propensity to buy value added products like beef sausage and tenderized meat products. Premium prices are charged in this high -end butcheries based on the source of supply of the meat which is primarily ranches (Gamba, 2005).

Consumers earning average or medium income dominate the middle market which offers meat on bone, boneless steaks, liver, green offals and tripe. The retail outlets at this level of the market have deep freezers where meat is temporarily stored but refrigeration is limited (Farmer and Bwika, 2012). The largest share of the Kenyan meat is formed by the low-end market where low class butcheries offer beef meat on bone which is normally displayed openly without refrigeration or an innovative packaging (Farmer, 2012).

Meat inspectors and public health officials are very important stakeholders in regulating the meat industry. Their responsibility is to ensure that the health and safety of the consumers is guaranteed (Mathi, 2016). They are located at the slaughterhouses and abattoirs where they inspect the carcass before every edible portion is allowed into the market. The veterinary officers ensure that the animals are in sound condition as they are ferried from part of the country to the other. Public health workers and veterinary officers all come from the government to ensure non-partisanship in their work (Mathi, 2016)

The meat value chains final target is the domestic market which consumes approximately 99% of the domestic production. A small percentage of meat is exported by the Kenya Meat Commission (KMC) and few private exporters who use KMC's facilities to process their products at fee (Farmer and Mbwika, 2012).

2.2 Ready to eat meat products

Ready to eat (RTE) meat are meat products intended to be consumed without further cooking and are in a form that is edible without additional preparation to achieve food safety and includes: dried meat, cooked cured or uncured muscle meat, cooked or uncooked fermented meat, luncheon meat and other ready-to-eat meat (US Department of Agriculture-Food Safety and Inspection Service (2003). RTE meat products follow the same basic process during production which includes: Farms, slaughterhouses, manufactures shops, restaurants, and transport of products between these places. There are different sources of contamination in each of these steps in the chain hence elimination of the microbes from these sources is essential in restricting bacterial contamination of the final meat products (Kurpus, 2018).

Several studies of ready to eat meat products indicate that microbial contamination of end products normally takes place during production and at retail stage and less frequently from the animal directly. Moreover, proper hygienic practices by the personnel and employees are also important factors in determining the quality and safety of the final products (Hellstrom *et al.*, 2010). Other studies have described deli meat products as high risk foods because of their high potential for contamination pathogenic microorganisms such as *Listeria monocytogenes* (MLA, 2003). The high risks are attributable to improper cooking, prolonged storage life and post processing handling and the ability of most meat products to support proliferation of microorganism even under refrigerated storage (FDA/USDA, 2003).

Cured ready to eat meat products are injected with nitrite pickling salt, soaked, and massaged. They are then cooked for about 10 minutes for a minimum temperature of 65°C which reduces microorganisms especially *Listeria monocytogens* present in meat but handling meat products after cooking can re-introduce the pathogens (Lianou and Sofos, 2007). Slicing of meat products after cooking is one of the post-cooking activities that can considerably contribute to the contamination of RTE meat products with pathogenic microorganisms (Kurpus, 2018).

In addition, many of these products are packed in vacuum packed or modified atmosphere packaging (MAP), which extends the refrigerated shelf life to several weeks by inhibiting the growth of spoilage organisms (NSW, 2007). While refrigeration can control other pathogenic organisms such as Salmonella, the growth of psychrotrophic (cold tolerant) organisms such as *Listeria monocytogenes* will not be inhibited. Beumer *et al* (1996) found that when a sample of ham was inoculated with 10 cfu/g of *Listeria monocytogenes*, the organism grew to levels of 10^8 cfu/g within 35 days, with the presence of CO_2 in the packaging.

2.3 Post-Slaughter losses along the meat value chain

Post-harvest Loss (PHL) encompasses both loss in quality and quantity of food along the value chain from the time of harvesting to consumption (Hodges *et al*., 2011). It can be caused by food wastage or other losses along the food supply chain. Postharvest losses of the meat produced can be as high as 50% and this may result into food insecurity and low profit margins along the meat value chain (MOLD, 2010; Lewa, 2010). Most of the post-harvest losses are caused by inappropriate post-harvest handling techniques and processing. These losses can be minimised by increasing efficiency along the chain and development of value added products (Aymerich *et al*., 2008).

FAO of U.N. recorded that approximately 1.3 billion tons in terms of wastage of food are witnessed annually (Gustavasson et al., 2011). Post-harvest loss of meat occurs at several stages after harvest and approximately 76.3% is lost between production, processing and packaging (FAO, 2011). Attempts to minimise these losses through value addition of the by- products from slaughterhouses are highly encouraged. Optimization of green offal and tripe into important commercial ready to eat processing components is one of such attempts. Green offal can be processed into ready to eat by-product, meat spreads and puddings with a higher shelf-life and hence minimise the potential by - products loss.

Lack of adequate capacity for new product development, proper equipment, monitoring inputs and processing parameters and skills have been identified as the major factors which contribute to enormous amount of wastage at processing (Mathi, 2016).

Meat by-products should be effectively utilised to improve the profitability of the mat industry. However, the market for by-products has slowly been reducing due to health issues and low prices. Most of the animal by-products are unsuitable for normal consumption due to their undesirable and unusual chemical and physical properties. Hence, an essential source of revenue is wasted and the disposal costs are increased.

2.4 By-products from slaughterhouses

All the materials obtained from the slaughtered animal apart from the meat that has been dressed can be described as by-products. They are basically classified into two main groups: Inedible by-products and edible by-products. Green offals and red offals most of which are edible are also yielded during slaughtering of the animals. Therefore, they are important sources of nutrients and also essential proteins needed by our bodies the moment they are incorporated in other products or prepared separately. Offals are the entrails mostly used as food and they include the whole animal excluding muscles and bones (Jayathilikan *et al*., 2011).

Variety meats (offals) are edible internal organs of butchered animals. In some slaughterhouses, separation, chilling and processing of these offals is done for value addition. Blood is consumed as food by many communities and source of animal feed in very many parts of the world including Kenya. Meat trimmings from the head can be consumed or discarded depending on the community. The fats obtained from the stomach of the cow are also edible (Morimuras *et al*., 2002). In the United Kingdom the variety meats are commercially classified as red offals such as liver and lungs, green offals and white offals such trimmed fats (Ockerman and Hansen, 2000).

Some offal in mammals such as stomachs, tripe, blood, intestines, udder and feet are only used in cooked state (Jayathilakan *et al*., 2011)

Some meat by-products need to be treated before consumers can purchase them. They need to be trimmed, chilled and packaged in way that is appealing to end consumers. Their overall acceptance depends on their cost, the level of nutrients and the price of the substitutes available in the market. Other by-products from slaughterhouses include the bovine pancreas and udder, glands, testes, tripes of goats and sheep (Liu, 2002). Liver pastes and sausages can be processed from organs such as liver (Devatkal *et al*., 2004). Some sausages and stuffing can be made from the lungs obtained from lamb calves in European and American nations (Darine *et al*., 2010).

Intestines can be utilized for making sausage casings (Bhaskar *et al*., 2007). However, they form a very important delicacy in the menu of most domestic settings in Kenya due to their cheap price hence affordable to many Kenyans. Traditional packaging equipment and instruments such as drums were made from hides and skins. Seats and drums used hides and skins as their main raw material. Gelatin and glue, reformulated sausage casings and skins are edible products that can also be made from hides of the cattle and contribute to more profitability (Benjakul *et al*., 2009).

2.5 Nutritional value of meat by-products

They have fat that improves the sensory appeal and benefits the body physiologically. Fat gives several desirable properties to food such as overall acceptance, improved texture and aroma. (Akoh, 1998).

The edible products from meat are rich in a lot of important nutrients. A few of them are utilized in form of medicine since there is presence of desirable nutrients which include vitamins, minerals, and amino acids. Tripe, Kidneys, lungs, blood and brains have higher moisture content compared to meat. Organ meats such as kidneys have more carbohydrates than some meat materials (Devatkal *et al*., 2004b).

The amount of protein in the tissue of lean meats is usually higher than in ears, tail and feet of beef cattle. However, the highest concentration of collagen is in feet, sinews and the ears (Unsal and Aktas, 2003). Tissues containing fat and intestines contain the lowest concentration of proteins. According to the United states Department of Agriculture (2001), beef without bones contains 14 % of protein and fat content of 30%.

Composition of amino acids in lean tissue differs with that of meat - by-products, due to high contents of connecting tissues. Consequently, variety meats and feet have higher level of amino acids such as glycine, proline and hydroxyproline. Lean meat usually contains less amount of vitamins compared with organ meat. The highest content of riboflavin is found in liver and kidneys (approximately 3.6 mg per 100g) which are about 10 times higher compared to lean meat. Liver also contains vitamin C, A, B12, B6, and B3.The content of polyunsaturated fatty acids is higher in organ and offals than in lean meats (Liu, 2002). Organ meats also contain high levels of cholesterol, pesticides and residues of drugs hence limiting their consumption by many people.

2.6 Mechanical Tenderization of beef and by-products

Consumers rate the quality of beef and beef by-products using tenderness as the main factor**.** The degree of tenderness of beef is influenced by two main factors namely background tenderness and the level of tenderness of the proteins. Background tenderness depends on the quantity and connective tissues varieties in a particular cut of the meat (Maddock, 2008). The toughness of the actual of the fibers of meat that are mainly affected by the age determines the level of tenderness of the muscle fibres which weaken with increase in storage period due to the breakdown by the inherent enzymes(Davis *et al*., 1975)**.**

2.6.1 Types of mechanical Tenderization

Tenderization of meat and by-products mechanically can be achieved through two process: 1) blade tenderization and 2) Mincing/maceration. The tenderness of the beef and by-products can also be enhanced through processes such as tumbling (Pietrasik and Shand, 2004)

2.6.1.1 Blade tenderization

Blade tenderization makes use of a set of blades which penetrates through the meat and interferes with the fibers in the muscles and connective tissue and enhances their tenderness. This improves the desirable properties of the beef such as flavor and tenderness (Jeremiah *et al*., 1999) .Indisputably, when blade tenderization is properly and effectively employed in the processing of meat and the by-products, it can minimize the level of variability in the products and also enhance the tenderness and palatability of the final products (Benitordelgado *et al*., 1994).

Blade tenderization can essentially be done on most beef cuts but the best outcome in terms of enhanced tenderness is on the tougher beef cuts. Other researchers have established that blade tenderization can boost the initial and the general tenderness of beef strip loin, inside and outside round steaks and chuck (Jeremiah *et al.*, 1999). According to this study tenderization of the beef cuts by use of blades or needles reduced the percentage of the round samples from inside considered to be tough from 52% to 20%, 16 % - 0% for samples which had undesirable flavor and also decreased the percentage of samples such as ribeye and the inside round from 12% to 0% and 36% to 8 % respectively.

Blade tenderization boosts tenderness of meat and meat products more than the levels achieved by aging solely without necessarily affecting palatability parameters such as the juiciness and the flavor (Pietrasik and Shand, 2004). It is frequently used to enhance the tenderness of the roasts made from beef and meant for sales at restaurants. This mechanical treatment before injection has also proved to be useful for textural traits of the final products and improvement of the cooking yields without influencing other desirable properties. It also decreases shear values by about 20% when beef roasts are subjected to tumbling for 0-2 hours compared with the beef roasts which are not mechanically tenderized.

Blade tenderization results into very minimal problems on the quality characteristics of the beef and beef products. A number of researchers have investigated cooking losses, drip/purge losses and the shelf-life of mechanically treated cuts and have found insignificant differences (Davis *et al.*, 1975). As a matter of fact, some researchers have reported increased cooking yields of rounds subjected to blade tenderization. At times, an insignificant increase in drip/purge losses occurs but the differences are minimal usually less than 1% (Pietrasik and shand, 2004)

2.6.1.2 Maceration/mincing

Mincing is a very efficient method of enhancing the tenderness of steaks from beef and beef products. It makes use of small metallic blades on rollers which macerate the steak's surface and completely changes its look and texture. Mincing is only done on beef steaks because the equipment designed for mincing and maceration can only work on the steaks. It is frequently done on extremely tough beef cuts like the inside round bovine beef, but can also be used for softer steaks such as chuck tenders. Mincing is mostly done at retail outlets because the disarrangement of the surface causes a shortened shelf life (Maddock, 2008)

2.6.2 Safety concerns of mechanically treated beef and beef products

Many consumers consider beef steaks and roasts to have very few or no safety issues compared to ground beef since they assume that contaminants are on the surface and cooking will eliminate them. However, this dynamic can change because during mechanical tenderization, bacteria can be transferred from the surface to the centre of the product (Heller *et al.,* 2007). Consequently, it is essential to put into consideration food safety related issues when beef and beef products are subjected to mechanical tenderization since some outbreaks of the diseases in mechanically tenderized beef products have been reported. Gill and McGinnis (2004) observed that the extent of contamination of deep tissues during mechanical tenderization depends on the initial microbial counts on the surfaces of meat and meat products. If the meat product is undercooked, the pathogenic microorganisms in deep tissues may survive and cause illness to consumers (Gill *et al.,* 2005).

In May 2005, USDA-Food Safety Inspecting Service ordered all the processors dealing with mechanically tenderized products from the beef to reexamine the HACCP plan for *Escherichia coli* 0157:H7 to reduce cases of disease outbreaks. A large number of researchers have carried out investigations on the effect of mechanical blade tenderization on the safety of the beef and other meat products (Gill *et al.,* 2005). For instance, Beef industry Food Safety Council has come up with best practice directions to reduce the risk of contamination by dangerous bacteria.

2.7 Tripe as by-product and its utilization

Tripe is an edible lining mostly found in stomachs of ruminant animals. It is mostly found in beef cattle. Bovine tripes are produced by the muscular stomach chambers of the cow which include: Abomasum, reticulum, rumen and omasum (Li *et al.,* 2012). Tripe refers to a cheap and common by-product with a very high value nutritionally (Table 2.1) and a unique taste. However, its shelf-life is very short and most communities utilize it in the preparation of stew which can be consumed together with a maize meal (Ndeddy *et al.*, 2011).

Though tripe tends to refer to the cow (beef) stomach cooked as food, a similar meal item may also be produced from any animal with a stomach. All animals with stomachs can produce tripe but different terms can used to describe tripe obtained from other animals to distinguish them from cow tripe. For instance, Paunch is the tripe produced from the pigs. Pig stomach is also eaten under the term, hog maw (Bender, 1992).

Tripes are usually washed before selling to make them more appealing to consumers. That process of washing is known as dressing. Dressing is done by washing the stomachs with water and trimming off the adhering fat and materials (Flyn and Fox, 1981). Thereafter, boiling and bleaching is done to give them whitish color linked with tripes displayed in butcher shops and stalls. Tripe dressing is done by professionals mandated to undertake the task. Tripe dressers and consumers in the United Kingdom have significantly reduced despite the popularity of the product to date due to the affluent life enjoyed in Britain. Consequently, it is now described as the food for pets and it is no longer a staple food (Houlihan, 2011).

Table 2.1 Nutritional composition of raw tripe

PROXIMATE	unit	Value/100g
Water	g	84.16
Energy	kcal	85
Protein	g	12.07
Total lipid (fat)	g	3.69
Calcium, Ca	mg	69
Iron, Fe	mg	0.59
Magnesium, Mg	mg	13
Phosphorus, P	mg	64
Potassium, K	mg	67
Sodium, Na	mg	97
Zinc, Zn	mg	1.42
Riboflavin	mg	0.064
Niacin	mg	0.881
Vitamin B-6	mg	0.014
Folate, DFE	µg	5
Vitamin B-12	µg	1.39
Vitamin E (alpha-tocopherol)	mg	0.09
Fatty acids, total saturated	g	1.291
Fatty acids, total monounsaturated	g	1.533
Fatty acids, total polyunsaturated	g	0.180
Fatty acids, total trans	g	0.150
Cholesterol	mg	122

Source: USDA Nutrient Database (2018)

2.8. Microbial composition of bovine tripe

Tripe is obtained from the cow's stomach through excision followed by emptying of the stomach contents. Walls of the stomach are then washed thoroughly with water but chemicals such as diactolate can be added to help in reducing off odors and green coloration on the tripe. Thereafter, scalding and cutting into small pieces is done followed by rinsing and packaging (Bensink *et al*., 2002).

When the contaminants are being removed the ambient temperatures have the ability to allow multiplication of undesirable pathogens and bacteria. *Enterobacteriaceae* is the primary group associated with contamination and spoilage of tripe and their detection indicates poor adherence to the basic hygiene measures in the whole processing operation and improper storage of food. (Gill and Landers, 2004)

Salmonella spp, *E.coli* and Shigella spp are some of the main species in this group and they have also been found in the environment of hospitals (Miranda *et al.,* 2008). As causative agents, they are associated with several infections which are food borne which includes infections of the urinary system. They are also known to cause deadly infections such as plague and infections of the breathing system (Seral *et al.,* 2002).

These bacteria have the potential to produce lipolytic enzymes and proteases which degrade meat products ultimately affecting their organoleptic and sensory properties (Losantos *et al.,* 2000) These enzymes degrade the structural components in products and produce off odours that affect the overall acceptability by consumers (Brightwell *et al.,* 2007).

The four chambers of the cow's stomach ferment the degraded cellulose (Teixeira *et al.,* 2009). Beef products are examined microbiologically before they are released to the market to ensure that bacteria that can cause food borne diseases are absent. *Staphylococcus*, *Bacillus*, *Corynebacterium* and *Campylobacter* are other groups of bacteria that have been identified in the bovine tripe (Bensink *et al.,* 2002).

2.9 Gaps in Knowledge

There are several gaps in knowledge along the meat value chain regarding edible by-products usage. There are no proper techniques of utilizing by-products from slaughter houses particularly tripe. Utilization of tripe by using them as the key ingredients in the development of the shelf stable ready to eat products would improve their consumption hence reducing losses after slaughter. This would certainly improve the income of slaughterhouse owners and communities in arid and semi-arid areas.

Stakeholders along the beef value chain have not sufficiently adopted developed meat by-products processing technologies and hence low-cost traditional meat processing and packaging techniques to add value to products that will improve household food security. Successful adoption of these technologies would provide a good income opportunity to households especially in ASAL regions. When the channels that are informal are revamped and resources invested in them, value addition of slaughter by-products will be greatly realized (Abegaz, 2009).

2.10 Thesis Layout

CHAPTER ONE: GENERAL INTRODUCTION.

The chapter gives the background information and the basis around which the research concept was based. It outlines the glaring problems facing pastoralism stakeholders including the poor utilization of by-products and high losses along the meat value chain.

CHAPTER TWO: LITERATURE REVIEW

A review of what has been done elsewhere with regard to by-products is outlined here. Potential utilization ways for several by-products has also been cited. Critical and comprehensive review of literature to identify gaps has also been done in this chapter.

CHAPTER THREE: UTILIZATION OF BEEF SLAUGHTER BY-PRODUCTS AMONG THE KENYAN PASTORAL COMMUNITIES AND PERI-URBAN AREAS: CASE OF TRIPE

This chapter comprises of abstract, introduction, study area, methodology, results and discussion and conclusion sections. It characterizes how various pastoral communities in the study area utilize slaughter by-products with the aim of picking up potential ones for use in commercial processing. This is eventually aimed at reducing post-slaughter losses in by-products of the slaughter houses.

CHAPTER FOUR: STORABILITY AND PHYSICO-CHEMICAL QUALITY OF READY TO EAT BOVINE TRIPE ROLLS UNDER DIFFERENT STORAGE CONDITIONS.

This chapter is divided into the following sections; abstract, introduction, methodology, results, discussion, conclusion and recommendations. It outlines the formulation of the bovine tripe rolls and laboratory analysis of attributes necessary for stable RTE meat products.

CHAPTER FIVE: MICROBIOLOGICAL STATUS OF READY TO EAT BOVINE TRIPE ROLLS UNDER DIFFERENT STORAGE CONDITIONS.

This chapter with introduction, methodology, results, discussions and conclusion sections, explains the hygiene of the bovine tripe rolls. It implies the effect of using bovine tripe as an ingredient as well as handling. The results insinuate the tripe rolls hygiene and fitness for consumption.

CHAPTER SIX: GENERAL CONCLUSION AND RECOMMENDATIONS

This chapter outlines the general conclusions for the research objectives. It also outlines recommendations that can be implemented to heighten further opportunities on the same research line.

CHAPTER THREE: CURRENT STATUS AND UTILIZATION OF BEEF SLAUGHTER BY-PRODUCTS BY THE PASTORAL COMMUNITIES IN KENYA: THE CASE OF BOVINE TRIPE

3.1 Abstract

Many animals including cattle, goats, sheep, and camel are slaughtered daily in the pastoral regions of Kenya due to high local demand for meat and meat by-products. However, high post-slaughter by-product losses have been reported due to poor handling and hygienic practices in slaughterhouses. Bovine tripe is one of the main by-products from the slaughter operation that can be utilized for food. However, there is very limited information on the current state of use of tripe by the pastoralists and other consumers in Kenya despite its high potential for utilization at commercial levels. This study was therefore designed to establish the utilization of beef tripe by pastoral communities and the peri-urban consumers in Kenya. The study was carried out in the pastoral Counties of Marsabit, Turkana, Kajiado and Garissa and, the Kiambu County bordering Nairobi County to represent the peri-urban area. The area of Kiambu County is peri-urban and it is also cosmopolitan in habitation. Mixed research methods were used in data collection.

The results showed that tripe from these pastoral regions can be utilized as human food and pet food. Bovine tripe yield based on live weight of cattle was found to be between 0.76-2.00% across all the slaughterhouses studied. The survey revealed that tripe used as food is prepared for consumption in different ways such as broiling (72.72%), braising (54.54%), frying (81.81%), cooking in liquids (63.63%) and stewing (36.36%) by the communities under study. The study found that the tripe is not effectively utilized leading to high post slaughter losses which differed

significantly ($p<0.05$) among the counties with Garissa county reporting the highest losses (>50%). When tripe is efficiently utilized by these communities, there will be a direct positive impact on the environmental pollution and the overall economy of the country.

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3.2 Introduction

Kenyan meat sector is essentially providing livelihood to pastoral communities, maintaining the production of livestock and in generation of a substantial amount of foreign income (MOLD, 2010). Besides meat, animal slaughtering also provides valuable by-products to the humans. According to Kenya National Bureau of Statistics (2009), the livestock resources are about 3.4 million and 14.1 million exotic and indigenous cattle respectively. Over 70% of the national livestock herd is raised by pastoralists. Pastoralists provide about 90% of the red meat that Kenyans consume while the other 10% is produced by cattle from the highland areas of Kenya (USAID, 2012). The processing of livestock during slaughter operations leads to high amounts of by-products.

In meat slaughtering operations, a by-product is everything yielded from an animal apart from the meat that has been dressed. The quantity of the by-products readily available to be utilized is obtained by getting the difference between 100 and the percentage of dressing. Animal by-products are basically divided into two main classes, edible and inedible by-products. The by-products from cattle account for about 60% on live weight basis out of which 20% are inedible and 40% are edible (Chatli *et al.,* 2005). The common edible by products includes tongue, tripe, liver, heart, brains, oxtail, trimmings, intestines; testicles, blood and spleen, and the inedible by-products include bones, hooves, blood (some communities) horns, and hides.

Bovine tripe is one of the main by-products utilized as food and also largely wasted by some pastoral communities in Kenya. Tripe is an edible lining mostly found in stomachs of ruminant animals and normally consumed together with maize meal (Ndeddy *et al.,* 2011). It is mostly found in beef cattle. Bovine tripes are produced by the muscular stomach compartments of the cow which include: Abomasum, reticulum, rumen and omasum. These chambers in the bovine stomach can be used as fermenters to degrade cellulose (Teixeira *et al.,* 2009). Traditions and cultures in different communities can determine whether the by-products from meat slaughtering operations will be considered as edible or inedible (Basu and Ockerman, 2004a).

Meat by-products can be used to develop new products with greater value if they are handled in a proper way (Zhang *et al*., 2010). However, huge losses of bovine tripe up to 0.75% of the live weights of the cattle are incurred post slaughter in these pastoral regions because they are not handled with as much care as the main carcass. Utilization of tripe especially in Turkana, Marsabit, Garissa and Kajiado is not very well organized hence exacerbates the wastage. The pastoral areas in Kenya experience extreme weather conditions especially high temperature that worsens the spoilage of these unutilized tripes. According to Jayathilikan *et al.*, (2012), when by-products are efficiently utilized, the gross income in beef industry might rise to approximately 11.4%.

According to the United States Department of Agriculture Economic research service (2011), meat by-products can give huge profits to processors and also pastoral communities upon improved utilization. For example, majority of men in Somali and part of Borana communities do not consume tripe because of traditions hence they discard it wholly and this may ultimately create major aesthetic and catastrophic health problems. When tripe that is produced in these pastoral regions is discarded in large volumes, they can be costly to treat and dispose ecologically (Ryder *et al*., 2015). The disposal costs can be compensated through generation of innovative products with higher value that can raise profitability.

Proper handling of slaughter by-products could increase slaughterhouse income by 15% (Bowater and Gustafson, 1988). However, there has been a gradual decline of the conventional markets meant for edible by-products due to reduced prices and rampant concerns about the health which have shifted the focus to non-food uses which include manufacture of animal feeds, pet food, pharmaceuticals and cosmetics (Rivera *et al*., 2000). Bovine tripes have the potential to be incorporated into the commercial products in the modern processing plants to increase their value and utilization without necessarily posing a threat to the acceptability of the products.

This study hence was aimed at assessing the current status of utilization, extent of losses and methods of preparation or processing of bovine tripe in the pastoral areas with the view to evaluating the potential of the by-products for incorporating them into the modern commercial meat processing industry.

3.3 Methodology

3.3.1 The study setting

The study was carried out in four Arid and semi-arid land (ASAL) counties where the pastoralists live namely Kajiado (2.0981° S, 36.7820° E), Garissa (0.1112° N, 40.3142° E), Marsabit (2.3369° N, 37.9904° E) and Turkana (3.1184° N, 35.5988° E). Kiambu County (1.1462° S, 36.9665° E) was also included to represent the peri-urban consumers in Kenya. The counties are shown in the Figure 1 below. The counties were purposively selected because they are the largest livestock producers in Kenya.

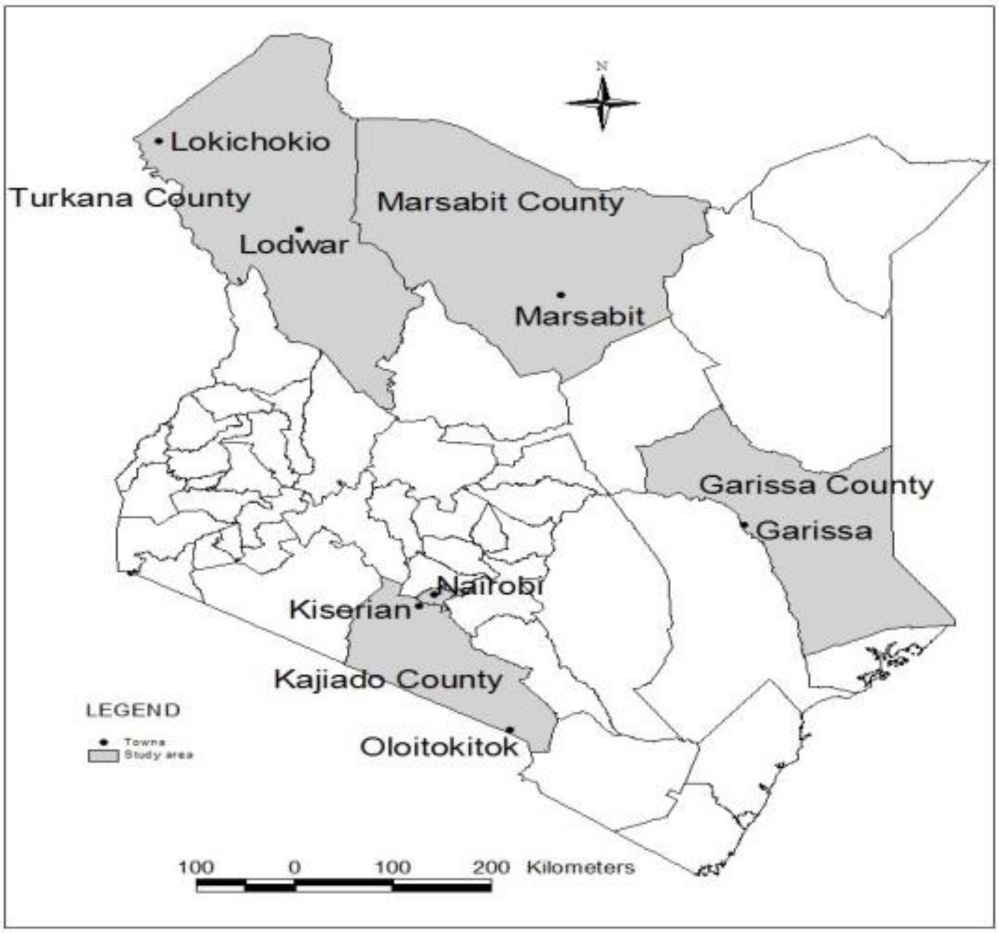

Figure 3.1: Map of Kenya with the highlighted study areas

3.3.2 The study design

The study design employed in this study was cross-sectional since the residents of the four counties have different socio-cultural backgrounds and traditions. Semi-structured questionnaire, focus group discussions, direct visual observations and key informant interviews were employed to get information from the study subjects.

The focus groups interviewed were key informants who were selected from each county as government veterinary officers, mainly meat inspectors who regularly interact with the local residents at the slaughterhouses and households. The focus groups comprised members of the community (five men and four women) who are well conversant with animal slaughter and product utilization. The above research tools were combined with personal visits of at least two slaughterhouses/abattoirs in each county.

3.3.3 Methods of data collection

Mixed research methods were used to collect data about the current slaughter practices and bovine tripe utilization from each pastoral region. Community residents who have first -hand knowledge about the community activities of meat slaughter were selected for focus group discussions, while the government meat inspectors were used as key informants. For each one of the groups, a check list of questions was used to collect the information on the slaughtering practices and the utilization of tripe by the local communities. A previously pretested questionnaire that was semi-structured was also employed to act as a guide in the interviews. The knowledgeable people (key informants) from the various communities in each county were involved in the administration of the questionnaires to aid in giving the cultural details and aspects regarding utilisation of the bovine tripe by local communities. The focus group discussion in each County consisted of 7-10 members (with gender consideration) and the ages of group members ranged from 35-67 years. These age groups of people were assumed to be knowledgeable enough about the by-products in their respective localities. The languages used were English, Swahili and sometimes local dialect when interpretation of some questions was needed. This was done with the help of native field assistants.

3.4 Statistical analysis

The data were analysed by SPSS version 20 for Windows. The chi-squared tests were performed to show the level of significance and association of the results obtained. All analyses were performed considering a 95 % level of confidence ($p<0.05$).

3.5 Results and Discussion

3.5.1 Status and economic activities in slaughter houses

Findings showed that all the slaughterhouses studied in the five counties normally slaughter beef cattle with each slaughtering at least 10-50 heads of cattle per day and some slaughtering over 200 heads per day (Table 3.1). This leads to the production of large volumes of by-products with bovine tripe being one of them. The study also revealed that 54.5% of the slaughterhouses do not sell their by-products including tripe immediately after slaughter (Table 3.1). The slaughterhouses also lack a well-organized market for the sale of their by-products. This coupled with lack of cold storage facilities exacerbates losses of valuable by-products especially tripe which have very short shelf-life (Brightwell *et al.*, 2007).

Table 3.1: Daily activities in slaughterhouses

Variable	percentage(n=21)
Animal slaughtered	
Sheep	36.40
Goat	81.80
Beef cattle	100.00
Donkey	9.09
Camel	63.60
Beef cattle slaughtered per day	
10-50	54.50
50-100	18.20
100-200	0.00
>200	27.30
Immediate sale of by-products	
Yes	45.50
No	54.50

There was a very high amount of bovine tripe produced in the slaughterhouses in all the ASAL counties studied. On the basis of live weights of the animals, the results showed that tripe accounts for approximately 8% of the total by-products form the slaughter operation. This is equivalent to about 0.76% - 2.0% of the animal's live weight (adult bull 1100kg and female 750kg). This is in agreement with the findings of Ockerman and Hansen, (2000) who reported similar quantities of bovine tripe in animals live weights. The rumen constituted the greatest percentage (0.7%) of the tripe, abomasum (0.16%), reticulum (0.20%) and omasum the least (0.18%). The pastoral communities produce the tripe from the cattle's stomach through the excision of the cow's stomach followed by the disembowelment of the contents which are then washed with water (Ndeddy *et al.,* 2011).

3.5.2 Utilization of tripe

The mode of utilization and consumption was also shared by some communities with human consumption being the most utilized method (Table 3.2). Distribution of uses of the tripe across the counties was determined by the dominant communities. The main methods noted include: human food, pet food, soup making and discarding where the tripe was not consumed at all (Figure 3.2). The largest percentage (28%) of the harvested tripe in Garissa was used as pet food and the rest was discarded while Turkana, Kajiado and Kiambu used a lot of the harvested tripe in soup and stew making (18.18%) (Figure 3.2). Some communities such as Somali in Garissa and Marsabit County do not consume the tripe due to traditions, culture and religious reasons and therefore discard all the harvested tripe. According to Jayathilikan *et al*., (2012), the religion, traditions and culture are determining factors in utilization of meat by-products as food. The usage of tripe in these pastoral regions shared basic treatments such as collection, washing, Cutting into whole or slicing into pieces, trimming, packaging. There was no significant ($p <0.05$) difference in the way tripe was used for soup making in Kiambu, Kajiado and Turkana Counties. This is because the dominant communities in these counties utilize bovine tripe as food and hence at times put it in the cooking pots to boil together with bones to make soup. The three counties also reported the highest utilization rates of over 18%. The tripe in general were utilised as local delicacies by most communities in these regions. They were either cooked by boiling and /or roasting or used as local sausage casings (Mathi, 2016). In Garissa and Marsabit Counties, only a few urban hotels commonly prepare tripe as part of their daily menu for consumption by a few target customers who are not of the Somali origin. However, no cases of soup making using tripe were reported in the two counties. This is due to deep rooted taboos in these communities which hinder them from consuming certain parts of the animal carcass. Lack of education and inadequate nutritional knowledge are the major causes of strict adherence to food habits and taboos that are extensively spread in various countries and might be related to religious beliefs and customs (Onuorah *et al*., 2003).

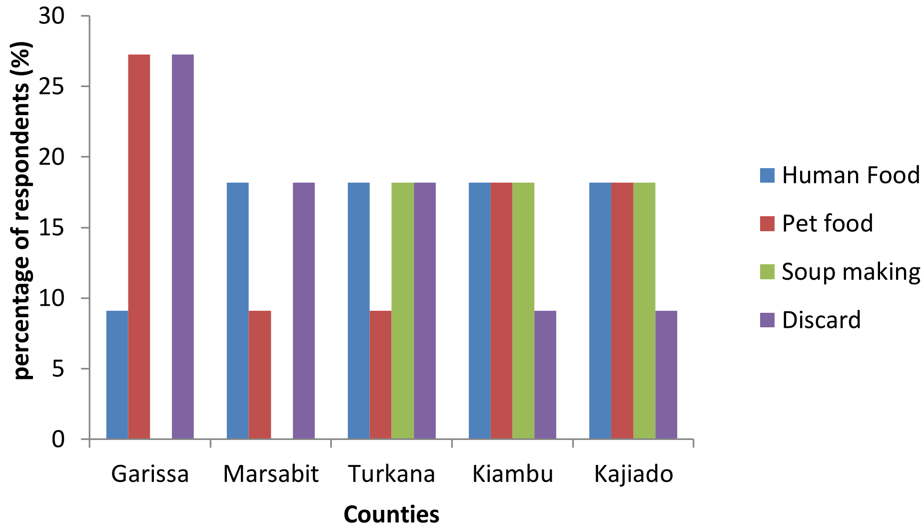

Figure 3.2: Graphical representation of uses of bovine tripe across the five counties

3.5.3 Methods of tripe preparation

The methods of preparation of bovine tripe for usage by households are shared by some communities in the pastoral regions studied with stewing and braising being the most likely methods of preparation and boiling the least. However, some methods differ significantly ($p<0.05$) across the counties as shown by the odd ratios and frequencies in the preparation methods (Table 3.2).

The degree of acceptability of tripe by communities in the peri-urban region of Kiambu was determined by a number of factors. These included the nutritional knowledge (where some consumers argued that meat is more nutritious than tripe and hence opt to buy meat at the expense of the tripe), the prevailing retail prices and the availability of substitute's products. The preparation methods and uses of tripe in Kiambu County varied from one community to the other where the same product was prepared and cooked differently for consumption by different communities. This is due to the fact that Kiambu County is cosmopolitan.

One of the major challenges reported across all the counties under study was the maintenance of hygiene in the collection, handling and preparation of the bovine tripe to maintain safety in consumption. This inhibited utilization of the products for food by some sections of the communities because the methods of preparation for consumption at the domestic level could not necessarily guarantee safety due to increased cases of food borne illnesses. According to *Ghazali et al., (2012)*, there has been an upsurge in food borne diseases due to rise in the number of people having meals out because the food is not prepared hygienically due to inadequate knowledge about personal hygiene.

The dominant communities in the counties had different local names for bovine tripe (Table 3.3). The communities prepared and stored tripe after evisceration from cow's stomach in various ways such as; soaking in salty water/ Pickling, storing as whole or sliced pieces, storing as fresh or cooked. Only areas with access to electricity enabled the traders and some local inhabitants to refrigerate or freeze the tripe. The study showed that tripes are very important food items to some communities in the pastoral regions.

The study also revealed that communities in Kajiado are more likely ($p<0.05$) to use braising, frying, stewing and broiling as preparation methods for tripe than boiling which has an odd ratio of 0.29 (Table 3.2). Communities in Garissa County are less likely to use boiling and broiling whose odd ratios are 0.07 and 0.67 respectively compared to other available methods of preparation (Table 3.2). In Marsabit County, the communities have a likelihood to use braising, stewing, broiling, boiling and frying as the main methods of preparation of tripe for consumption. In Kiambu County, most communities are less likely to use boiling as a method of preparation of tripe with most communities preferring to use other available methods as shown in table 3.3. Boiling, braising, stewing and broiling have a high likelihood to be used as preparation methods in Turkana while frying is equally likely ($p<0.05$) to be used.

Table 3.2: Odds ratios for Preparation methods of tripe

County	**Preparation method**					
	Frequency	Boiling	Braising	Frying	Stewing	Broiling
Kajiado	Proportion (%)	9.09	9.09	18.18	9.09	18.18
	Odds	0.29	1.25	1.29	1.25	1.50
Garissa	Proportion (%)	9.09	0	27.27	18.18	18.18
	Odds	0.07	2.67	1.33	3.33	0.67
Marsabit	Proportion (%)	18.18	18.18	18.18	0	18.18
	Odds	1.5	3.00	1.29	2.25	1.50
Turkana	Proportion (%)	18.18	18.18	0	0	0
	Odds	1.50	3.00*	0*	2.25	9.00*
Kiambu	Proportion (%)	9.09	9.09	18.18	9.09	18.18
	Odds	0.29	2.25	1.29	1.25	1.50
Total	Proportion (%)	63.63	54.54	81.81	36.36	72.72

***** Significant at $p<0.05$

>1- Likelihood to happen

<1-less likely

0-equally likely (only when significant at 0.05)

Table 3.3: Preparation, storage and utilization methods of Bovine tripe

County and dominant community	Tripe local name	Preparation and storage after evisceration	Preparation Methods for usage by household
Turkana(Turkana)	Ng'aboi	Remove faeces and ingesta, soak in salty water, wash and stored whole.	Cooked in liquid/water, braised
Marsabit(Borana, Redille,Orma)	marrumaan	Remove adhering faeces store Whole and fresh	Cooked in liquid, broiling, Fried, braised
Kajiado(Maasai)	Emonyita	Whole, Fresh, and pickled	Fried, braised, broiled or cooked in liquid with other meats
Garissa	Alooley/Alool	Whole, Sliced	Raw Pet food, Sausage ingredient
Kiambu	Matumbo	Whole, frozen, fresh, refigerated refrigerated, pickled.	Broiling, cooking in liquid, prepared as casings for sausages Fried and stewed.

3.5.4 Bovine tripe losses from slaughterhouses

The losses in tripe ranged from less than 5% to over 50% in the five counties studied. Garissa County reported the highest losses of bovine tripe with over 50% of the harvested tripe being discarded by the dominant Somali community while Kiambu County reported the least losses to the tune of less than 5% (Figure 3.3). However, some respondents reported losses of between 5-30% in the same county. This is because Kiambu is cosmopolitan and some inhabiting communities do not consume tripe. These losses can also be attributed to lack of cold storage facilities and proper technologies to extend the shelf-life of harvested tripe and other by-products (Liu, 2002).

In Marsabit, Turkana and Kajiado, the slaughterhouses studied reported losses between 30-50%. This is because of some taboos (Somali men should not eat tripe) in the region that prohibit some local communities especially Somali from consuming tripe hence some tripe ends up being discarded. The huge losses are also due to lack of preservation technologies needed to extend the shelf-life of the by-products in the areas. Some communities argued that the tripe is too tough to chew even after cooking and hence throw it away after evisceration. The inherent toughness due to huge contents of collagen makes it hard to chew and also increases the cooking time (Anna *et al*., 2008). As a result, its utilization has not realized full potential and this further exacerbates the losses.

The challenge in maintenance of hygiene during the collection and handling of tripe due to insufficient water and lack of knowledge on food safety has also limited its utilization among sections of the communities in Kajiado, Marsabit, Garissa and Turkana since the methods of preparation for consumption could not guarantee food safety. In Kiambu County, most slaughterhouses visited had enough water and washing of tripe was done properly hence increasing acceptability and consumption which reduce losses. When rumen contents are effectively washed, residual contamination is greatly minimised, this reduces cross-contamination hence better hygiene and longer shelf-life (Gill, 1988).

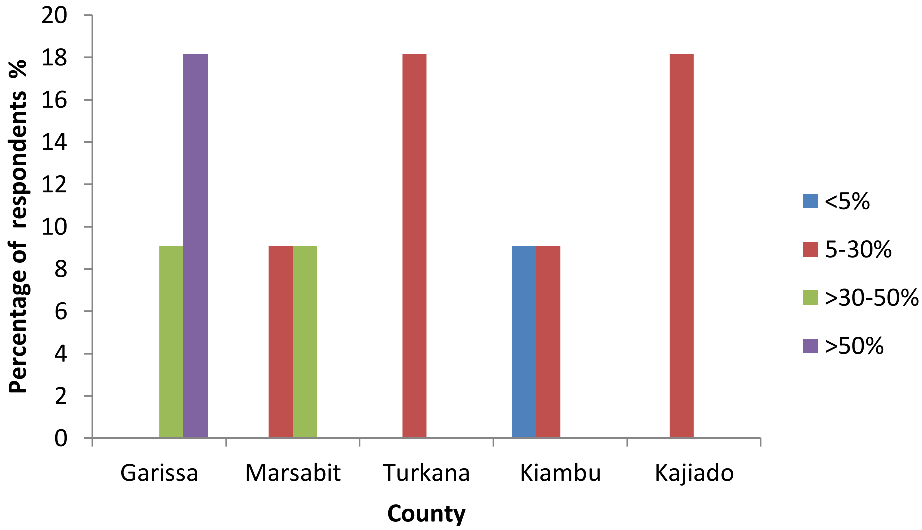

Figure 3.3: Tripe losses across the five counties

The study also showed that there was no significant ($p>0.05$**)** association between the organization of the market for bovine tripe and the counties as all the five counties lacked a well - organized market. This also contributed to losses as some slaughterhouses could not sell all the tripe immediately after slaughter as they wait for random buyers to come and purchase them.

The findings also revealed that Marsabit, Garissa, Turkana and some slaughterhouses in Kajiado do not have adequate water hence improper washing of the tripe. This coupled with high temperatures experienced in these regions favors an upward increase in the population of undesirable bacteria resulting in huge losses of tripe (Ndeddy *et al*., 2011). Garissa, Kajiado, Marsabit and Turkana reported the highest post slaughter losses compared with Kiambu during storage (Table 3.4). Garissa had the highest with 27.27% and Kiambu the least with 9.09%. The major causes of losses incurred during storage as reported in the five counties include: rotting, excessive water loss and darkening and drying with rotting contributing the largest percentage (27%) and darkening the least (9%) (Table 3.4). Local butcheries were the main buyers of the tripe across all the counties contributing over 80% of the total purchases with supermarkets buying the least (Table 3.4). Unhygienic conditions and lack of cold storage facilities in slaughterhouses and butcheries favors the multiplication of undesirable microorganisms which might be pathogenic to consumers and can cause spoilage of tripe. Spoilage microorganisms minimize the quality and shelf-life of food products eventually lowering the market value and increases losses to stakeholders in meat value chain (Bensink *et al*., 2002). These unhygienic conditions exacerbate spoilage of tripe and consequently post slaughter losses.

Table 3.4: Post slaughter handling of tripe

Variable	County				
	Garissa	**Marsabit**	**Turkana**	**Kiambu**	**Kajiado**
Organized market					
Yes	0.00	0.00	9.09	0.00	0.00
No	27.27	18.18	9.09	18.18	18.18
χ^2	3.93				
Losses in storage					
Rotting	27.27	18.18	18.18	18.18	18.18
χ^2	0.00				
Darkening and drying	9.09	9.09	18.18	9.09	0.00
χ2	5.80				
Excessive water loss	18.18	9.09	0.00	18.18	9.09
χ^2	5.79				
Sales to Butcheries					
50-80%	0.00	0.00	9.09	0.00	0.00
>80%	27.27	18.18	9.09	18.18	18.18
χ^2	3.93				
Sales to Supermarket					
5-10%	27.27	18.18	18.18	9.09	18.18
>5-10%	0.00	0.00	0.00	9.09	0.00
χ^2	3.93				
Sales to Hotels					
5-10%	18.18	18.18	0	18.18	18.18
>5-10%	9.09	0.00	18.18	0.00	0.00
χ^2	3.93				

NB- There was no significant difference among the variables at $p<0.05$

Bovine tripe has high amounts of vitamins, minerals, proteins, nicotinic acid and fat. It has several roles such as adding strength to stomach and the spleen, to replenish kidney and strengthen the middle burner (Lin *et al.*, 2012). Post slaughter losses should therefore be reduced to prevent loss of such a valuable by-product.

Research on tripe processing technology should be enhanced to attain the balance between the cost of production and safety of the final products in order to curb the losses in the value chain. This will definitely assist in realizing the full economic value of tripe in these pastoral regions, create employment and improve the growth of beef industry.

3.5.5 Risks posed to the consumer by tripe preparation methods

When evisceration is being done from the stomach of slaughtered beef cattle, contamination of the tripe by intestinal bacteria from the fecal matter is inevitable via direct contact with it (Bensink *et al*., 2002). The processing equipment in the slaughterhouses that are not properly washed and poor personal hygiene of flayers may lead to cross contamination hence spread of bacterial species. This cross examination is exacerbated by the fact that most slaughterhouses in the surveyed pastoral regions lack adequate water for cleaning and maintaining the general hygiene. These bacterial species and cross contamination can cause food borne diseases especially when the tripe is not properly cooked. Food borne illnesses are caused by toxins and other bacteria released by microorganisms available in food products. Some of these pathogens are introduced when the food is in the field or during the preparation for consumption (Doyle and Evans, 1999).

Bovine tripe has been shown to contain several bacterial groups that have also been found in meat products. These bacterial groups include *Enterobacteriaceae group, Escherichia coli, Pseudomonas spp, Bacillus and staphylococcus spp* (Bensink *et al*., 2002). These bacteria can survive in tripe especially when cooking, braising, stewing, broiling and frying are not properly done. They are also known to cause a lot of food borne illnesses such as infections of respiratory and urinary tracts, plague and diarrheal diseases (Seral *et al*., 2002).

Enterobacteriaceae family found in bovine tripe has the capacity to produce proteases and also lipolytic enzymes which are known to negatively affect the organoleptic characteristics in meat products (Losantos *et al*., 2000). The two groups of enzymes degrade the structural components in meat producing off odors that lowers the acceptability of food by consumers and also negatively affects the marketing range of the product (Brightwell *et al*., 2007). It is therefore very important to ensure that tripe is properly handled and fully cooked to get rid of these pathogenic microorganisms.

3.5.6 Conclusions

The utilization of bovine tripe from slaughterhouses is not very efficient and this causes huge losses in pastoral regions of Kenya. The mode of preparation, utilization and consumption of bovine tripe is also shared by some communities across the pastoral regions. A substantial amount of tripe is discarded due to inherent toughness, traditions, cultures and lack of appropriate technologies needed for value addition to extend the shelf life. Beside pollution and hazardous aspects, in most cases, the bovine tripe has the potential to be converted into a more valuable product with greater value such as a ready to eat bovine tripe roll with a higher shelf-life. Today's technology can be employed to allow better and more efficient utilization of the bovine tripe. This is essential to increase the profit and reduce the production costs in the meat industry at large and maintain its viability.

CHAPTER FOUR: STORABILITY AND PHYSICO-CHEMICAL QUALITY OF READY TO EAT BOVINE TRIPE ROLLS UNDER DIFFERENT STORAGE CONDITIONS

4.1 Abstract

Cooked ready to eat bovine tripe rolls were developed from a combination of rumen, reticulum, abomasum and omasum parts of bovine tripe. Blade tenderization and mincing treatments were used to improve the tenderness of the products which were stored at refrigerated condition in vacuum and aerobic packages. Evaluation of the products was done for physico-chemical and sensory characteristics at methodical interval of 7 days during the storage period of 28 days. Significant changes ($p<0.05$) in sensory and physico- chemical characteristics were observed in minced and blade tenderized products under different packaging conditions. The cooking losses (9.07%-12.09%) and shear force values (2.31N-4.43N) among the minced, blade tenderized and control (Non-tenderized tripe) products differed ($p<0.05$) significantly during storage. The storage period caused notable changes ($p<0.05$) in pH, peroxide value, Thiobarbituric acid (TBA) value, Moisture content, tyrosine value and extract release volumes (ERV) under different packaging conditions. The average pH ranged from 6.4 to 6.0, ERV (22.2-17.9), Peroxide value (1.81-16.04 meq/kg), TBA (0.55-0.91mg malonaldehyde/kg) and tyrosine value (0.43-0.78 mg tyrosine /100g). The extract release volume, TBA and peroxide values for vacuum packed products were significantly ($p<0.05$) lower than in aerobically packed products. Sensory evaluation scores for all the samples under vacuum packaging were well within the acceptable limits up to 28 days of storage at 4±1 °C. However, all the samples stored aerobically were acceptable until 21 days of storage after which extremely high off odors due to increased lipid oxidation which reduced their scores significantly ($P<0.05$). Hence, vacuum packaging was extra effectual than aerobic packaging in inhibiting oxidation of lipids, protecting the organoleptic quality of the product as well as extending the shelf-life of the ready to eat product.

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4.2 Introduction

The population of livestock in Kenya is about 14.1 million for indigenous cattle and 3.4 million for exotic cattle while over 70% of the whole population is raised by the pastoralists (Farmer and Mbwika, 2012). Although cattle are slaughtered mainly for meat, large volumes of by-products with significant value are also generated. Most of the by-products constitute an excellent source of nutrients such as minerals and vitamins (Garcia *et al*., 2011). However, a lot of the slaughter by-products especially bovine tripe are not fully utilized because of the socio-cultural beliefs, their natural state and lack of technology for value addition (Abegaz, 2009).

Bovine tripe accounts for approximately 0.75%-2.0% yield by live weight (Ockerman and Hansen, 2000), which is about 5.62kgs/cattle. In Kenya, majority of communities in the pastoral regions and other slaughter establishments/slabs discard tripe after slaughter due to its innate toughness caused by large amounts of collagen that makes it extremely hard to chew. This toughness coupled with poor keeping quality and its low value aesthetically has made it hard to utilize tripe in commercial applications for value addition (Parivell, 1999). It is not practical to discard tripe because it has strong economic potentials in the development of new products with added value upon overcoming the above limitations successfully by enhancing tenderness using appropriate processing technologies (Toldra and Reig, 2011). The added value is realized through shelf stability, improved sensory qualities (flavor and texture) or even more convenience in terms of handling of the final product.

Blade tenderization and mincing are well acknowledged and recognized mechanical techniques of tenderizing meat and meat by-products in the meat industry (Alaa *et al*., 2014). The two processes disrupts the structure of muscles, break down the external part of the meat by-product and releases the myofibrillar proteins consequently increasing solubilisation and extractability of muscle proteins leading to enhanced product yield and softness of the end by-products or meat (Pietrasik and Shand 2004). According to Benito-Delgado *et al*., (1994), blade tenderization entails penetrating the muscles with sharp thin blades which are closely spaced. The long muscle fibers are cut into smaller and shorter segments significantly improving the tenderness of the meat cuts. Most researchers have reported that mechanically tenderized ready to eat meat products are less tough than the control ones and that mechanical tenderization is one of the frequently used and effective methods of tenderizing meat and meat-by-products. Research has also shown that mechanical tenderization of meat products decreases the shear force required to chew cooked meat products (Flores *et al*., 1986). Mincing entails passing fresh meat /by-product via a meat mincer which disintegrates the connective tissues making them softer and less obstructive upon cooking. It is becoming one of the most employed techniques in development of new meat products and meat processing (Anna *et al*., 2008).

Bovine tripe is a commodity that spoils easily, hence there is need to strategize on a preservation technique that can slow down the rate of spoilage and still maintain the products quality during storage. If suitable storage and packaging conditions are used, they play a significant role in preserving the products quality during storage (Lavieri and Williams, 2014). It has been reported that meat products developed through mechanical tenderization had more desirable acceptability until the 15th day during refrigerated storage in vacuum packages (Anna *et al.,* 2008). It has also been shown that vacuum packaging creates anaerobic environment and conditions that retain the quality and extends the oxidative shelf-life of meat and meat-products. Therefore, the current study was designed to evaluate the efficacy of mechanical tenderization methods on the physico – chemical qualities of cooked bovine tripe rolls during refrigerated storage (4±1 °C) under vacuum and aerobic packages.

4.3 MATERIALS AND METHODS

4.3.1 Sample collection and preparation

The bovine tripe was obtained from a local slaughterhouse (Bahati slaughterhouse, Limuru) which possesses the required authorisation from local authorities about health and hygiene practices. Other ingredients were bought from an authorised supplier in Nairobi city. Fat and other extraneous substances attached to the surface of tripe were separated using a knife followed by thorough washing. The tripe was then cut into (8×8cm) pieces for ease of mechanical tenderization. The already processed casings with internal diameter of 5 cm were bought from authorized processor in Nairobi city. Other ingredients were bought from an authorised supplier in Nairobi city.

4.3.2 Product formulation and treatments

The formulated ready to eat product consisted of the following ingredients: bovine tripe, common table salt, sodium tripolyphosphate, $NaNO_2$, ascorbic acid, spices, and flakes of ice. A series of preparatory trials were carried out in order to develop the final formula for a ready to eat bovine tripe rolls. Different additives and seasonings used in the formulations are shown in Table 4.1. Blade tenderization (BT) and mincing are the treatments that were used to prepare bovine tripe. Bovine tripe pieces were tenderized three times using a blade tenderizer which is operated mechanically. This was followed by sectioning the tenderized pieces into even chunks of 2 cm by 2 cm and was used to prepare blade tenderized bovine tripe rolls.

Bovine tripe pieces subjected to partial freezing (-2°C) were ground twice using a meat grinding machine and a 3 mm plate and used to prepare ground/minced cooked bovine tripe rolls.

2 cm by 2cm bovine tripe chunks (Non-tenderized) were used to prepare the control products.

Table 4.1: Additives and seasonings for a 500g product formulation

Additives	Quantity (g)	Seasonings	Quantity (g)
Common salt	8	White pepper	1
Sodium tripolyphosphate(STTP)	1.5	Nutmeg	0.15
Ascorbic acid	0.15	Mace ground	0.3
Monosodium glutamate(MSG	0.25	Coriander & Ginger	0.4
Nitrite pickling salt	1.5		
Total	11.4	Total	1.85

4.3.3 Experimental Design

The project's experimental design was a complete randomized design because the experiment studied the effect of one primary factor (Table 4.2). The experiment compares the values of a response variable based on the different levels of that primary factor.

Table 4.2 Experimental Design of bovine tripe rolls production

Treatments	**Particle sizes**
Control (Non-tenderized tripe rolls)	2 x 2 cm
Blade tenderized tripe rolls	2 x 2 cm
Minced tripe rolls	3 mm

4.3.4 Preparation of the product

After tenderization and mincing, bovine tripe samples (BT samples and minced samples) were weighed separately and mixed in meat mixing machine at a speed of 250rpm for 5min with sodium triphosphate and sodium chloride. After 5 minutes, ascorbic acid, additives and seasonings, $NaNO_2$ and ices flakes were incorporated into the mass and mixing proceeded for another 5 minutes in order to get a homogenous mass.

500 grams of the homogenous meat mixture was put manually into casings. Cooking of the stuffed mixture took place hot water that had been pre-heated till the inner temperature of 83 ±1°C was achieved and retained for 15 minutes. Probe thermometer was used to record the temperature.

After cooking was done, the RTE bovine tripe rolls were left to cool down packed in LDPE and put in a refrigerator to chill for about 13 hours. Thereafter, the mass was cut into thin pieces using a meat slicing machine and packed under both vacuum and aerobic conditions using PET pouches. Storage of the samples was done at 4±1 °C and evaluation carried out at 0, 7, 14, 21 and 28 days.

Blade tenderization

Bovine tripe
↓
Removal of fat and extraneous matter (Trimming)
↓
Cut into 10×10 cm chunks
↓
Blade tenderize
↓
Section into uniform pieces (2cm)
↓
Addition of salts and spices
↓
Mixing of ingredients completely (meat mixer)
↓
Stuffing into casings
↓
Cooking (internal temp 83◦C)
↓
Cooling
↓
Package in LDPE
↓
Chilling in refrigerator (13 hrs)
↓
Package in PET
↓
Store at 4◦C and Evaluation

Mincing

Bovine tripe
↓
Removal of fat and extraneous matter
↓
Partial freezing (-2°C)
↓
Mincing (using 3mm plate)
↓
Addition of salts &spices
↓
Mixing of ingredients
↓
Stuffing into casings
↓
Cooking (internal temp 83◦C)
↓
Cooling
↓
Package in LDPE
↓
Chilling in refrigerator
↓
Package in PET
↓
Store at 4 ◦C and Evaluation

Figure 4.1: The RTE Bovine tripe rolls processing flow diagram

4.4 Analytical methods

4.4.1 Proximate composition

4.4.1.1 Determination of moisture content

The AOAC approved method 950.46 (AOAC, 2006) was used. Approximately 5g of the sample was weighed in aluminium made dish which was placed in an oven at 105°C for approximately 5 hours. Cooling followed and both the dish and the residue were weighed. The difference in weight between the original fresh sample weight and the dried sample gave the moisture content. This was expressed as per cent moisture content.

4.4.1.2 Determination of fat content

The soxhlet method according to AOAC Approved method 954.02 (AOAC, 2006) was used to determine the crude fat content of the products. 5g of pounded sample was accurately weighed into an extraction thimble containing cotton wool which was then transferred into the sohxlet extractor and extraction of the fat done in a tared flask for 8 hours using petroleum ether (B.P. 40-60^oC). Evaporation of the fat was done in a rotary evaporator. The drying of the residue was done in an air oven at 105ºC for about 1 hour and then weighed. Determination of the fat content was done and values expressed in form of percentage of the sample dry matter content.

4.4.1.3 Determination of protein content

The approved AOAC (2006) Kjeldahl 992.15 method was used for crude protein determination. 0.5g of the sample were accurately weighed and placed in a Kjeldahl flask, folded in a nitrogen free filter paper. A catalyst tablet and sulphuric acid were carefully added to digest the sample in a fume chamber. Phenolphthalein was used as the end point indicator before the Kjeldahl flask was connected to a distillation unit. 40% NaOH solution was used for back titration against a 0.1N NaOH solution. The standard conversion factor for Nitrogen into crude protein content of the sample was 6.25.

4.4.1.4 Determination of ash Content

The approved AOAC (2006) Method 942.05 was used. Charred samples were placed in dishes followed by heating for 6 hours at 525ºC till the ash that was white in colour was gotten to a constant weight. The weight of the obtained ash was divided by the sample weight and expressed into percentage.

4.4.1.5 Determination of crude fiber

Method 978.10 of AOAC (2006) was used. Ten gram of sample was digested with 200 ml of boiling 0.225N Sulphuric acid in heating mantle for 30 minutes with condenser. After boiling, the contents were filtered in the fluted funnel and washed with boiling water to free from acids. This was then boiled with preheated 200 ml of 0.313N NaOH for 30 minutes in heating mantle with condenser. The sample was then filtered and washed in fluted funnel. The material was dried, weighed and then ashed in the furnace at 540˚C. Subtraction of ash weight from weight of acid, alkali treated sample give weight of crude fiber.

$$\text{Crude fiber (\%)} = \frac{\text{Weight of crude fiber}}{\text{Weight of sample taken}} \times 100$$

4.4.2 Determination of cooking loss

The methods described by Pietrasik and Shand (2004) were used to determine the cooking losses. A sample of known weight was cooked until its centre attained a temperature of 83^{o}C. Cooking loss was expressed as per cent loss in weight between the initial and the after cooking weights of the sample.

4.4.3 Determination of shear force value

The procedure described by Anna *et al.,* (2008) was used. Bovine tripe rolls were sliced into 1 cm^2 sections and positioned perpendicularly to the blade. Warner–Bratzler shear press machine was used to shear the sections. The recording was done to get the average shear force values of 10 observations that were made.

4.4.4 Determination of peroxide value (PV)

Determination of PV was done using the procedure of Richards and Hultin (2000) but the method was slightly modified as per Maqsood *et al.,* (2015) descriptions. Cumene hydro peroxide at a concentration of 2ppm was used to prepare a standard curve with the concentration range of 0.5-2 ppm.

4.4.5 Determination of extract release volume (ERV)

Jay and Hollingshed (1990) methods were used to determine ERV. Fifteen grams of ground product were measured and mixed thoroughly with 60 ml of distilled water in a homogeniser. The suspension was rapidly transferred into a funnel supplied with paper number one (Whatman) The ERV of the product was determined by recording the volume of the filtrate obtained in the initial 15 minutes.

4.4.6 Determination of thiobarbituric acid value (TBA)

The methods of Witte *et al.,* 1970 were used in estimation of TBA values. Trichloroacetic acid extracts obtained from all the products were employed in determination of the absorbance at 532 nm. Calculation of TBA was done as mg malonaldehyde per kg of product sample making use of standard graphs formulated using known concentration of malonaldehyde as reference.

4.4.7 Determination of tyrosine value

The methods described by Strange *et al.,* 1977 were used to determine the tyrosine value of the samples. 2.5 ml of Trichloro acetic acid (TCA) extract was diluted with equal quantity of purified H_2O in test tubes. To this, 10ml of 0.5N sodium hydroxide was added followed by 3ml of dilute folin ciocalteu phenol reagent. After mixing, the mixture was kept for 15 minutes a room temperature. The developed blue color was measured as absorbance value at 660 nm in a spectrophotometer using a blank (5ml of 5% TCA) for comparison. With reference to a standard graph, the tyrosine value was calculated and expressed as mg of tyrosine /100gm of the sample.

4.4.8 Determination of pH

Determination of pH was done by adopting the procedure laid down by AOAC (2006) method 981.12 using digital pH meter (Elico model L 1-10 T, Chennai) with a glass probe electrode. About 10 g of each sample were mixed thoroughly for 1min in a blender with 50 ml of distilled water and the volume topped up to 100 ml and pH was recorded.

4.4.9 Sensory evaluation

Sensory evaluation was conducted on days 0,7 14, 21, 28 days of storage by lining up a panel of 32 utrained members who are familiar with meat products and whose key focus was on Appearance and colour, odour, taste, tenderness, juiciness and overall acceptance. Coding was done randomly using three digit codes to enable subjective, unbiased and independent exercise among the panelists. They were instructed to finish with all attributes of one sample before proceeding to another to aid objectivity. Rinsing water was duly provided for mouth rinsing between samples tasting. Panelists were subjected to similar operating conditions. A nine point hedonic scale was used by the panelist for their judgment with 9 being like extremely and 1 dislike extremely as described by Meilgaard *et al.*, (2006).

4.5 Statistical analysis

The data were analysed using one-way analysis of variance (ANOVA) and the Duncan's multiple range tests for multiple mean comparisons. The data were processed using Genstat software version 15.0 and significance was defined at $P<0.05$. Sensory analysis descriptive data was analysed using SPSS for windows version 20 and the difference in means done using the Duncan's multiple test at $P<0.05$.

4.6 Results and Discussion

4.6.1 Proximate composition of differently processed tripe during storage

Results for overall treatment means for proximate composition which include moisture content, crude fat, crude protein, crude ash and crude fiber contents are shown in table 4.1. The following were the average ranges observed across all the products; Moisture content 68.66-72.25%, Crude protein 62.81-66.97%, crude fat 7.60-7.92%, crude fibre 2.31-2.61% and crude ash 3.71-3.93%. Results for change in proximate composition of the products during the storage period at 4±1°C under vacuum and aerobic packaging conditions are shown in Figures 4.2-4.6.

Table 4.3: Proximate composition of differently processed tripe

Storage condition	Treatments*	Proximate Components				
		Moisture%	Crude Protein%	Crude Fat%	Crude Fiber%	Crude ash%
Vacuum	Control	72.25±1.69[a]	66.97±3.61[a]	7.72±0.42[a]	2.61±0.18[a]	3.93±0.24[a]
	Minced	70.36±1.49[b]	66.95±2.78[a]	7.78±0.30[a]	2.31±0.16[a]	3.84±0.18[a]
	BT tripe	68.93±0.82[c]	62.81±1.14[b]	7.60±0.85[a]	2.33±0.23[a]	3.78±0.10[a]
Aerobic	Control	70.07±2.71[bc]	66.00±5.14[a]	7.92±0.44[a]	2.56±0.20[a]	3.82±0.24[a]
	Minced	69.47±3.17[cd]	65.94±6.19[a]	7.69±0.28[a]	2.60±0.24[a]	3.85±0.33[a]
	BT tripe	68.66±2.62[cd]	63.08±4.67[b]	7.75±0.82[a]	2.52±0.23[a]	3.71±0.22[a]

*Values with different letters in the superscript along a column are significantly different at $p<0.05$. All values are in dry matter basis except for moisture. KEY: BT- Blade tenderized

4.6.1.1 Moisture content of bovine tripe rolls

Packaging significantly affected the moisture content ($p<0.05$) with vacuum packaged products retaining higher overall moisture content than aerobically packaged products (Table 4.1). The results are in accordance to the findings of Vaudagna *et al.,* (2002), who found out that vacuum packaging reduces loss of water in meat products. The results are in line with the findings of Lin *et al.,* (2004), who reported that vacuum packaging results in lower weight loss of the meat products. The control products (non-tenderized mechanically) had the highest moisture content which ranged from 70.07 to 72.25 for aerobic and vacuum conditions respectively. The moisture content for the control product differed significantly ($p<0.05$) from the minced and Blade tenderized products. Blade tenderized (BT) products recorded the lowest moisture content in both aerobic and vacuum conditions but the difference was not significant at $p<0.05$. The lower moisture content in tenderized products could be due to high losses of moisture during mincing which increases the surface area for moisture loss. The water in BT products was also poorly bound hence easily lost (Anna *et al.,* 2012). Blade tenderization creates holes in the meat products that increase moisture loss (Pietrasik and Shand (2004). Moisture content decreased gradually during storage in both packaging conditions (Figure 4). These changes are attributable to loss of moisture via the packaging materials containing some permeable films (Anna *et al.,* (2008), Sahoo and Anjaneyulu (1997). Biswas *et al.,* (2011 b) and Sharma *et al* (2017) also reported decrease in, moisture content of meat products during cold storage.

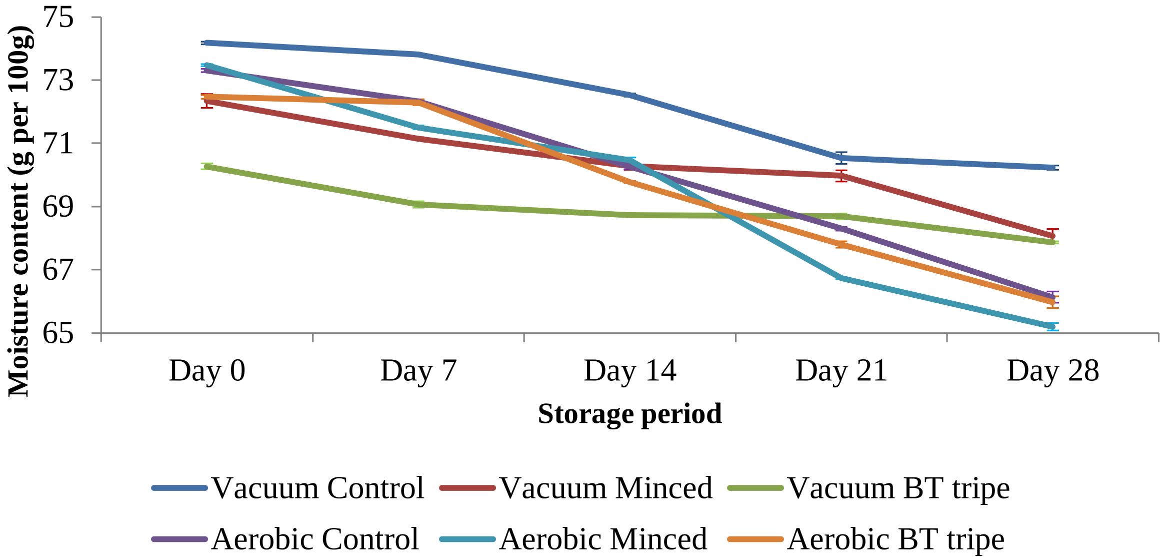

Figure 4.2: Moisture content of bovine tripe rolls stored for 28 days (The error bars indicate standard error of the means)

4.6.1.2 Protein content of bovine tripe rolls

The crude protein of minced products and control products (non-tenderized mechanically) did not differ significantly ($p<0.05$) in both packaging conditions (Table 4.1). However, there was a significant difference ($p<0.05$) between the blade tenderized products and all the other products that were not tenderized. Blade tenderized products had the lowest protein content of 62.81 and 63.08 for vacuum and aerobic packages respectively. These results were in agreement with Pietrasik and Shand 2004, who found that the protein content of blade tenderized meat roasts was lower compared to non-tenderized. There was a slight increase in crude protein content in all the products during the storage period (Figure 4.3). This is due to reduction of moisture during storage which leads to a corresponding increase in density of the proteins in the product (Nielson, 2010; Gerber, 2007). Sharma *et al.*, 2002 also reported that a decrease in moisture content leads to an increase in protein of the meat products. Sachdev *et al*., 2002 also found that protein content increased when moisture reduced significantly during the refrigeration and frozen storage of cooked chicken meat. Similar findings were reported by Rahman *et al.*, 2017, who observed an increase in protein content of cooked beef during refrigerated storage. Resident microorganisms whose population increases during storage also utilize non-protein nitrogenous materials to synthesize proteins resulting in the increase of protein content (Agunbiade *et al.*, 2010).

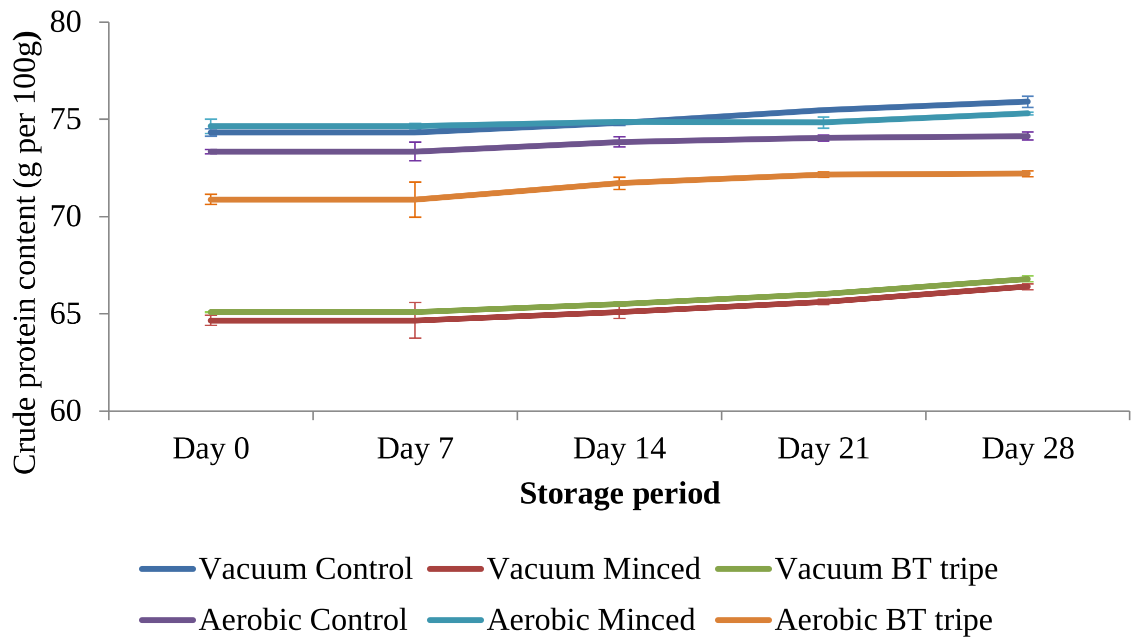

Figure 4.3: Protein content of Bovine tripe rolls stored for 28 days. (The error bars indicate standard error of the means; All values are in dry matter basis)

4.6.1.3 Crude Fat content of bovine tripe rolls

Crude fat content of all the products ranged from 7.60% to 7.92 % in the developed products. The difference in crude fat was not significant ($p<0.05$) in all the products (Table 4.1). The type of the package had no significant effect on the crude fat content. Malik and Sharma, (2014) also observed that packaging had no effect on crude fat of the RTE buffalo meat products stored under vacuum and aerobic conditions. As the storage period advanced, a corresponding increase in fat was observed across all the products under aerobic and vacuum packaging conditions (Figure 4.4). This can be attributed to the effects of concentration of moisture loss (Sharma et al., 2017). These findings also corroborate with the report of Rajkumar *et al.*, (2004), who observed that moisture loss contributed to the higher crude fat content of the goat patties during refrigerated storage. Fernandez *et al.*, (2005) also reported that as the moisture content reduces nutrients density increases.

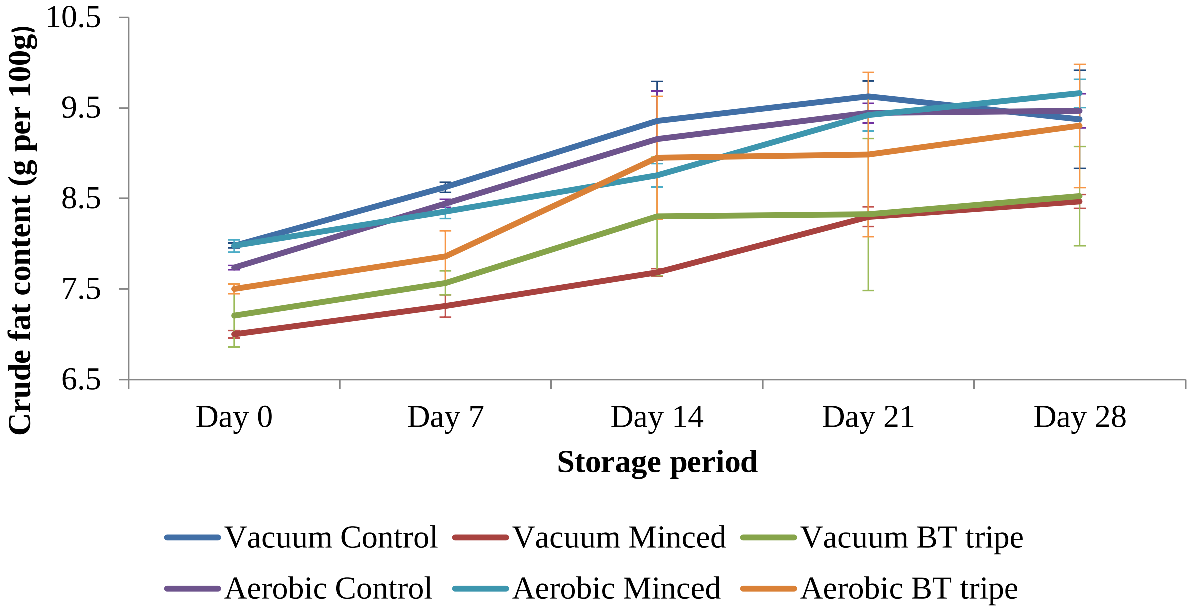

Figure 4.4: Crude fat content of tripes stored for 28 days. (The error bars indicate standard error of the means).

4.6.1.4 Crude Fibre of bovine tripe rolls

The average Crude fibre content in all the products ranged from 2.31 % to 2.61 % on dry matter basis (Table 4.1). The content was almost the same in all the products under aerobic and vacuum packaging condition and the slight difference noted was not significant ($p<0.05$). The overall crude fibre content increased ($p<0.05$) across the storage period but the increases were insignificant (Figure 4.5). This increase can be attributed to decrease in the moisture content of the products with refrigeration storage which increased the density of crude fibre (Sharma *et al.*, 2017; Nielson, 2010; Fernandez *et al.*, 2005). The present findings are also in line with earlier report (Thind *et al.*, 2006), who found that the fibre content of cooked chicken patties increased with decrease in moisture content during the extended cold storage.

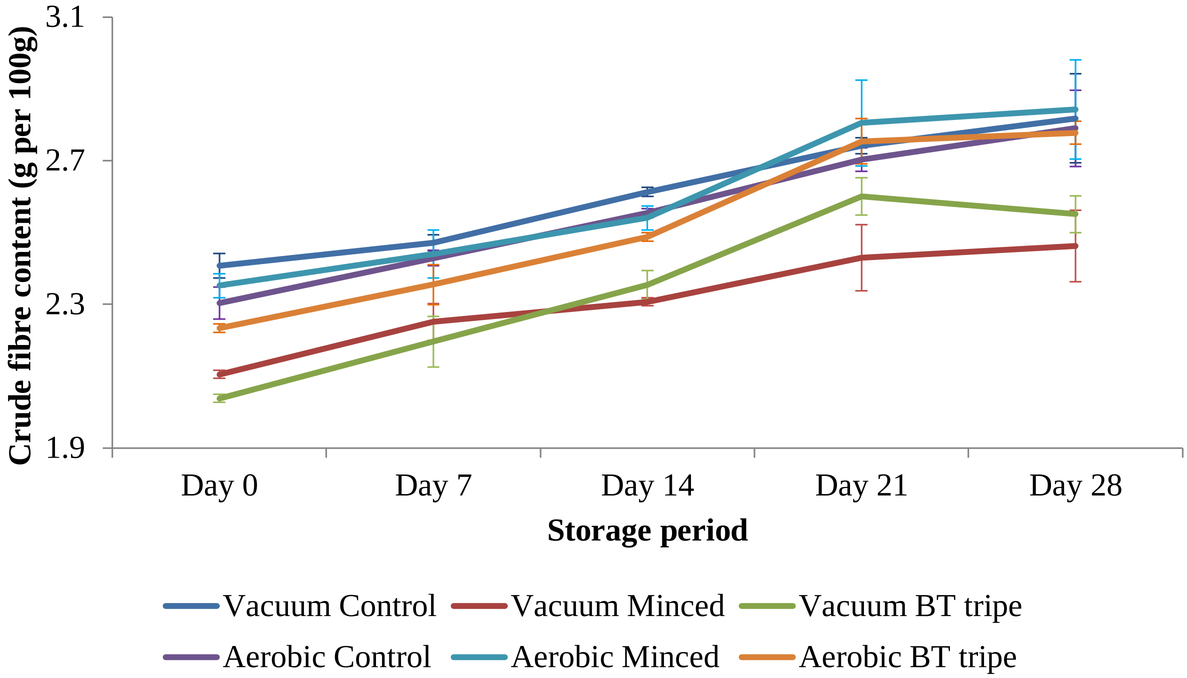

Figure 4.5: Crude fibre content of tripe stored for 28 days. (The error bars indicate standard error of the means)

4.6.1.5 Crude Ash of bovine tripe rolls

The crude ash content ranged from 3.71% to 3.93% for blade tenderized aerobically packaged product and control (non-tenderized product) vacuum packed product respectively (Table 4.1). There was a slight difference in crude ash content in all the products but the difference was not significant ($p<0.05$). The crude ash content increased gradually during the refrigerated storage in both packaging conditions but the increase was not significant ($p<0.05$). According to Rahman *et al.*, (2017), the increase can be attributed to the decrease in the moisture content of the products during the refrigerated storage that led to increased concentration of the minerals/higher mineral density. Thind *et al.*, (2006), also reported increase in ash content of cooked chicken patties with increase in the storage period.

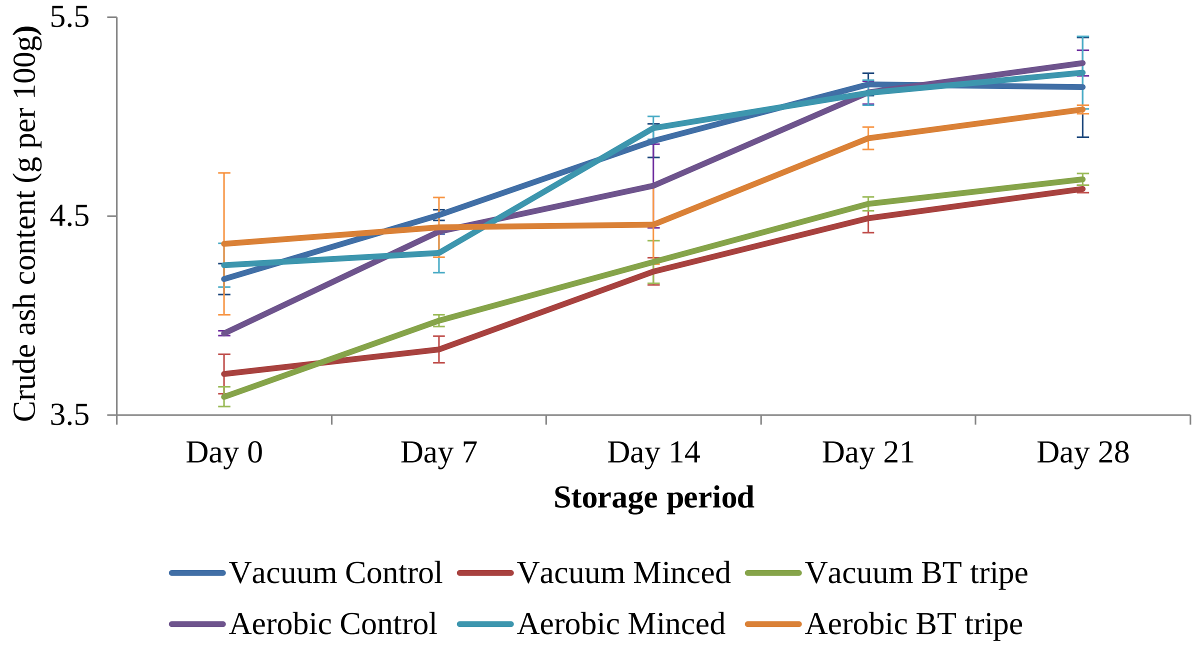

Figure 4.6: Crude ash content of tripe stored for 28 days. (The error bars indicate standard error of the means).

4.6.2 Shear Force Value (SFV) of the Products

Results for the shear force values of the ready to eat bovine tripe rolls are shown in figure 4.7. Tenderness and hardness are very important attributes when chewing meat products and can determine consumer preference of the product. In this study, the two attributes were determined using shear force. The product processed by mincing had the lowest SFV of 2.31 N while the control product (made of bovine tripe not subjected to mechanical tenderization) had the highest SFV of 4.43 N. The SFV for control product (non-tenderized tripe rolls) were significantly higher ($p<0.05$) compared with the minced bovine tripe rolls and blade tenderized bovine tripe rolls. The mean SFV for blade tenderized product was marginally higher than the minced product, however, the difference was still significant ($p<0.05$).

Mincing drastically reduced the hardness of the bovine tripe hence the low shear force values. Berry *et al.*, (1999) also observed that shear force value of cooked beef patties reduced significantly after mincing. Keller *et al.*, (1994) found that meat products developed from meat with large particles had higher shear force values. Mechanical treatment of the samples caused disruption of the structure of connective tissues and weakens the protein network in the tripe leading to lower SFV. Other authors found that mechanical treatment decreases the force needed to shear the roasts meat samples (Flores *et al.,* 1986) and reduces Warner-Bratzler hardness shear force values (Shackelford *et al.,* 1989) of cooked meat products. It has been shown that mechanical tenderization improves the tenderness of less tender cuts of meat products and hence has currently become an efficient and effective technology of improving tenderness of meat and meat products (Pietrasik and Shand, 2004). This adds value to the whole carcass by allowing the processors to sell products that are tender, raise the final returns of meat processors and leads to satisfaction of the demands of all the consumers.

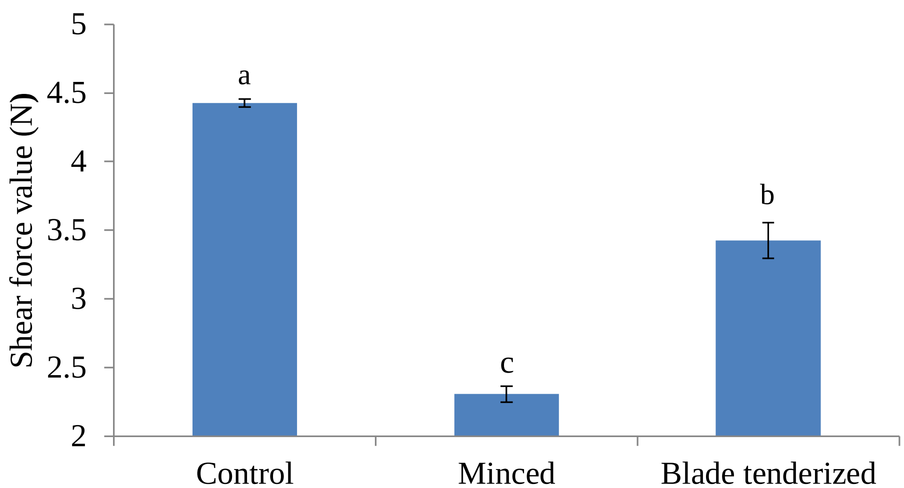

Figure 4.7: Shear force values of differently processed bovine tripe rolls*(The error bars indicate standard error of the mean. Bar with different letters are significantly different at $p<0.05$).

4.6.3 Cooking Losses of the RTE products

Results for cooking loss of the RTE bovine tripe rolls are presented in the figure 4.8. The losses ranged from 9.07% for Control (Untreated tripe samples) to 12.09% for the minced samples. The cooking losses for the three products differed significantly ($p<0.05$), but the losses were significantly lower in the product that was not subjected to any mechanical treatment (Control). The low cooking losses of the control product are as a result of its larger size of the particles and lower extraction levels of the protein due to less mechanical disruption of the tripe structure (Anjaneyulu *et al.,* 1989). The higher cooking losses of the minced products are due to effects of mincing where the myofibrillar proteins are fragmented increasing the surface area for loss (Bowker *et al.,* 2007). Lin and Keeton (1994) investigated and found that use of coarse mincing in meat products that are pre-cooked increases cook yield due to improved extractability of the proteins which causes greater solubilisation of protein muscles. Pietrasik and Shand (2004) also reported that blade tenderization results in increased cooking losses due to the holes created by the blade tenderizer which increases moisture loss.

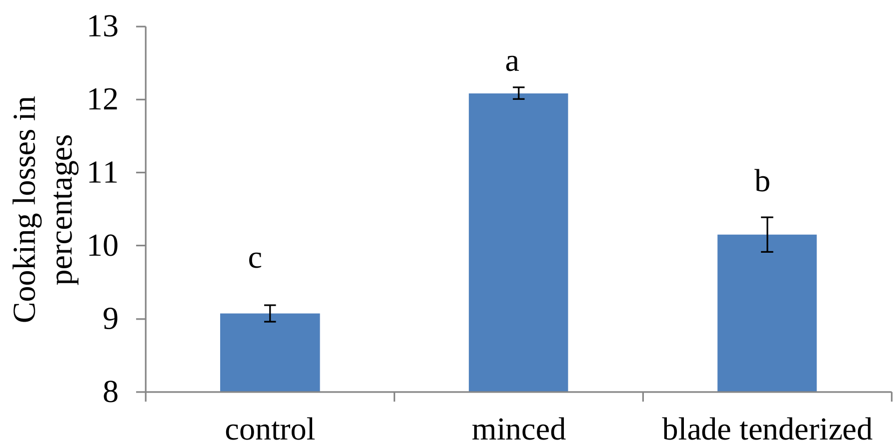

Figure 4.8: cooking losses of differently processed bovine tripe rolls (The error bars indicate standard error of the means. Bar with different letters are significantly different at $p<0.05$)

4.6.4 Changes in Physico-chemical characteristics during storage

4.6.4.1 pH

There results for Changes in pH of aerobically and Vacuum packed mechanically tenderized Bovine tripe rolls during the 28 days refrigerated storage are shown in Table 4.3. There was no significant ($p<0.05$) difference in the pH of minced, blade tenderized and control (non-tenderized tripe) RTE bovine tripe rolls. The vacuum packaged products had a higher pH compared to aerobically packaged products. This corroborates with the findings of Muthulakshmi *et al.,* (2015) who observed that hen meat samosa stored under vacuum had higher pH than aerobically packed ones. In the vacuum packaged products, pH declined significantly ($p<0.05$) as the storage period increased until the 14th day. Afterwards, the pH increased significantly. The decrease can be attributed to cross linking reactions whereby the amino groups are removed from the product causing the pH to decrease (Ockonkwo *et al.,* 1992). Proteolysis yields compounds that are nitrogenous and they could have caused increase in pH after the 14th day (Aksu & Kaya 2005). In aerobically packaged products, pH significantly ($p<0.05$) decreased throughout the storage period. Throughout the storage period, the microbial counts increases, breaks down carbohydrates and produce lactic acid which decreases the pH (Incze, 1992). The above results are in agreement with the findings of Devatkal and Mendiratta (2001) who also found that the pH of cooked restructured pork rolls reduced significantly during storage under refrigeration conditions. The average treatment means for blade tenderized products had greater pH values than the control and minced products in both packaging conditions. This is due to higher proteolytic activities in comparison with other products (Anna *et al.,* 2012).

Table 4.4 : Changes in pH of Vacuum and aerobically packaged Bovine tripe rolls during refrigerated storage (4±1 °C) for 28 days.

Storage condition	Treatment*	Storage period (days)					Treatment means ± SE
		0	7	14	21	28	
Vacuum	Control	$6.3±0.02^{a}$	$6.2±0.01^{a}$	$6.1±0.01^{a}$	$6.1±0.04^{a}$	$6.3±0.02^{a}$	$6.2±0.01^{A}$
	Minced	$6.4±0.02^{a}$	$6.3±0.01^{a}$	$6.0±0.02^{b}$	$6.1±0.01^{a}$	$6.2±0.02^{b}$	$6.2±0.01^{A}$
	BT tripe	$6.4±0.03^{a}$	$6.3±0.02^{a}$	$6.1±0.02^{b}$	$6.2±0.01^{a}$	$6.3±0.01^{a}$	$6.3±0.03^{B}$
Aerobic	Control	$6.3±0.02^{a}$	$6.2±0.02^{a}$	$6.0±0.02^{b}$	$5.9±0.02^{b}$	$5.9±0.02^{c}$	$6.0±0.02^{A}$
	Minced	$6.3±0.01^{a}$	$6.2±0.02^{a}$	$6.0±0.02^{b}$	$5.9±0.12^{c}$	$5.8±0.02^{c}$	$6.0±0.04^{B}$
	BT tripe	$6.4±0.02^{a}$	$6.2±0.03^{a}$	$6.1±0.03^{b}$	$6.0±0.02^{bc}$	$5.8±0.02^{c}$	$6.1±0.02^{B}$
Average		$6.4±0.02^{a}$	$6.2±0.02^{a}$	$6.1±0.02^{b}$	$6.0±0.04^{b}$	$6.0±0.02^{b}$	

*Values with different letters (lowercase along the row and upper case along the column) were significantly different at $p<0.05$.

4.6.4.2 Extract release volume (ERV)

Results for the ERV for the RTE bovine tripe rolls are shown in table 4.4. The average treatment means for extract release volume ranged from 19.4±0.31 to 20.6 ± 0.30 ml in both packaging conditions. The study showed that ERV values for blade tenderized rolls were significantly ($p<0.05$) lower compared with the control (non-tenderized) and minced bovine tripe rolls. However, overall treatment means for the minced and control products did not differ significantly in both aerobic and vacuum packaging conditions.

ERV values decreased significantly ($p<0.05$) as the storage period advanced all the values were below the specified limit of 17 millilitres for meat products (Pearson 1967). The ERV decreased as storage period progressed due to increase in microbial growth (Kumar *et al.*, 2007). The current results are in accordance with the report of Jay and Shelef (1976). They discovered that storage of meat results into multiplication of microorganisms which consequently causes change in proteins of meat and meat products through proteolysis and hence cause increase in hydration capacity which causes decrease in extract release volume values. ERV is very good indicator of spoilage in meat products. It is based on the amount of aqueous extract released from slurry of product when allowed to pass through filter paper for a given period of time (Pearson 1967). The product with a relatively low microbial population releases large volumes of extract (High ERV) while product in the process of microbial spoilage with high bacterial growth releases less (Low ERV).

Table 4.5: Changes in Extract release volume (ERV) in (ml) for RTE bovine tripe rolls

Storage condition	Treatments*	Storage period (days)					Treatment means ± SE
		0	7	14	21	28	
Vacuum	Control	$22.1±0.62^{a}$	$21.6±0.28^{a}$	$21.0±0.38^{a}$	$19.5±0.12^{a}$	$18.6±0.12^{b}$	$20.6±0.30^{A}$
	Minced	$22.5±0.63^{a}$	$21.5±0.31^{a}$	$19.9±0.32^{ab}$	$19.4±0.24^{b}$	$18.7±0.28^{a}$	$20.4±0.36^{A}$
	BT tripe	$21.9±0.58^{a}$	$20.2±0.46^{b}$	$19.2±0.28^{b}$	$18.1±0.26^{c}$	$17.8±0.18^{c}$	$19.4±0.35^{B}$
Aerobic	Control	$22.2±0.61^{a}$	$21.1±0.58^{a}$	$20.3±0.22^{b}$	$19.1±0.52^{b}$	$17.8±0.12^{c}$	$20.1±0.41^{A}$
	Minced	$22.5±0.62^{a}$	$21.2±0.36^{a}$	$20.2±0.22^{b}$	$19.0±0.22^{b}$	$17.3±0.18^{c}$	$20.0±0.32^{A}$
	BT tripe	$21.7±0.60^{a}$	$20.8±0.12^{a}$	$20.4±0.28^{b}$	$18.2±0.42^{bc}$	$17.4±0.12^{c}$	$19.7±0.31^{B}$
Average		$22.2±0.61^{a}$	$21.1±0.35^{a}$	$20.2±0.28^{b}$	$18.9±0.30^{c}$	$17.9±0.17^{c}$	

*Values with different letters (lowercase along the row and upper case along the column) were significantly different at $p<0.05$.

4.6.4.3 Peroxide value

Table 4.5 shows the peroxide values of the RTE bovine tripe rolls. As observed, peroxide values increased significantly throughout the storage period from 1.81±0.15 on day 0 to 16.04±3.58 meq/kg on 28th day, indicating no tendency to stabilize regardless of the packaging used. This can be attributed to accumulation of primary oxidation products. Vacuum packed products had lower peroxide values throughout the storage period compared to the aerobically packed products but the difference was not significant ($p<0.05$). This is due to absence of enough oxygen to initiate peroxidation reactions (Sharma et al., 2017). The overall treatment means for vacuum and aerobically packed products differed significantly ($p<0.05$) with vacuum packed samples exhibiting way lower peroxidation values of between 7.43- 7.47 meq/kg compared to aerobically packed samples range of 11.05-11.81meq/kg. Peroxide values are low at the beginning of the shelf-life of food (Abou- Charbia, 2002). The polyunsaturated and unsaturated fatty acids present in the fats, usually react with oxygen to form fatty acid hydro- peroxide which are unstable and breakdown into various compounds which consequently produce off-flavors; leading to a stale, rancid flavour in foods and increase in peroxide values (Kerler and Grosch, 1996). Peroxide value is essential in indicating the primary oxidation stages and its detection in meat products show that odor and taste are deteriorating and the product is becoming rancid (Jin *et al.*, 2009). Bimbo (1998) found that the recommended peroxide values in most meat products range from 3-20meq/kg. Therefore vacuum packaged RTE bovine tripe rolls exhibited a better keeping quality compared to aerobically packaged products as the peroxide values were far much below the limits. However, all the products were well within the allowable set limits of 25meq/kg in foods (Evranuz, 1993).

Table 4.6: Peroxide values as O_2(meq/kg) of RTE bovine tripe rolls.

Storage condition	Treatment*	Storage period (days)					Average
		0	7	14	21	28	
Vacuum	Control	1.81 ± 0.06^a	5.22 ± 0.61^b	7.84 ± 0.20^c	9.76 ± 0.13^d	12.71 ± 0.11^e	7.47 ± 3.88^A
	Minced	1.77 ± 0.14^a	4.95 ± 0.09^a	8.18 ± 0.72^c	9.71 ± 0.41^d	12.55 ± 0.70^e	7.43 ± 3.90^A
	BT tripe	1.83 ± 0.19^a	4.79 ± 0.28^b	7.98 ± 0.52^c	10.21 ± 0.56^d	12.50 ± 0.47^e	7.46 ± 3.95^A
Aerobic	Control	1.84 ± 0.12^a	6.19 ± 0.27^b	11.46 ± 0.48^c	16.42 ± 0.51^d	19.31 ± 0.56^e	11.05 ± 6.65^B
	Minced	1.83 ± 0.18^a	6.62 ± 0.42^b	12.04 ± 0.37^c	16.72 ± 0.26^d	19.67 ± 0.05^e	11.38 ± 6.74^B
	BT tripe	1.78 ± 0.26^a	7.32 ± 0.23^b	13.83 ± 2.28^c	16.61 ± 0.53^d	19.51 ± 0.42^e	11.81 ± 6.73^B
Average		1.81 ± 0.15^a	5.85 ± 1.00^b	10.22 ± 2.55^c	13.24 ± 3.46^d	16.04 ± 3.58^e	

*Values with different letters (lowercase along the row and upper case along the column) were significantly different at $p<0.05$.

4.6.4.4 Thiobarbituric acid value (TBA)

The rate of secondary break down of lipids in the bovine tripe rolls and expressed as mg malonaldehyde/kg meat product is shown in table 4.6. The average day values for the TBA were between 0.55 and 0.91 mg malonaldehyde/kg. TBA values increased progressively during the entire period of refrigerated storage. However, all the TBA values obtained ranged within the limits of 1 to 2 mg malonaldehyde/kg specified for meat products (Anna *et al.*, 2012) for the whole period of storage under aerobic and vacuum packaging conditions. TBA values for control products (non-tenderized) were significantly lower than minced and Blade tenderized (BT) products in both aerobic and vacuum packaging during the entire storage periods. Minced bovine tripe rolls had higher ($p<0.05$) overall TBA values means than BT products. Aerobically packed products showed significantly ($p<0.05$) higher TBA values than vacuum packed products for the entire storage period. This is because the oxygen was not available in the latter to propagate the oxidative lipids reactions and hence prevented disintegration of primary oxidation products to secondary products (Devatkal *et al.,* 2004). Many researchers have reported an irrevocable increase of TBA values of meat products stored under refrigeration conditions during the entire storage time (Rajkumar *et al.,* 2004; Singh *et al.,* 2014). Microbial load and TBA values correlate positively as Sudheer *et al.* (2011) observed and hence the increased microbial counts during storage might have caused rise in oxidative changes which eventually caused increase in TBA values ((Jay, 1996). The results for the current study are in agreement with Brenesselova *et al.,* (2015) who observed that vacuum packed ostrich meat products had lower TBA values compared to non-vacuum packed products during 21 days under refrigeration. Fernandez-Lopez *et al.,* (2008) also found that malonaldehyde values in the ostrich steaks under aerobic package were significantly higher compared to vacuum-packaged counterparts under refrigeration temperature for 18 days. Therefore vacuum packaging can be employed as a more efficient and effective approach of slowing down oxidation of lipids and its deleterious effects in meat products.

Table 4.7: Thiobarbituric acid values (TBA) in (mg malonaldehyde/kg) of RTE bovine tripe rolls.

Storage condition	Treatment*	Storage period (days)					Treatment means ± SE
		0	7	14	21	28	
Vacuum	Control	0.52±0.04^{a}	0.58±0.02^{a}	0.64±0.01^{ba}	0.74±0.02^{c}	0.76±0.02^{c}	0.65±0.02^{A}
	Minced	0.54±0.02^{a}	0.64±0.03^{b}	0.78±0.02^{c}	0.82±0.01^{c}	0.94±0.01^{d}	0.74±0.02^{B}
	BT tripe	0.56±0.03^{a}	0.65±0.02^{b}	0.72±0.01^{b}	0.74±0.02^{c}	0.82±0.04^{c}	0.70±0.02^{B}
Aerobic	Control	0.53±0.02^{a}	0.59±0.04^{a}	0.68±0.02^{b}	0.84±0.02^{c}	0.96±0.02^{d}	0.72±0.02^{A}
	Minced	0.56±0.01^{a}	0.66±0.02^{b}	0.79±0.01^{c}	0.83±0.01^{c}	0.98±0.03^{d}	0.76±0.01^{A}
	BT tripe	0.56±0.02^{a}	0.68±0.03^{b}	0.75±0.04^{c}	0.79±0.01^{c}	0.97±0.02^{d}	0.75±0.02^{A}
Average		0.55±0.02^{a}	0.63±0.03^{b}	0.73±0.02^{c}	0.79±0.02^{c}	0.91±0.02^{d}	

*****Values with different letters (lowercase along the row and upper case along the column) were significantly different at $p<0.05$.

4.6.4.5 Tyrosine value

Results for tyrosine value for the RTE bovine tripe rolls are shown in table 4.7. The average days means ranged between 0.43-0.78 mg tyrosine/100 g. There was a significant ($p<0.05$) and progressive increase in tyrosine value as the storage period advanced. However, vacuum packed products recorded lower tyrosine values than aerobically packaged products during the entire storage time. According to Daly *et al.*, (1976), tyrosine value effectively monitors the quality of meat and meat products during storage and continuous increase indicates denaturation and successive proteolysis of proteins. The average treatment means for tyrosine value were between 0.64-0.68 mg tyrosine/100 g for aerobically packaged products but the difference was not statistically significant. There was a significant difference ($p<0.05$) between the blade tenderized tripe rolls, minced tripe rolls and control (non-tenderized rolls) under vacuum packaging condition. Pearson (1967) reported that increase of tyrosine value in meat and meat products can be attributed to the denaturation process that generated free amino acids. The results of the present study corroborates with the findings of Anna *et al.,* (2008); Anna *et al.,*(2012) who found that tyrosine values of vacuum and aerobically packed cooked buffalo rolls increase with storage period under refrigeration conditions.

Table 4.8: Tyrosine value in (mg tyrosine/100 g) of RTE bovine tripe rolls.

Storage condition	Treatment*	Storage period (days)					Treatment means ± SE
		0	7	14	21	28	
Vacuum	Control	$0.44{\pm}0.03^{a}$	$0.58{\pm}0.02^{b}$	$0.66{\pm}0.03^{c}$	$0.72{\pm}0.01^{d}$	$0.77{\pm}0.02^{d}$	$0.63{\pm}0.02^{A}$
	Minced	$0.43{\pm}0.02^{a}$	$0.56{\pm}0.01^{b}$	$0.62{\pm}0.02^{c}$	$0.66{\pm}0.01^{c}$	$0.73{\pm}0.01^{d}$	$0.60{\pm}0.01^{A}$
	BT tripe	$0.44{\pm}0.01^{a}$	$0.51{\pm}0.02^{b}$	$0.56{\pm}0.04^{b}$	$0.62{\pm}0.01^{c}$	$0.68{\pm}0.04^{c}$	$0.56{\pm}0.02^{B}$
Aerobic	Control	$0.43{\pm}0.02^{a}$	$0.65{\pm}0.03^{c}$	$0.69{\pm}0.02^{c}$	$0.78{\pm}0.03^{d}$	$0.86{\pm}0.02^{e}$	$0.68{\pm}0.02^{A}$
	Minced	$0.44{\pm}0.01^{a}$	$0.63{\pm}0.02^{c}$	$0.65{\pm}0.01^{c}$	$0.79{\pm}0.04^{d}$	$0.85{\pm}0.03^{e}$	$0.67{\pm}0.02^{A}$
	BT tripe	$0.42{\pm}0.02^{a}$	$0.62{\pm}0.02^{c}$	$0.61{\pm}0.03^{c}$	$0.75{\pm}0.01^{d}$	$0.81{\pm}0.02^{e}$	$0.64{\pm}0.02^{A}$
Average		$0.43{\pm}0.02^{a}$	$0.60{\pm}0.02^{b}$	$0.63{\pm}0.03^{c}$	$0.72{\pm}0.02^{d}$	$0.78{\pm}0.02^{d}$	

*Values with different letters (lowercase along the row and upper case along the column) were significantly different at $p<0.05$.

4.6.5 Changes in sensory attributes of RTE bovine tripe rolls during storage

The scores for the sensory attributes of bovine tripe rolls during refrigeration storage are presented in table 4.8. Packaging and storage time had a significant effect ($p<0.05$) on the sensory characteristics of the RTE bovine tripe rolls; BT-Blade Tenderized.

The overall days' means for appearance and color ranged between 8.2 ± 0.09 and 6.8±0.15 and a significant ($p<0.05$) decrease was observed during the entire storage period in both packaging conditions. Decrease in color and appearance scores with storage can be attributed to non-enzymatic browning due to oxidation of lipids and also surface drying of the products (Chenman *et al.,* 1995). Overall treatment means showed that minced tripe rolls and blade tenderized rolls had better color and appearance ratings than the control products (Non-tenderized mechanically).Vacuum packaged bovine tripe rolls had significantly ($p<0.05$) higher scores than the aerobically packaged ones.

Odor scores reduced significantly ($p<0.05$) during the storage period in both vacuum and aerobic packaging. However, vacuum packaged products had significantly higher scores than aerobically packed products throughout the storage period. Overall treatment means for odor scores for control, minced and blade tenderized products did not differ significantly ($p<0.05$) in vacuum packed products. Odor reduction during the entire storage time could be attributed to increased growth of microorganisms and oxidation of lipids (Devatkal & Mendiratta 2001). Aerobically packed rolls recorded lower odor scores due to presence of oxygen which accelerated microbial growth and faster break down of lipids resulting in faster production of off odours.

Taste scores decreased as storage period advanced in all the products in both packaging conditions. The overall treatment means showed that there was a significant ($p<0.05$) difference between vacuum packaged bovine tripe rolls and aerobically packaged rolls. Vacuum packed rolls had higher taste scores than aerobically packaged ones. This is due to presence of enough oxygen in aerobic packages which initiated peroxidation reactions and favored faster growth of microorganisms. This caused development of rancid taste and deterioration of organoleptic quality with storage (Rajkumar *et al.*, 2004).

Table 4.9: Sensory evaluation of vacuum and aerobically packed RTE bovine tripe rolls during refrigerated storage (4± 1 °C)

Storage Conditions	Treatments/ Parameters	Storage Period (days)					Treatment Means ± SE
		0	7	14	21	28	
Vacuum	**COLOR**						
	Control	8.3±0.08^{a}	8.0±0.22^{a}	7.8±0.26^{a}	7.4±0.21^{a}	7.1±0.02^{a}	7.7±0.16^{A}
	Minced Tripe rolls	8.2±0.11^{a}	8.2±0.08^{a}	8.1±0.12^{a}	7.7±0.12^{a}	7.5±0.09^{a}	8.0±0.10^{A}
	BT-Tripe rolls	8.3±0.14^{a}	8.1±0.14^{a}	8.1±0.12^{a}	7.9±0.14^{a}	7.3±0.24^{ab}	7.9±0.16^{A}
Aerobic	Control	8.2±0.12^{a}	7.9±0.12^{a}	7.2±0.08^{a}	6.1±0.14^{bc}	5.9±0.24^{c}	7.1±0.13 ^{B}
	Minced Tripe rolls	8.2±0.08^{a}	8.0±0.08^{a}	7.4±0.12^{a}	6.6±0.12^{b}	6.2±0.22^{bc}	7.3±0.12 ^{B}
	BT-Tripe rolls	8.1±0.06^{a}	7.9±0.06^{a}	7.3±0.16^{a}	6.5±0.24^{b}	6.5±0.06^{bc}	7.3±0.13 ^{B}
	Average ± SE	8.2 ± 0.09^{a}	8.0±0.11^{a}	7.7±0.14^{b}	7.0±0.16^{c}	6.8±0.15^{c}	
Vacuum	**ODOR**						
	Control	8.1±0.08^{a}	7.9±0.12^{a}	7.1±0.16^{b}	6.5±0.14^{c}	6.1±0.24^{c}	7.1±0.15^{A}
	Minced Tripe rolls	8.2±0.07^{a}	7.9±0.08^{a}	6.8±0.18^{b}	6.5±0.11^{c}	6.2±0.22^{c}	7.0±0.13^{A}
	BT-Tripe rolls	8.1±0.12^{a}	7.8±0.06^{a}	6.9±0.11^{b}	6.6±0.23^{c}	6.1±0.06^{c}	7.1±0.12^{A}
Aerobic	Control	8.4±0.11^{a}	7.0±0.11^{b}	6.1±0.06^{c}	5.1±0.10^{d}	4.3±0.18^{e}	6.2±0.11 ^{B}
	Minced-Tripe rolls	8.2±0.09^{a}	7.2±0.09^{b}	6.4±0.17^{c}	4.9±0.11^{d}	4.5±0.12^{de}	6.2±0.12 ^{B}
	BT-Tripe rolls	8.3±0.18^{a}	7.1±0.12^{b}	6.3±0.14^{c}	5.2±0.08^{d}	4.6±0.16^{de}	6.3±0.14 ^{B}
	Average ± SE	8.2 ± 0.11^{a}	7.5±0.10^{a}	6.6±0.14^{b}	5.8±0.12^{c}	5.3±0.16^{c}	
Vacuum	**TASTE**						
	Control	7.8±0.09^{a}	7.6±0.12^{a}	7.2±0.05^{a}	6.6±0.06^{a}	6.2±0.21^{ba}	7.1±0.11^{A}
	Minced Tripe rolls	7.9±0.05^{a}	7.7±0.17^{a}	7.1±0.10^{a}	6.7±0.15^{a}	6.3±0.27^{ba}	7.1±0.15^{A}
	BT- Tripe rolls	7.8±0.29^{a}	7.6±0.28^{a}	7.1±0.13^{a}	6.8±0.28^{a}	6.4±0.06^{ba}	7.1±0.21^{A}
Aerobic	Control	7.4±0.04^{a}	7.1±0.01^{a}	6.0±0.05^{ab}	5.8±0.14^{b}	4.6±0.08^{c}	6.2±0.06 ^{B}
	Minced Tripe rolls	7.8±0.09^{a}	6.9±0.13^{a}	6.3±0.11^{ab}	5.9±0.12^{b}	4.7±0.04^{c}	6.3±0.10 ^{B}
	BT-Tripe rolls	7.7±0.13^{a}	6.8±0.05^{b}	6.2±0.09^{ba}	5.7±0.07^{b}	4.5±0.10^{c}	6.2±0.09 ^{B}
	Average ± SE	7.7 ± 0.12^{a}	7.3±0.13^{b}	6.7±0.08^{c}	6.3±0.14^{c}	5.4±0.13^{c}	
Vacuum	**TENDERNESS**						
	Control	6.6±0.02^{a}	6.2±0.11^{a}	6.1±0.15^{b}	5.5±0.31^{c}	5.2±0.09^{c}	5.9±0.14^{A}
	Minced Tripe rolls	7.8±0.07^{a}	7.6±0.19^{a}	7.2±0.16^{a}	6.7±0.16^{a}	6.1±0.07^{b}	7.1±0.13^{B}
	BT- Tripe rolls	7.1±0.11^{a}	6.8±0.02^{a}	6.7±0.18^{a}	6.4±0.04^{a}	6.1±0.08^{b}	6.6±0.09^{B}
Aerobic	Control	6.5±0.08^{a}	6.2±0.25^{a}	6.2±0.23^{ab}	5.3±0.12^{c}	5.1±0.10^{c}	5.8±0.16 ^{A}
	Minced Tripe rolls	7.9±0.29^{a}	7.5±0.56^{a}	7.3±0.01^{a}	6.3±0.15^{a}	5.7±0.12^{c}	6.9±0.23 ^{B}
	BT-Tripe rolls	7.2±0.23^{a}	6.6±0.09^{a}	6.4±0.02^{a}	6.2±0.08^{a}	5.5±0.12^{c}	6.4±0.11 ^{B}
	Average ± SE	7.2 ± 0.13^{a}	6.8±0.20^{b}	6.7±0.13^{c}	6.1±0.14^{c}	5.6±0.10^{c}	

Vacuum	**JUICENESS**						
	Control	7.9 ± 0.08^{a}	7.7 ± 0.16^{a}	7.2 ± 0.25^{a}	6.0 ± 0.11^{b}	5.9 ± 0.04^{b}	6.9 ± 0.14^{A}
	Minced Tripe rolls	8.4 ± 0.17^{a}	8.4 ± 0.13^{a}	8.3 ± 0.19^{a}	6.6 ± 0.26^{b}	6.2 ± 0.08^{b}	7.6 ± 0.13^{B}
	BT - Tripe rolls	8.1 ± 0.12^{a}	7.9 ± 0.12^{a}	7.7 ± 0.28^{a}	6.4 ± 0.02^{b}	6.2 ± 0.12^{b}	7.3 ± 0.09^{B}
Aerobic	Control	7.5 ± 0.18^{a}	7.7 ± 0.20^{a}	7.2 ± 0.13^{a}	6.0 ± 0.22^{b}	5.4 ± 0.31^{c}	6.8 ± 0.16^{A}
	Minced Tripe rolls	8.3 ± 0.09^{a}	8.1 ± 0.48^{a}	7.3 ± 0.11^{a}	6.3 ± 0.19^{b}	5.8 ± 0.02^{c}	7.2 ± 0.23^{B}
	BT-Tripe rolls	8.4 ± 0.05^{a}	7.6 ± 0.19^{a}	6.9 ± 0.08^{ab}	6.1 ± 0.05^{b}	5.7 ± 0.21^{c}	6.9 ± 0.11^{A}
	Average ± SE	8.1 ± 0.12^{a}	7.9 ± 0.21^{a}	7.4 ± 0.17^{a}	6.2 ± 0.14^{b}	5.9 ± 0.13^{c}	
Vacuum	**OVERALL ACCEPTABILITY**						
	Control	7.3 ± 0.12^{a}	7.1 ± 0.19^{a}	6.8 ± 0.11^{ab}	6.5 ± 0.10^{b}	6.2 ± 0.05^{b}	6.8 ± 0.11^{A}
	Minced Tripe rolls	8.1 ± 0.77^{a}	8.0 ± 0.14^{a}	7.5 ± 0.15^{a}	7.3 ± 0.09^{a}	7.1 ± 0.04^{a}	7.6 ± 0.24^{B}
	BT-Tripe rolls	8.2 ± 0.05^{a}	8.0 ± 0.22^{a}	7.4 ± 0.05^{a}	7.1 ± 0.04^{a}	6.8 ± 0.07^{ab}	7.5 ± 0.09^{B}
Aerobic	Control	7.4 ± 0.09^{a}	7.2 ± 0.05^{a}	6.5 ± 0.13^{b}	6.3 ± 0.32^{b}	5.8 ± 0.18^{c}	6.6 ± 0.15^{A}
	Minced Tripe rolls	8.2 ± 0.21^{a}	8.1 ± 0.06^{a}	7.6 ± 0.11^{a}	7.3 ± 0.25^{a}	5.7 ± 0.09^{c}	7.4 ± 0.14^{B}
	BT – Tripe rolls	8.1 ± 0.26^{a}	8.0 ± 0.09^{a}	7.4 ± 0.12^{a}	7.2 ± 0.02^{a}	5.8 ± 0.36^{c}	7.3 ± 0.17^{B}
	Average ± SE	7.9 ± 0.25^{a}	7.7 ± 0.13^{b}	7.2 ± 0.11^{c}	7.0 ± 0.14^{c}	6.2 ± 0.13^{c}	

Values with different letters (lowercase along the row and upper case along the column) were significantly different at $p<0.05$

Storage days' mean scores for tenderness ranged between 7.2 ± 0.13 and 5.6±0.10 and the scores reduced as the storage period advanced. Tenderness was not significantly ($p<0.05$) affected until the 7th day of storage. Thereafter, a significant decrease in tenderness was noted in both packaging conditions. This could be attributed to degradation of protein muscles during storage under refrigerated conditions (Ann *et al.,* 2012). The average means for all the treatments showed lesser scores for tenderness for control products (non-tenderized bovine tripe rolls) and larger scores for minced and blade tenderized bovine tripe rolls.

Storage days' mean scores for juiciness ranged between 8.1 ± 0.12 and 5.9±0.13 and the scores reduced as the storage period advanced in both aerobic and vacuum packages. However, the decrease was not of any statistical significance ($p<0.05$) until after the third week of refrigerated storage. Dehydration and moisture loss of the bovine tripe rolls during storage under refrigeration could be attributed to decrease in juiciness scores (Anna *et al.,* 2008). The average treatment mean scores for juiciness revealed significantly ($p<0.05$) larger scores for blade tenderized and minced tripe rolls than in control samples.

The overall acceptability ratings declined with the advancement of storage time. This is due to decrease in scores for odor, color and appearance, juiciness and tenderness throughout the course of storage. The overall acceptability of the RTE products in both packaging conditions did not differ significantly ($p<0.05$) until the 14^{th} day of storage. Devatkal and Mendiratta (2001) reported similar findings of the reduction in general acceptability of pork rolls throughout the duration of storage. Minced and blade tenderized rolls had significantly ($p<0.05$) higher overall acceptability scores compared to the control products (non-tenderized tripe rolls) in both aerobic and vacuum packaging conditions. Overall acceptability scores for vacuum packed products were higher than aerobically packed products during the entire storage period.

4.6.6 Conclusion

Mechanical treatment (Blade tenderization and mincing) is beneficial in improving the tenderness and eating quality of bovine tripe. There are significant changes in the sensory and physico-chemical characteristics of products during refrigerated storage under vacuum and aerobic conditions but the standards remain inside the limits approved for RTE meat products. Both aerobic and vacuum packaged products are acceptable up to 28 days under refrigeration but the sensory scores after 21^{st} day of storage are higher in vacuum packed products than aerobically packed products. Therefore, the current study shows that vacuum packaging has a definite advantage over aerobic packaging in extending the storage life of RTE meat products with no significant effect on the overall eating and sensory qualities the product.

CHAPTER FIVE: MICROBIOLOGICAL STATUS OF READY TO EAT (RTE) BOVINE TRIPE ROLLS UNDER DIFFERENT STORAGE CONDITIONS

5.1 Abstract

Bovine tripe is a meat by-product known to favour microbial growth and can be incorporated in foodstuffs or used as a stand–alone food component. However, its utilization among sections of communities in Kenya has been limited due to inherent toughness and short-shelf-life which hinders its commercial applications. While, tripe can be the major source of microbial contamination, personnel hygiene and handling of equipment during production can be another potential source of contamination. This study was hence designed to find out the suitability and safety for consumption of bovine tripe rolls produced from bovine tripe and stored at $4\pm1^{\circ}$C for 28 days under aerobic and vacuum packaging conditions. The products were developed by mechanical tenderization processes by mincing and blade tenderization then cooked till the middle temperature of $83 \pm 1^{\circ}$C was attained and then stored under different packaging conditions. The evaluation of the product for microbial quality was done using the standard analytical methods at intervals of 7 days for 28 days under refrigeration conditions. The results revealed an acceptable trend which indicated good hygienic handling of products during processing. The detected bacterial counts were in the ranges specified for RTE meat products by Kenya bureau of Standards (KEBS) for the 28 days storage period of vacuum packaged products. However, the microbial counts in aerobically packaged products were significantly ($p<0.05$) higher than in vacuum packed products and slight off odours and slime appeared on 28th day of storage. *Listeria monocytogens, Campylobacter, Escherichia coli and Salmonella spp* were all absent in both aerobic and vacuum packed products. The highest days means counts for *total viable counts, clostridium perfringens, staphylococcus aureus, yeast and molds, psychrophilic counts* and *lactobacillus spp* were 5.4 $\log_{10}$ cfu/g, 1.7 $\log_{10}$ cfu/g, 1.9 $\log_{10}$ cfu/g, 4.1 $\log_{10}$ cfu/g,

5.2 $\log_{10}$ cfu/g, 2.1 $\log_{10}$ cfu/g respectively in both packages. Therefore, bovine tripe rolls prepared by mechanical tenderization can best be stored for 28 days under vacuum packaging at 4±1°C and 21 days for aerobic packaging at the same temperature.

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5.2 Introduction

Ready to eat (RTE) bovine tripe rolls are some of the meat products that possess huge potential for microbial spoilage. They are developed from bovine tripe which contains high quality proteins, minerals and vitamins (Seong *et al.,* 2014). All over the world, slaughter houses generate huge volumes of bovine tripe which is under-utilized due to its inherent tough nature requiring long cooking times and also highly perishable (Araba, 2006). For instance, according to Ockerman and Hansen (2000), it has been estimated that 5.62kgs/cattle of bovine tripe are harvested after slaughter. The microbial quality of bovine tripe is generally poor due to readily available nutrients and unhygienic conditions during collection, handling and processing and hence can cause food borne illnesses (Abd *et al.,* 2018).

In order to convert the highly perishable and tough bovine tripe into an attractive, more convenient and generally acceptable novel product, appropriate technologies need to be employed for value addition. Mechanical tenderizing has been used extensively to enhance the tenderness and palatability of meat and meat products (Wicklund *et al.,* 2006). This is achieved through mincing or by use of blades and it entails penetrating and manipulating the muscles of meat or meat by-products to tenderize them (Pietrasik and Shand, 2004). Mechanically tenderized meat products pose a high microbial risk to consumers since the pathogens on the surface of meat or meat by-product can be carried into the deep tissues of the cuts that were previously sterile. The newly introduced pathogens can proliferate and increase in population especially if the meat product is undercooked consequently shortening the storage life of the product (Johns *et al.,* 2011). The complicated construction design and difficulty in disassembling the equipment used for mechanical tenderization can pose a challenge during cleaning and sanitizing which can enable the pathogens to remain within the niches of the equipment hence contaminating the product (Youssef *et al.,* 2014).

Cooked meat products can act as the growth media for bacteria, molds and yeast some of which can be pathogenic (Jay *et al*., 2005). *Listeria monocytogens, Clostridium perfringens, Salmonella spp* and *Campylobacter* are normally of particular interest because they are indicators of food safety. They are dominant in meat products and have been associated with diseases outbreaks (Jacxsens, 2009). These microorganisms can enter the product from spices and other ingredients, equipment, improper handling and processing, recontamination during post processing handling and storage. Proper heating of meat products during processing has been found to be effective in reduction of microbial counts of the final products (Gungor, 2010). Although cooking drastically reduces the initial population of bacteria, some vegetative cells and bacterial spores can survive. As a result, it is essential to prevent post cook contamination of the end-product by ensuring that they are stored at low enough temperature to prevent microbial growth.

Use of appropriate packaging and storage (cold treatment) condition plays a significant role in preserving the microbial quality of meat products (Lavieri and Williams, 2004). Vacuum packaging has been found to prolong the storage life of meat products by reducing undesirable bacterial growth (Strydom and Jones, 2014). Therefore, the aim of the present research was to evaluate the microbiological status of the RTE bovine tripe rolls produced by mechanical tenderization and stored under aerobic and vacuum packaging conditions at refrigeration temperatures.

5.3 Materials and methods

The study was conducted at the Department of Food Science, Nutrition and Technology, College of Agriculture and Veterinary Science, University of Nairobi. The Analytical tests were carried out in the food chemistry and food microbiology laboratories.

5.3.1 Sample collection and preparation

The bovine tripe was obtained from a local approved slaughterhouse (Bahati slaughterhouse, Limuru) which possesses the required authorisation from local authorities about health and hygiene practices. Other ingredients were bought from an authorized supplier in Nairobi city. Fat and other extraneous substances attached to the surface of tripe were separated using a knife followed by thorough washing to removal any adhering intestinal content and mucous lining. The tripe was then cut into (8×8cm) pieces for ease of mechanical tenderization. The already processed casings with internal diameter of 5 cm were bought from authorized processor in Nairobi city. Other ingredients were bought from an authorised supplier in Nairobi city.

5.3.2 Product formulation and treatments

The formulated ready to eat product consisted of the following ingredients: bovine tripe, common table salt, sodium triphosphate, $NaNO_2$, ascorbic acid, spices, and flakes of ice (Table 5.1). A series of initial/preliminary trials were conducted in order to develop the final formula for a ready to eat bovine tripe rolls. Different additives and seasonings used in the formulations are shown in Table 1. Blade tenderization (BT) and mincing are the treatments that were used to prepare bovine tripe rolls. Bovine tripe pieces were tenderized three times using a blade tenderizer which is operated mechanically. This was followed by sectioning the tenderized pieces into even chunks of 2 cm by 2 cm and was used to prepare blade tenderized bovine tripe rolls.

Bovine tripe pieces subjected to partial freezing (-2°C) were ground twice using a meat grinding machine and a 3 mm plate and used to prepare ground/minced cooked bovine tripe rolls.

2 cm by 2cm bovine tripe chunks (Not subjected to any mechanical treatments) were used to prepare the control products.

Table 5.1: Additives and seasonings for a 500g product formulation

Additives	**Quantity (gm.)**	**Seasonings**	**Quantity (gm.)**
Common salt	8	White pepper	1
Sodium tripolyphosphate(STTP)	1.5	Nutmeg	0.15
Ascorbic acid	0.15	Mace ground	0.3
Monosodium glutamate(MSG	0.25	Coriander & Ginger	0.4
NPS	1.5		
Total	11.4	Total	1.85

5.3.3 Experimental design

Experimental design is as has been illustrated in chapter 4 section 4.3.3 in table 4.2.

5.3.4 Preparation of the product

After tenderization and mincing, bovine tripe samples (BT samples and minced samples) were weighed separately and mixed in meat mixing machine at a speed of 250rpm for 5min with sodium triphosphate and sodium chloride. After 5 minutes, ascorbic acid, additives and seasonings, $NaNO_2$ and ices flakes were incorporated into the mass and mixing proceeded for another 5 minutes in order to get a homogenous mass.

500 grams of the homogenous meat mixture was put manually into casings. Cooking of the stuffed mixture took place in hot water that had been pre-heated till the temperature at the middle reached 83 ±1°C. The temperature was retained for approximately 15 minutes. Probe thermometer was used to record the temperature.

After cooking was done, the RTE bovine tripe rolls were left to cool down packed in LDPE and put in a refrigerator to chill for about 13 hours. Thereafter, the mass was cut into thin pieces using a meat slicing machine and packed under both vacuum and aerobic conditions using PET pouches. Storage of the samples was done at 4±1 °C and microbial evaluation carried out at 0, 7, 14, 21 and 28 days.

Blade tenderization

Bovine tripe preparation
↓
Removal of fat and extraneous matter (trimming)
↓
Cut into 10×10 cm chunks
↓
Blade tenderize
↓
Section into uniform pieces (2cm)
↓
Addition of salts and spices
↓
Mixing of ingredients completely (meat mixer)
↓
Stuffing into casings
↓
Cooking (internal temp 83◦C) -15 min
↓
Cooling
↓
Package in LDPE
↓
Chilling in refrigerator (13hrs)
↓
package in PET
↓
Store at 4◦C and Evaluation

Mincing

Bovine tripe preparation
↓
Removal of fat and extraneous matter
↓
Partial freezing
↓
mincing (using 3mm plate)
↓
Addition of salts &spices
↓
Mixing of ingredients
↓
Stuffing into casings
↓
Cooking (internal temp 83◦C)-15 min
↓
Cooling
↓
Package in LDPE
↓
chilling in refrigerator (13hrs)
↓
package in PET
↓
Store at 4 ◦C & Evaluation

Figure 5.1: The RTE bovine tripe rolls processing flow diagram

5.4 Analytical methods

The RTE bovine tripe rolls were analysed for various microorganisms to evaluate the microbiological profile in order to speculate the overall keeping quality and general hygiene. The microbial tests were conducted for a period of 28 days for proper comparison with the RTE meat products in the commercial market. The objective was to get an accurate estimate of the products microbial shelf-life in relation to the conventional RTE meat products.

The tests were conducted after every 7 days for 28 days throughout the refrigerated storage period. The microorganisms of interest were those relevant to safety problems of cooked meat products. *Listeria monocytogens, Campylobacter, Salmonella spp* and *Clostridium perfringens* were of critical significance since they act as indicators of food safety and they are dominant in meat products (Jacxsens, 2009). *Staphylococcus aureus* was used to indicate the hygiene of personnel during processing while Total viable counts (TVC) were used as indicators of general microbial quality of the RTE bovine tripe rolls. Psychrophilic bacteria are nutritionally versatile and ecophysiologically resilient species and hence can grow even in refrigerated temperatures hence responsible for faster spoilage of meat products under refrigeration. *Lactobacillus spp* were used as indicators of quality deterioration since they cause souring below the casing of meat products (Jay *et al.,* 2005). Growth of yeasts and molds forms gray slime on the surface of meat products hence discoloring it and their analysis acted as indicator of spoilage defects on the surface of the RTE tripe rolls during storage.

5.4.1 Determination of Total viable counts

ISO method 4833:2003 (ISO 2003) was used for enumeration of the total viable counts (TVC) Triplicate plates with plate count agar were used for enumeration. They were incubated for 72 hours at $30\pm1^{o}C$ after which bacterial counts were converted to $\log_{10}$ cfu/g of the sample.

5.4.2 Determination of *Escherichia coli*

Based on ISO method 16649-2:2001(ISO 2001), the *E. coli* will be accordingly enumerated. 8g of the sample were homogenized in 90ml of peptone water. Serial dilutions of the homogenized solution were prepared and plating done in triplicate on the selective agar media. After 48 hours of incubation at 44 $^{\circ}$C, blue green colonies for *E.coli* were counted and expressed as $\log_{10}$ cfu/g of the sample.

5.4.3 Determination of Yeasts and Molds

ISO method 21527-1:2008(en) was used. Potato Dextrose agar (PDA) was used to enumerate yeasts and molds using pour plating method. Incubation of the plates was done for 5 days at 25±1 °C. The sum total of CFU of presumptive yeast and molds per gram of sample was calculated.

5.4.4 Determination of *Salmonella*

The ISO method 6579:2002 (ISO 2002) was used for enumeration of *salmonella* species. 25g of sample were homogenized with peptone water and incubated at 37±1^{o}C for 18±2 hours. The inoculums were shifted to Rappaport- Vassiliadis broth and selenite cysteine broth from the pre-enrichment broth and incubation done at 41.5±1^{o}C and 37±1^{o}C for 24 hours for selective enrichment. A loopful of the selective enrichment was streaked onto two solid selective media: Brilliant green agar (BGA) and xylose lysine desoxycholate agar (XLD). XLD agar was incubated at 37±1^{o}C and observed after 24±3 hours for typical *Salmonella* transparent red halo and a black centre.

5.4.5 Determination of *Staphylococcus aureus*

EN ISO method 6888-1:1999 (ISO 1999) was used detect and enumerate *Staphylococcus aureus.* A sterile pipette was used to transfer in triplicate the sample dilutions onto the Baird Parker agar. Incubation of the plates was then done at 35-37^{o}C for 24±2 hours, then re-incubated for further 24±2 hours. Observation was made for typical colonies appearing black or grey, shining and convex, 1-1.5mm in diameter after 24hours and 1.5-2.5mm after 48 hours of incubation, surrounded by a clear zone but partially opaque zone. The coagulase positive staphylococci were then expressed as cfu/g of sample.

5.4.6 Determination of *Clostridium perfringens*

Enumeration was done using the ISO method 7937:2004 (ISO 2004). 1ml of appropriate sample dilutions were transferred and inoculated in a sterile pipette into empty petri dishes. 10ml of the sulphite-cycloserine agar (SC) which maintained at 44-47^{o}C in the water bath was poured into the petri dishes and mixed well with the inoculum by gently rotating each dish. After the media solidification, a 10ml over layer of the CS was added and allowed to solidify. The plates were then incubated under anaerobic conditions for 22 hours at 37^{o}C. Isolation of Clostridium perfringens was done immediately after enrichment, on iron sulphite agar at 46°C for 18 hours. Colonies which were typically black were picked and Lactose sulphite medium test (LS) was used to perform the confirmatory test. Tubes containing lactose sulphite media were examined after 24 hours for gas production and formation of black colour. Durham tubes containing black precipitate and with gas was confirmed positive for the *Clostridium perfringens* which was expressed as cfu/g.

5.4.7 Determination of *Listeria monocytogenes*

Method 11290-01:2004 (ISO 2004) was used to enumerate the organism *Listeria monocytogenes.* Fraser broth was used as a selective enrichment media and plating was done using Listeria agar and incubation was done at 37^{o}C for 24±3 hours. The confirmatory test used to confirm the *Listeria monocytogens* was carbohydrate utilization. Typical *Listeria monocytogens* colonies appear blue green with an opaque halo on the *Listeria* agar.

5.4.8 Determination of *Campylobacter*

ISO method 10272-2006 (ISO 2006) was used for enumeration. Bolton broth was used as enrichment media. A modified charcoal cefoperazonedeoxycholate agar (mCCD) was used for incubation at 41.5^{o}C for 44±4 hours. Typical colonies of *Campylobacter* are seen as greyish on mCCD agar, mostly with a metallic sheen and are flat and moist with a tendency to spread. The numbers of *campylobacter* per gram of the sample were calculated from the number of colonies per plate.

5.4.8.1 Determination of *Lactobacillus Spp*

The methods described by APHA (1992) were used for enumeration of *lactobacillus spp*. De Man, Rogosa and Sharpe agar (MRS agar) together with 10ml of glycerol were used to enumerate lactobacillus counts and the incubation of the plates was done for 48 hours at 35±1 °C. The numbers of *Lactobacillus* per gram of the sample were calculated from the number of colonies per plate.

5.4.8.2 Determination of *Psychrophilic counts*

The methods described by APHA (1992) were used for enumeration of Psychrophiles. A standard reference method where pour plates are incubated for 10 days at 7˚C was used for determination of *Pseudomonas* colony counts.

5.5 Statistical analysis

After enumeration, the counts were represented as colony forming units per gram (cfu/g). Microsoft excel was used to convert the figures into logarithmic version presented as log_{10}. Data was then subjected to Analysis of Variance (ANOVA) while Duncan's multiple range tests at $P \leq 0.05$ was used to compare the least significant differences of the means. Data analysis was done using Genstat version 16 for windows.

5.6 Results and Discussions

Listeria monocytogens, Campylobacter, Salmonella spp and *Clostridium perfringens* were absent in RTE bovine tripe rolls during the storage period in both vacuum and aerobic packaging conditions. Kenya Bureau of Standards legal limits require that these microorganisms be absent from the cooked meat products. According to Jacxsens (2009), *Salmonella spp, Campylobacter, Listeria monocytogens* and *Clostridium perfringens* are critical indicator microorganisms for status of food safety in the entire world. Moreover, Hsieh and Ofori (2011) reported that *Salmonella spp* and *Listeria monocytogens* caused over 1500 deaths in the USA due to contamination of food.

Most researchers have discussed several approaches of controlling microbial infestation on cooked meat products such as application of a HACCP system in the production process. However, adherence to good manufacturing practices (GMP) is a prerequisite for a successful HACCP system (Sperber *et al.*, 1998). Subjecting meat products to cold treatment especially refrigeration also works against several microorganisms including *Salmonella spp*, *Listeria monocytogens* and *Campylobacter* (Cutter and Siragusa, 1998). *Escherichia coli* have also been found in meat products made from bovine tripe by other researchers. Bachir and Mehio (2001) reported that unhygienic and improper handling of food increases the likelihood of contamination by *Escherichia coli.* Hence, the absence of *Escherichia coli* in the RTE bovine tripe rolls demonstrated proper and hygienic handling in addition with clean equipment and work area during the processing.

5.6.1 Total viable counts (TVC)

The average day means showed a significant increase ($p<0.05$) in TVC as the storage time advanced (Table 5.2). In spite of that, the proliferation of TVC in the middle of 14th and 21st day was not statistically significant in both aerobic and vacuum packed RTE bovine tripe rolls. The general treatment averages showed significantly more ($p<0.05$) TVC for minced bovine tripe rolls than control (non-tenderized) bovine tripe rolls. This is attributable to the higher surface area of the minced products hence easily penetrated by microorganisms. However, the total treatment means for minced and blade tenderized products in both packaging conditions did not differ significantly ($p<0.05$). The TVC during the entire storage period were well within the Kenyan safe limits of 6.0 log_{10} cfu/g for meat products as stipulated by Kenya bureau of standards (KEBS). Generally, vacuum packaged products had lower TVC than aerobically packed products. This is due to inhibitory effects on growth of microorganisms by vacuum packaging (Huffman *et al.,* 1975 and Maqsood *et al.,* 2016). Similar findings of increase in TVC as storage period advanced were reported by Devatkal and Mendiratta (2001) when they studied storage of pork rolls that had been restructured. The above results are also in line with the findings of Holy and Holzapet (1988) who found that the storage life of refrigerated and vacuum packaged comminted beef was better than for aerobically packaged ones.

Table 5.2: Total viable counts profile (log_{10} cfu/g) of RTE Bovine tripe rolls under different packaging conditions during refrigerated storage

Storage condition	Treatment*	Storage period (days)					Treatment means ± SE
		0	7	14	21	28	
Vacuum	Control	2.1 ± 0.04^{a}	3.4 ± 0.25^{b}	4.1 ± 0.13^{c}	4.5 ± 0.21^{c}	4.6 ± 0.22^{c}	3.7 ± 0.17^{A}
	Minced	2.2 ± 0.12^{a}	3.8 ± 0.09^{b}	4.5 ± 0.25^{c}	4.9 ± 0.24^{c}	5.1 ± 0.31^{d}	4.1 ± 0.20^{B}
	BT tripe	2.1 ± 0.06^{a}	3.6 ± 0.14^{b}	4.4 ± 0.13^{c}	4.8 ± 0.48^{c}	4.9 ± 0.24^{c}	4.0 ± 0.21^{B}
Aerobic	Control	2.2 ± 0.12^{a}	3.5 ± 0.14^{b}	4.5 ± 0.23^{c}	4.6 ± 0.13^{c}	5.7 ± 0.06^{d}	4.1 ± 0.14^{A}
	Minced	2.3 ± 0.05^{a}	3.9 ± 0.05^{b}	4.8 ± 0.41^{c}	4.9 ± 0.03^{c}	6.0 ± 0.08^{e}	4.4 ± 0.12^{B}
	BT tripe	2.1 ± 0.07^{a}	3.8 ± 0.06^{b}	4.6 ± 0.02^{c}	4.9 ± 0.11^{c}	5.9 ± 0.15^{e}	4.3 ± 0.08^{B}
Average		2.2 ± 0.08^{a}	3.7 ± 0.12^{b}	4.5 ± 0.20^{c}	4.8 ± 0.20^{d}	5.4 ± 0.18^{e}	

*****Values with different letters (lowercase along the row and upper case along the column) were significantly different at $p<0.05$. BT-tripe- Blade tenderized tripe rolls; Minced- Minced bovine tripe rolls; Control- Non tenderized tripe bovine tripe rolls.

5.6.2 *Staphylococcus aureus*

The average counts for *Staphylococcus aureus* were between 1.2 and 1.9 log_{10} cfu/g in both storage conditions (Table 5.3). The counts increased progressively as storage time advanced in the three treatments under both packaging conditions but the counts were slightly higher in aerobic than vacuum packed products. The results are in accordance with Brenesselova *et al.*, (2015) who noticed higher staphylococcal counts in aerobically packed ostrich meat in comparison to vacuum packaged one. Staphylococcus species are capable of growing both aerobically and anaerobically since they are facultative anaerobic organisms hence they multiplied during storage leading to increase in their population. However, the numbers fell within the KEBS allowable legal limit of $\log_{10}$ 2.0 colony forming unit per gram. Minced and blade tenderized tripe rolls treatment averages were non-significant ($p>0.05$) after 28 days of storage in both aerobic and vacuum packaging conditions. *Staphylococcus aureus* indicates the efficacy of proper handling food products during processing. Bachir and Mehio (2001) observed that improperly handled food introduces pathogens to the final product. Staphylococci are all over the environment of the humans and those present in the nose often contaminates the hands, face and fingers as food handlers' involuntary moves their hands hence increasing chances of cross-contamination (Lues and Van, 2007). This accounts for the presence of Staphylococcus *aureus* in the Bovine tripe rolls. The results for this study were in line with the findings of Anna *et al.,* (2012) who observed continuous rise of staphylococcal counts in meat rolls stored under vacuum and refrigerated conditions.

Table 5. 3: *Staphylococcus aureus* profile (log10 cfu/g) of RTE Bovine tripe rolls under different packaging conditions during refrigerated storage.

Storage condition	Treatment*	Storage period (days)					Treatment means ± SE
		0	7	14	21	28	
Vacuum	Control	1.1 ± 0.07^{a}	1.2 ± 0.04^{a}	1.4 ± 0.03^{a}	1.5 ± 0.07^{a}	1.8 ± 0.06^{b}	1.4 ± 0.05^{A}
	Minced	1.3 ± 0.06^{a}	1.4 ± 0.02^{a}	1.6 ± 0.09^{a}	1.7 ± 0.02^{b}	1.7 ± 0.03^{d}	1.5 ± 0.04^{B}
	BT tripe	1.2 ± 0.08^{a}	1.3 ± 0.03^{a}	1.5 ± 0.05^{a}	1.6 ± 0.08^{a}	1.9 ± 0.07^{c}	1.5 ± 0.06^{B}
Aerobic	Control	1.2 ± 0.12^{a}	1.3 ± 0.03^{a}	1.5 ± 0.13^{a}	1.7 ± 0.11^{b}	1.8 ± 0.09^{d}	1.5 ± 0.10^{A}
	Minced	1.3 ± 0.05^{a}	1.5 ± 0.02^{a}	1.7 ± 0.28^{b}	1.8 ± 0.02^{b}	1.9 ± 0.04^{c}	1.6 ± 0.08^{B}
	BT tripe	1.2 ± 0.07^{a}	1.4 ± 0.05^{a}	1.6 ± 0.01^{a}	1.9 ± 0.04^{c}	2.0 ± 0.16^{c}	1.6 ± 0.07^{B}
Average		1.2 ± 0.08^{a}	1.4 ± 0.03^{b}	1.6 ± 0.10^{c}	1.7 ± 0.06^{c}	1.9 ± 0.08^{d}	

*Values with different letters (lowercase along the row and upper case along the column) were significantly different at p<0.05. BT-tripe- Blade tenderized tripe rolls; Minced- Minced bovine tripe rolls; Control- Non tenderized tripe bovine tripe rolls.

5.6.3 *Clostridium perfringens*

The overall day means for *Clostridium perfringens* counts were between 1.7 l - 1.1 $\log_{10}$ cfu/g (Table 5.4). The decreasing trend observed in both aerobic and anaerobic packages throughout the storage period is attributable to the low storage temperatures. These results corroborates with the findings of Juneja *et al.,* (1993) who reported a progressive decrease in *Clostridium perfringens* counts in vacuum and aerobically packed cooked beef during refrigerated storage. The highest counts were 1.8$\log_{10}$ cfu/g on day 0 for minced bovine tripe rolls while the lowest counts were on day 28 at 1.0 $\log_{10}$ cfu/g for blade tenderized and control products. The counts were way below the set lethal limits of 4.0 $\log_{10}$ cfu/g stipulated by KEBS. The overall treatment means showed no significant ($p>0.05$) difference among all the products in both aerobic and vacuum packaging. *Clostridium perfringens* are important indicators of food safety and they are linked to bans imposed on meat products by importing countries (Heinitz *et al*., 2000). The importance of *Clostridium perfringens* is the increasing reports that some strains can proliferate at refrigeration temperatures previously thought to inhibit growth of pathogenic microorganisms (Johnson, 1990).

Table 5.4: *Clostridium perfringens* profile (log_{10} cfu/g) of RTE Bovine tripe rolls under different packaging conditions during refrigerated storage

Storage condition	Treatment*	Storage period (days)					Treatment means ± SE
		0	7	14	21	28	
Vacuum	Control	1.6±0.02[a]	1.4±0.10[a]	1.3±0.08[a]	1.2±0.01[ab]	1.2±0.11[ab]	1.3±0.11[A]
	Minced	1.8±0.01[a]	1.4±0.02[a]	1.3±0.06[a]	1.1±0.02[b]	1.1±0.03[b]	1.3±0.04[A]
	BT tripe	1.7±0.07[a]	1.5±0.02[a]	1.5±0.05[a]	1.2±0.06[ab]	1.2±0.02[ab]	1.4±0.05[A]
Aerobic	Control	1.7±0.01[a]	1.3±0.12[a]	1.2±0.02[ab]	1.1±0.11[b]	1.0±0.01[b]	1.3±0.10[A]
	Minced	1.8±0.02[a]	1.3±0.01[a]	1.3±0.04[a]	1.2±0.02[b]	1.1±0.02[b]	1.3±0.08[A]
	BT tripe	1.5±0.01[a]	1.4±0.03[a]	1.2±0.03[ab]	1.1±0.04[b]	1.0±0.02[b]	1.2±0.07[A]
Average		1.7±0.02[a]	1.4±0.05[b]	1.3±0.05[b]	1.2±0.04[b]	1.1±0.04[b]	

*Values with different letters (lowercase along the row and upper case along the column) were significantly different at p<0.05. BT-tripe- Blade tenderized tripe rolls; Minced- Minced bovine tripe rolls; Control- Non tenderized tripe bovine tripe rolls

5.6.4 Yeasts and molds

Yeast and mold counts were not detected on day 0 in both packaging conditions (Table 5.5). This is attributable to environmental stress especially cooking that subjected the cells to metabolic injury hence they were unable to form colonies. Nonetheless, as the storage period advanced, the injured cells got repaired and were able to form colonies on 7th day (Anna *et al.*, 2012). Mold and yeast counts progressively increased with storage period in both packaging conditions. The vacuum packed products had significantly lower ($p<0.05$) yeast and mould counts compared to aerobically packed products during the entire storage period. This could be attributed to higher amount of oxygen in aerobic packages that facilitated faster proliferation of yeast and molds (Malik and Sharma, 2014).The ability of vacuum packaging to retard the multiplication of molds and yeast during storage was also reported by Rao *et al.,* (2005). Minced and blade tenderized products treatment averages showed a significantly higher ($p<0.05$) molds and yeast counts compared to control. However, the difference between minced and blade tenderized rolls in both aerobic and vacuum conditions was non-significant ($p<0.05$). The above results are in agreement with Malik and Sharma (2014) who reported significantly higher yeasts and mold counts in aerobically packaged RTE meat products compared to vacuum packaged ones.

Table 5.5: Yeasts and molds profile (log_{10} cfu/g) of RTE Bovine tripe rolls under different packaging conditions at refrigerated storage

Storage condition	Treatment*	Storage period (days)					Treatment means ± SE
		0	7	14	21	28	
Vacuum	Control	ND	2.3±0.28^{a}	3.2±0.02^{a}	3.5±0.25^{a}	3.5±0.12^{a}	3.1±0.11^{A}
	Minced	ND	2.6±0.15^{a}	3.3±0.22^{a}	3.4±0.17^{a}	3.9±0.14^{bc}	3.3±0.04^{B}
	BT tripe	ND	2.6±0.11^{a}	3.6±0.23^{b}	3.7±0.09^{b}	4.1±0.18^{c}	3.5±0.05^{B}
Aerobic	Control	ND	2.5±0.14^{a}	3.5±0.21^{a}	3.9±0.26^{bc}	3.9±0.02^{bc}	3.5±0.10^{A}
	Minced	ND	2.8±0.18^{a}	3.7±0.06^{b}	4.2±0.08^{c}	4.5±0.12^{d}	3.8±0.11^{B}
	BT tripe	ND	2.9±0.12^{a}	3.8±0.10^{b}	4.3±0.06^{c}	4.4±0.28^{d}	3.9±0.14^{B}
Average			2.6±0.16^{a}	3.5±0.14^{b}	3.8±0.15^{c}	4.1±0.14^{d}	

*Values with different letters (lowercase along the row and upper case along the column) were significantly different at $p<0.05$. BT-tripe- Blade tenderized tripe rolls; Minced- Minced bovine tripe rolls; Control- Non tenderized tripe bovine tripe rolls; ND- Not Detected

5.6.5 *Lactobacillus* spp

The average day's means showed significant increase in *Lactobacillus* spp counts as the storage period advanced in both packaging conditions. However, the increase was not significant ($p<0.05$) on day 0 and day 7 in all the products. Similar trend was reported by Masqood *et al.*, (2016) who observed progressive increase in lactobacillus counts during refrigerated storage of camel meat. Jones *et al.,* (1988) also reported continuous increase of *lactobacillus* spp counts of restructured meat products during storage at low temperature under vacuum packaging. Average treatment means showed non-significant difference between the control, minced and blade tenderized bovine tripe rolls. The average treatment means indicated significantly higher (p<0.05) counts in vacuum packaged products compared to aerobically packaged ones. These results are in accordance with the findings of Doulgeraki *et al.*, (2012) who reported high counts of *lactobacillus* spp in vacuum packed meat and meat products stored at 4°C during storage. The lactobacillus counts were between the specified range for meat products despite the increase in their counts during the refrigerated storage (Jay *et al.*, 2005).

Table 5.6 : *Lactobacillus* spp profile (log_{10} cfu/g) of RTE Bovine tripe rolls under different packaging conditions during refrigerated storage

Storage condition	Treatment*	Storage period (days)					Treatment means ± SE
		0	7	14	21	28	
Vacuum	Control	$1.3±0.18^a$	$1.4±0.12^a$	$1.8±0.06^b$	$2.3±0.11^c$	$2.3±0.21^c$	$1.8±0.14^A$
	Minced	$1.5±0.11^a$	$1.5±0.06^a$	$1.9±0.16^b$	$2.1±0.12^{bc}$	$2.4±0.15^c$	$1.9±0.12^A$
	BT tripe	$1.4±0.06^a$	$1.5±0.13^a$	$1.8±0.08^b$	$2.3±0.10^c$	$2.4±0.11^c$	$1.9±0.11^A$
Aerobic	Control	$1.4±0.02^a$	$1.4±0.26^a$	$1.5±0.08^a$	$1.5±0.12^a$	$1.8±0.16^b$	$1.5±0.13^B$
	Minced	$1.2±0.18^a$	$1.3±0.10^a$	$1.4±0.11^a$	$1.5±0.09^a$	$1.9±0.05^b$	$1.5±0.11^B$
	BT tripe	$1.3±0.06^a$	$1.4±0.11^a$	$1.5±0.11^a$	$1.5±0.06^a$	$1.8±0.04^b$	$1.5±0.08^B$
Average		$1.4±0.10^a$	$1.4±0.13^a$	$1.7±0.10^b$	$1.9±0.10^c$	$2.1±0.11^d$	

*Values with different letters (lowercase along the row and upper case along the column) were significantly different at p<0.05. BT-tripe- Blade tenderized tripe rolls; Minced- Minced bovine tripe rolls; Control- Non tenderized tripe bovine tripe rolls

5.6.6 Psychrophilic counts

There were no colonies on the initial day of storage in minced, blade tenderized as well as control (non-tenderized) products in both aerobic and vacuum packaging conditions (Table 5.7). This is attributable to retardation of log phase due to abrupt adjustment of the physical environment which caused reduction in metabolic rate of the Psychrophiles (Gupta and Sharma, 2017). As the storage period progressed, the injured cells regenerated leading to formation of colonies on the 7th day of storage. Gadekar *et al.*, (2014) observed psychrophilic counts form 15th day going forward during the storage of restructured meat products from goat. From day 7, psychrophilic counts increased significantly (p<0.05) in all the products in both packages as the storage period advanced. However, the counts were higher in aerobically packaged products compared to vacuum packaged ones throughout the storage period. Anna *et al.,* (2012) deduced that raised levels of CO_2 as a result of vacuum packaging retarded the proliferation of psychrophilic bacteria hence the lower counts. The results of this study are in line with the findings of Maqsood *et al.,* (2016) who found that the psychrophilic counts of vacuum packaged camel meat samples were lower than counts for aerobically packed ones during the refrigerated storage. The overall treatment means in respective packaging conditions did not did not differ significantly. The appearance of visible slime and off odors in aerobically packaged products on the 28th day showed a marginal spoilage stage which is a major food safety concern. Other researchers have reported that vacuum packaging is more efficient in reducing psychrophilic counts of meat products compared to aerobic packaging (Bingol and Ergun, 2011; Fernandez-Lopez *et al.,* 2008; Lorenzo and Gomez, 2012).

Table 5.7 Psychrophilic bacterial counts profile ($\log_{10}$ cfu/g) of RTE Bovine tripe rolls under different packaging conditions during refrigerated storage

Storage condition	Treatment*	Storage period (days)					Treatment means ± SE
		0	7	14	21	28	
Vacuum	Control	ND	2.5 ± 0.18^{a}	3.1 ± 0.05^{b}	4.3 ± 0.18^{c}	4.4 ± 0.28^{c}	3.6 ± 0.14^{A}
	Minced	ND	2.6 ± 0.22^{a}	3.7 ± 0.21^{b}	4.2 ± 0.31^{b}	4.6 ± 0.23^{c}	3.8 ± 0.24^{A}
	BT tripe	ND	2.3 ± 0.15^{a}	3.6 ± 0.32^{b}	4.4 ± 0.33^{c}	4.5 ± 0.42^{d}	3.7 ± 0.31^{A}
Aerobic	Control	ND	2.8 ± 0.06^{a}	3.3 ± 0.26^{b}	4.8 ± 0.11^{c}	5.6 ± 0.16^{e}	4.1 ± 0.15^{B}
	Minced	ND	2.5 ± 0.08^{a}	3.8 ± 0.02^{b}	4.9 ± 0.27^{c}	5.9 ± 0.05^{e}	4.2 ± 0.11^{B}
	BT tripe	ND	2.4 ± 0.05^{a}	3.7 ± 0.12^{b}	4.6 ± 0.07^{c}	6.1 ± 0.04^{e}	4.2 ± 0.07^{B}
Average			2.5 ± 0.12^{a}	3.5 ± 0.16^{b}	4.5 ± 0.21^{c}	5.2 ± 0.20^{d}	

*Values with different letters (lowercase along the row and upper case along the column) were significantly different at $p<0.05$. BT-tripe- Blade tenderized tripe rolls; Minced- Minced bovine tripe rolls; Control- Non tenderized tripe bovine tripe rolls. ND- Not Detected.

5.7 Conclusion

This study revealed that it is practically possible to obtain tenderized meat product with a good microbiological quality by use of mechanical tenderization methods. Proper and hygienic handling practices during processing are paramount to ensure an acceptable general hygiene. The results of this study showed that vacuum packaging is more effective in slowing down microbial growth and maintaining the quality of meat products for longer period compared to aerobic packaging. The study also indicates that mechanically tenderized RTE bovine tripe rolls can be stored at 4±1 $^{\circ}$C for 28 days under vacuum packaging and 21days under aerobic packaging without significantly affecting the microbial quality.

CHAPTER SIX: GENERAL CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

Utilization of bovine tripe is not very efficient and this causes huge losses in pastoral regions and other studied slaughter establishments in Kenya. The mode of preparation, utilization and consumption of bovine tripe is also shared by some communities across the study regions. The study also established the main factors that contribute to huge wastage of bovine tripe in slaughterhouses and sections of communities in Kenya are traditions and cultures, inherent toughness which makes it hard to chew and lack of appropriate technologies needed for value addition to extend the shelf life.

Mechanical treatment methods such as mincing and blade tenderization can be used to enhance tenderness of the tough tripe and improve their eating quality. When the developed RTE bovine tripe rolls are kept at refrigerated temperature under vacuum packaging conditions, the shelf-life can be remarkably extended to 28 days. The sensory scores and overall quality of aerobically packaged bovine tripe rolls decline after 21 days of storage. This shows that vacuum packaging has a definite advantage over aerobic packaging in extending the storage life of RTE meat products with no significant effect on the overall eating and sensory qualities.

It is practically possible to produce tenderized tripe rolls which are safe and hygienic using the mechanical tenderization methods as proved by the microbial examination outcome. Proper and hygienic handling practices during processing are paramount to ensure an acceptable product is obtained. Vacuum packaging effectively slows down the microbial growth and maintains the quality of the products longer than aerobic packaging as shown in this study.

This research also showed that innovative product development can effectively address a wide range of problems by proper utilization of by-products such as bovine tripe. Bovine tripe rolls can address the problem of food insecurity without encountering unfavorable outcomes on the economic and ecological situations.

6.2 RECOMMENDATIONS

A lot of information particularly on new technologies needs to be disseminated to help in reduction of post-slaughter losses in slaughterhouses and among the communities in the study areas. There is need to invent more technologies for development of new products which will ultimately lower the wastages of tripe and improve income for stakeholders along the meat value chain. To enhance utilization of the bovine tripe, new ways of utilizing them should be explored. Bovine tripe can be incorporated in other meat products such as meat balls, sausages and smokies to maximize their consumption.

There is need to establish cleaning programmes with subsequent monitoring and microbiological verification to determine effectiveness in slaughterhouses and in butcheries. This will minimize cross-contamination and dirt on the tripe and other by-products and consequently extend their shelf-life. Thorough trainings should also be conducted to create awareness among communities and help them in removing the beliefs and traditions that restrict them from consuming tripe. Educating the communities that discard bovine tripe that it is highly nutritious and healthy would change their mindset and enhance the consumption which ultimately will reduce losses along the meat value chain.

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APPENDICES

Appendix 1: Slaughterhouse and focus group discussion interview guide
Surveyor …………………………………
Project ………………………………….
Date ………………………………….
Establishment/slaughter house………………………………….

1. Which type of animals do you slaughter? Tick appropriately.
a) Cattle

b) Goats

c) Sheep

d) Camel

e) Donkey

f) Others (specify)…………………………………………………………

2. How many animals do you slaughter on a daily basis?
a) 1-10

b) 10-50

c) 50-100

d) 100-200

e) Above 200.

3. What are the by-products you get after slaughtering your animals? Tick appropriately.
a) Blood

b) Offal

c) Legs

d) Skin and hide

e) Horns and hooves

f) Tripe (Omasum, abomasum, rumen, reticulum)

g) Others (specify)…………………………………………………………………………

4. How do you utilize the tripe mentioned above? Briefly describe.

5. Do you sell the tripe immediately after slaughter?

a) Yes b) No

6. What methods do you use to prepare tripe for consumption? Briefly explain.

7. What are the estimated losses in percentage of bovine tripe from slaughterhouses?

8. How do you store the tripe after evisceration/slaughter?

9. Do you have an organized market for the tripe?

a) Yes b) No

10. What are the major causes of losses during storage?

11. Who are the major buyers of bovine tripe?

12. In your opinion, do you think there are meat products that can be made using bovine tripe or by-products? If yes, which product and how would they be made.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

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Appendix 2: Sensory evaluation score sheet.
Score sheet number …………………………………………

Date of analysis ……/……/2018

Name/initials of analyst ……………………………………....

Sensory evaluation
You are provided with coded samples of bovine tripe rolls. Please evaluate each of the samples presented to you for six (5) sensory attributes namely; **odour, colour and appearance, taste, tenderness, Juiciness and overall acceptability**. Each sensory attribute is represented by a hedonic scale ranging from "9=like extremely) and "1=dislike extremely". Score each attribute using the scale provided at the bottom of the page and record the score of your response in the appropriate space on the grid provided. You will be provided with water and crackers in between samples. Please provide a general comment on the sensory properties of the samples at the end of the exercise.

Sample	Odour	Color	taste	tenderness	juiciness	Overall acceptability

Scale
Score
1………………………………………Dislike extremely
2………………………………………Dislike very much
3………………………………………Dislike moderately
4………………………………………Dislike Slightly
5………………………………………Neither like nor dislike
6………………………………………Like slightly
7………………………………………Like moderately
8………………………………………Like very much
9………………………………………Like extremely
Comments……………………………………………………………………………………………
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